AN ASSESSMENT OF THE WILD CYCLOPIA SUBTERNATA (VLEITEE) RESOURCE

A thesis submitted in fulfilment of the requirements for the degree

of

Masters of Science

in Geography

at

Rhodes University, South Africa

Department of Geography

Faculty of Science

By

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March 2021

ACKNOWLEDGMENTS:

I wish to express my gratitude to my supervisor, Gillian McGregor, who taught me more than she ever needed to and guided me to places I never thought I could go. Additionally, to my brother David thank you for the hours. I am grateful to the remember of the honeybush community who willing shared their knowledge with me - and in particular to the harvesters - who allowed me to accompany them in their harvesting and taught me about their trade.

ABSTRACT:

Cyclopia spp. is used for the production of Honeybush tea, an herbal tea which is used in many cases as a substitute for rooibos tea. The wild harvesting of this fynbos plant still brings in up to 85% of the annual crop and as such needs to be carefully monitored in order to avoid over harvesting and the destruction of biodiversity within the Eastern and Western Cape mountain regions of Southern Africa. Due to the concerns of overharvesting and unsuitable use of the wild resource issues of supply security have been raised. There is a lack of formal knowledge relating to the plant, its harvesting, the industry and its economic potential. This study aimed to amend this scarcity by contributing to the knowledge of *C. subternata* as a wild harvested plant, the physical environment favoured by *C. subternata,* sustainable use through harvesting of the wild plant and harvesting methods specific to this honeybush species. The research concludes by presenting a guideline for best harvest practices of the wild *C. subternata* plant.

Ethics approval: Rhodes University Science Faculty. Reference number: SCI2017/063

Chapter 1

THE NATURE AND STATE OF CYCLOPIA SUBTERNATA IN THE WILD

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AIM

The aim of this research was to investigate the nature and state of the *C. subternata* wild resource with a view to develop guidelines for the sustainable harvest thereof. The aim of this chapter was to introduce the research and give an overview of the Honeybush industry and relevant past research.

MOTIVATION

In the honeybush industry, there is a lack of formal knowledge relating to the plant, its harvesting, the industry and its economic potential. This study aimed to amend this scarcity by contributing to the knowledge of *C. subternata* as a wild harvested plant, the physical environment favoured by *C. subternata,* sustainable use through harvesting of the wild plant and harvesting methods specific to this honeybush species.

An increased demand has led to strain on the resource, which is still largely wild harvested (Joubert *et al.,* 2011). Motivation for this study came from the recognition by industry stakeholders of the value of the wild crop for the various industry stakeholders (Bester, 2013). The only way to maintain the sustainable use of the wild honeybush resource is through defined guidelines, which needed to be formalised. A set of guidelines for *C. intermedia* (85% of the wild crop) was published in response. This research aimed to provide the necessary background information (for example: population sizes, harvesting methods, harvesting yields and growth conditions) for the development of a similar set of guidelines for *C. subternata* harvesting. Through data gathered in this study, a set of guidelines for the best practices of harvest for sustainable wild crop use was put forward. Not only will the best practices contribute to the longevity of the wild crop itself, and aid in ensuring supply to the overseas market, but it will also meet the requirements of environmentally conscious consumers. Sustainable use of the product will ensure biodiversity and economic benefit to the economically marginal rural areas where honeybush is harvested. Along with conservation, jobs will be put forward for monitoring plant populations, harvesting, processing and product distribution.

The broader motivation for this research came from the fact that wild populations of *C. subternata* were observed to decline due to overharvesting (S van der Merwe, personal communication, July 2018; Joubert *et al.,* 2011; Schutte, 1995). Given the demand for the crop and its importance to livelihoods in the rural Eastern Cape, Langkloof and Tsitsikamma regions, there is a need to gather formal knowledge regarding the growth and harvesting of the plant to enable sustainable use.

Sustainability is more commonly viewed from an ecological perspective in terms of plant or animal populations. Because sustainability is the main focus of this study, it must be defined in a context specific to the field which is being studied. Cunningham (2001) defines a sustainable system for harvesting as one where fruits, seeds or other plant parts can be harvested indefinitely from an area without detrimental impact on the structure and dynamics of the harvested plant populations.

The lack of any formal guides or records for sustainable harvesting of *C. subternata* has created the potential for unsustainable practices during harvesting. Although *C. subternata* accounts for only 10% of the total annual crop, this small proportion has an impact on the industry and the livelihood of those involved (McGregor, 2017a). Species such as *C. subternata* can be cultivated on large stands without many external inputs. A stand of *C. subternata* can become a source of income for farmers as well as increasing job potential in the economically marginal areas of the Eastern Cape. Understanding the wild growth of *Cyclopia spp.* can aid in establishing suitable cultivation practices. The cultivated sector still has much room for growth and if managed correctly can help ensure the security of wild honeybush populations. This study not only aimed to ensure the sustainability of the plants but also aimed to provide the basics required for the development of a resource assessment system, which would lead to monitoring of populations and thus also contribute to job creation and skills development for the local communities.

C. subternata is classified as a protected species and a permitting system was implemented in the Eastern Cape (DEDEAT, 2011). Guidance on harvesting practices alongside the permitting system could ensure the sustainable use of honeybush in the wild. The development of survey methods as part of this research would allow for long-term monitoring to be put in place so that the species could be used sustainably. The study aimed to determine the typical population sizes (density/hectare) along with estimated recovery periods after harvesting in order to draw up the best practice guidelines for harvesting.

Not only is it important to make sure populations are harvested correctly, but it is also vital to make sure populations are not harvested too often or without the opportunity to reseed. Therefore, a resource assessment had to be done on wild populations having the potential to be harvested in order to determine the criteria. Once the best practice principles were established, it had to be defined for each location specifically. This was required due to the fact that each growth site had unique rainfall, aspect, slope, moisture levels and soil conditions, which would lead to different growth rates. The variability of growth for honeybush had to be taken into consideration in order to ensure future population success.

This research was "engaged" in that it aimed to create a dialogue between the community members who were involved with the day-to-day processes of the honeybush industry as well as to record the knowledge which had been passed down from harvester to harvester. The use of scientific research along with knowledge from these individuals could create a collaborative effort, which would aid in the understanding of not only the *Cyclopia spp.* but also the societal well-being as a whole.

The 1997 White Paper on Education (Department of Education, 1997) identified community engagement at South African universities as one of the pillars of higher education. According to the Council for Higher Education (2004), through engaging with communities, universities can use their resources and expertise to resolve issues that are relevant to their communities. The broader scope of "engaged scholarship" (Boyer, 1996) is a preferred term because it encompasses community engagement plus other important aspects of the role of universities. In a review of research articles on engaged scholarship, Beaulieu, Breton and Brousselle (2018) conclude that engaged scholarship focuses on individual and social well-being as well as on citizenship. The engaged researcher is seen as one who engages with the wider society, recognising it as part of his or her social accountability and civic responsibility in dealing with issues of public relevance at local, national and international level.

INTRODUCTION

Cyclopia species are endemic fynbos plants that occur naturally in South Africa and are used to make tea, which has been shown to have great economic potential in the South African and global market. The potential for the products to be used on an international scale for herbal teas and sweet beverages is set to expand in the near future (Kamara *et al.,* 2004).

Due to the current boom in the herbal drinks market and the unique fynbos environment in which *Cyclopia species* are found, the need to protect the plants and use the resource sustainably is at an all-time high. While the product does create a value added to human welfare the focus of this research is in understanding the wild harvesting and the risks of unsustainable harvesting practices (Costanza *et al.,* 1997). Costanza *et al.* (1997) state that with increased pressure on the natural resource, there is likely to be a decline in the availability of the crop, which will lead to a lack of supply to the market. Due to this increased pressure there is a need for resource assessments, harvesting guidelines and sustainability within the industry to ensure the survival of the plant.

Due to the economic potential of the crop, the honeybush industry has grown rapidly. Of the total annual crop of about 350 tons (McGregor, 2017a), 85% is exported to many countries across the globe to be used as herbal tea (Joubert *et al.,* 2011). The industry thus needs to be carefully monitored in order to avoid overharvesting and the destruction of biodiversity in the Eastern and Western Cape regions of South Africa. The farming of wild honeybush is a moderately regulated practice, which is controlled by the farmers who own the land. Due to the increase in demand for the crop in the international market, Joubert Joubert, Bester, De Beer and De Lange (2011) highlight issues which need to be resolved in research in order to ensure a steady supply. These concerns include overharvesting and unsuitable use of the wild resource, which will impact the supply to the market and the livelihoods of local producers. There is little or no scientific information on sustainable use of this wild resource. Anecdotal evidence has been used as the basis for harvesting methods, but this evidence needs to be formalised in order to ensure that these methods pose as little risk to the plant populations as possible. Assessing and documenting the extent of a wild resource such as the honeybush population and working on harvesting intervals can ensure that the crop is used in a sustainable manner into the future (Schippmann, Leaman & Cunningham*,* 2002).

While the wild crop has been the basis of the industry, the cultivation of *Cyclopia subternata* is the most reliable way to sustain the industry and keep the pressure off the wild crop (Potts, 2017). Potts (2017) warns that there is limited knowledge of using plants from a narrow genetic pool in order to establish a viable cultivated crop and that this could impact both the cultivation and wild sector. More research is required in order to fully understand this.

Honeybush is a uniquely South African product, which should fetch a premium price on the export market. Emerging overseas markets and high levels of export will continue to increase the demand for honeybush locally. While this does benefit the local Langkloof community, the industry cannot supply that which is required by the international market at this time (Polak & Snowball*,* 2017). There is a need to understand and map the local distribution and state of the population in order to facilitate the possible growth in the overseas market. This will allow for the expansion of the global market, ensure the livelihoods of the local communities involved in the industry and provide a sustainable use approach.

The dissertation is presented in the following format: each objective is presented as a chapter on its own in a format which lends itself to publication. Therefore, each chapter has its own aim, objective, methods, literature review, results, discussion and conclusion. The chapters are as follows:

Chapter 1 deals with an introduction to the honeybush harvesting industry, the aims and objectives of the research as a whole. The methods used are highlighted along with the study area geography and the broader context literature. Chapter 2 deals with the mapping of the resource. The mapping employed a range of methods to gather all existing spatial (and other data) on *C. subternata* and this chapter presents an up-to-date and first-distribution map of *C. subternata*. Chapter 3 characterises a range of wild *C. subternata* populations in terms of their density and environmental requirements for growth. While understanding the ecology and biology of the plant is essential in understanding the growth and harvestability, it is not the focus of this study. Distribution mapping, documenting of best practice harvesting methods and sustainable use of the plant from a geographical perspective are the focus of this work.

A resource assessment through a case study of the MTO forestry lands forms the basis for Chapter 4. The case study acted as a pilot study for the creation of the resource assessment methods. Much like in Chapter 2, a range of methods were used to determine the location of *C. subternata* plants on the MTO lands. The population distribution and extent were determined and a harvest survey was conducted to estimate yields throughout the MTO lands.

Chapter 5 combines information from the previous chapters to create a set of standards to guide proper harvesting techniques and principles, which is essential in ensuring the sustainability of the species as a whole. These principles were based on the results of this research and information from multiple existing harvesting guideline-type documents.

Study Area

The area of interest, indicated in Figure 1-1, is located in South Africa on the boundary of the Eastern and Western Cape regions from outside Port Elizabeth (Elands Valley) to just beyond Riversdale. The area is used for many different farming activities such as commercial fruit growing, forestry and livestock farming. The majority of the *C. subternata* populations are concentrated in the Langkloof mountain range with patches of growth occurring on the coastal mountains and plains in the Tsitsikamma region.

All species of *Cyclopia* occur within the fynbos biome, the largest biome in the Cape Floristic Region. The dominant geology belongs to the Table Mountain group of sandstones and quartzites resulting in nutrient-poor soils. The area receives 60% of the annual average rainfall during the winter rainfall period. The east of the region experiences year-round rainfall, while spring and autumn see higher rainfall periods, thus most of the region experiences bimodal rainfall (McGregor, 2017a).

Specific sites were chosen throughout the distribution range of *C. subternata* in order to gain a better understanding of the nature and state of the plant. These included sites within the Mountains to Ocean (MTO) forestry lands located in Lottering and Witelsbos plantations north-east of Pletternberg bay and within privately owned land on the Tsitsikamma mountain range – north of George – and areas in the Langkloof mountain range.

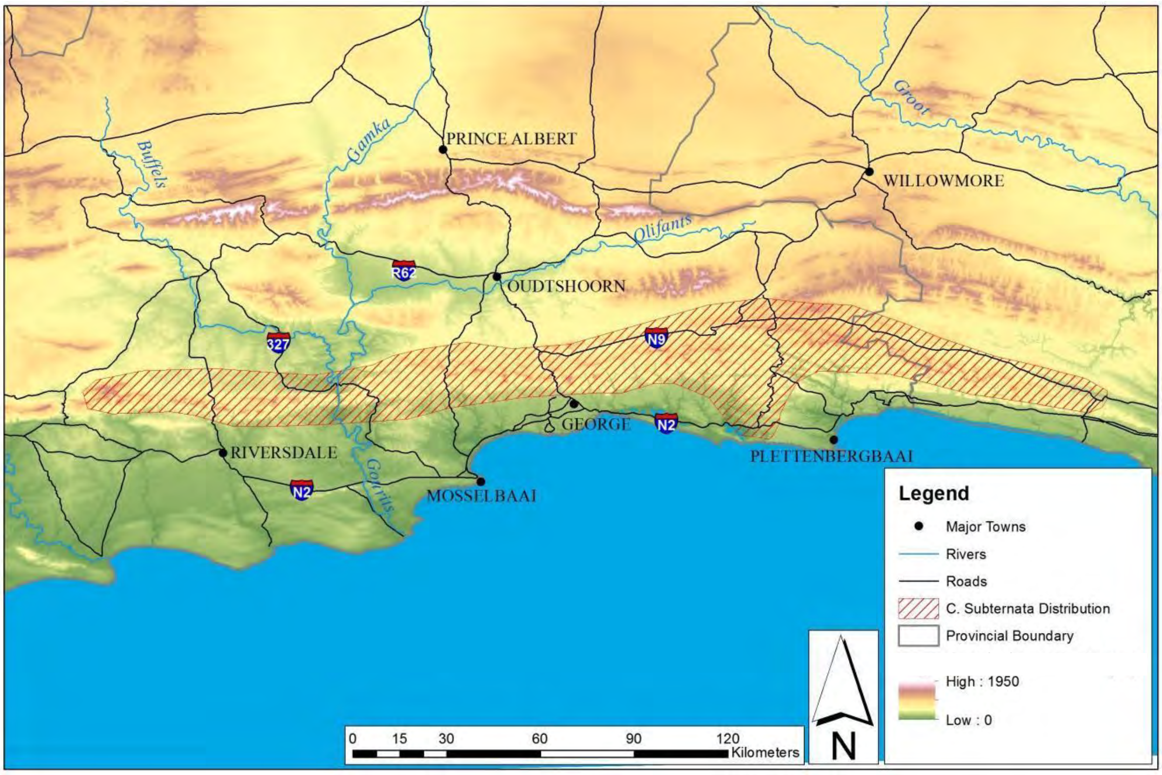


Figure 1-1 Study area including the full distribution range of *C. subternata*

Objectives

Each of the following objectives was explored within their own chapter in the research:

1) to establish an overview of the honeybush industry and to establish a scope for the research
2) to create a new detailed distribution map of the *C. subternata* resource through modelling, expert mapping and field mapping.
3) to characterise the extent of the wild *C. subternata* resource in terms of its density and typical environmental requirements for growth and use.
4) to conduct a resource assessment of the *C. subternata* resource on the MTO lands to capture context specific information about the harvest history and the resource distribution in this area.
5) to conclude with the recommended guidelines that would promote sustainable harvesting of *C. subternata* based on the information gathered in this research.

Review of Literature

Background on Honeybush and the Industry

Cyclopia is a genus of fynbos plants that grow mainly in the Cape Fold mountain regions of South Africa. Vleitee or *Cyclopia subternata* is commonly found along the southerly slopes of the coastal mountainous regions of the Tsitsikamma, Outeniqua and Langeberg mountains (North, Joubert, De Beer, De Kock & Joubert, 2017) and is the focus of this study. The production of honeybush tea depends on wild *Cyclopia* plants because most of the processed material is derived from wild populations. The process of making honeybush tea starts with harvesting the wild crop (any *Cyclopia spp.)*, then delivery to a processor, cutting, high-temperature oxidation (fermentation), and finally, drying (Du Toit, Joubert & Britz, 1998).

Figure 1-2 Photo of a typical *C. subternata* plant in flower in the wild (Van der Walt, 2017)

Regular harvesting provides more desirable plant material for processors because the stems do not become too woody and thick for the cutting machines. However, it is essential that a reseeder such as *C. subternata* is not cropped heavily as this leads to damage and kills the plant (North *et al.,* 2017). In the past, harvesting occurred during plant flowering time so that the harvesters could easily identify the crop, and it was also believed that the flowers were essential to the sweet taste of the tea (North *et al.,* 2017). Du Toit *et al*. (1998) advise against harvesting during flowering as this has a negative effect on the re-establishment of the population because potential for seed pod production is removed. Although plant age does not affect the taste of the tea, the age of the plant and the regrowth can affect the aroma of the tea (North *et al.,* 2017).

Joubert *et al.* (2011) suggest that to best understand the harvesting of *Cyclopia spp.*, it should be viewed from a number of different perspectives such as the plant as a harvested wild crop; the effect of commercial cultivation on the livelihood of wild harvesters; the effect of a lack of legislation and overharvesting on the crop; the historical evidence of population densities and how these populations have changed due to harvesting practices.

In order for the herbal tea market to grow, it requires a steady supply of crop, which can only be achieved by using both the wild and the cultivated sectors. In the African context, medicinal plants are often the most easily accessible and cheapest means of healthcare (Mahomoodally, 2013). Therefore, these plants are used widely in rural communities. Their use also depends on the fact that knowledge, which was gained from hundreds of years of trial and error, has been passed on from generation to generation (Mahomoodally, 2013). According to Wynberg (2017), honeybush traditional knowledge rests with the Khoisan, who were the first to use the plant for its medicinal properties.

It is estimated that 80% of the African population relies on wild harvested plants for day-to-day use, yet scientific research on these medicinal plants has been limited (Mahomoodally, 2013; Moyo *et al*., 2015). There is still a dearth of scientific knowledge of medicinal plants, in particular with regard to sustainable harvesting. There is a need to increase research into, for example, herbal teas in order to establish whether the wild harvesting practices are sustainable. Moyo *et al.* (2015) refer to factors such as bulb size, non-consistent supply of plant material and the distance required to get to plants as factors which need to be examined for wild harvesting and sustainability of wild plant use.

Honeybush can be classified as a medicinal and aromatic plant (MAP) due to its use as a herbal tea. Schippmann, Leaman and Cunningham (2002) define MAP species as plants used not only in a medical sense but also as condiments, food or in cosmetics. A large part of the demand for the tea is due to the health qualities associated with the plant (Kamara *et al.,* 2004). On a global scale, there is an increased demand in the tea market for 'healthy teas' such as honeybush and rooibos (Shoup, 2016 and Ajuwon *et al.,* 2018). This has promoted research on the health benefits of the tea [1] and on improving cultivation for production, but there has not been much focus on the nature and state of the wild resource.

[1] Some health benefits include anti-cancer properties (Joubert *et al.,* 2008), skin photo-protection and skin cell viability (Petrova *et al.,* 2011; Magcwebeba *et al.,* 2016), anti-obesity (Dudhia *et al.,* 2013; Pheiffer *et al.,* 2013) and anti-diabetic properties (Muller *et al.,* 2011; Chellan *et al.,* 2014; Schulze *et al.,* 2015).

Due to the localised growth of many medicinal plants, the globalisation of their use has become a problem. This has led to overexploitation and the extinction of some species. Of the 1 100 plants used for medicinal purposes worldwide, 8% originate from Africa (Moyo et al., 2015). Some areas have a great number of endemic species which cannot be found anywhere else on the planet. These biodiversity hotspots are under threat and need to be conserved in order to ensure that these areas sustain global biodiversity. "The forests and other remnant habitats in hotspots represent just 2.4% of Earth's land surface. But you'd be hard-pressed to find another 2.4% of the planet that's more important" (Conservation International, 2019, p. 1). When looking more specifically at the Cape Floristic Region, there is 69% endemism, which houses 12 endemic families and 160 endemic genera (CEPF, 2001). This high endemism has created massive international scientific interest and has aided in the overexploitation of medicinal crops. Research on its own cannot be the culprit; factors such as habitat destruction, competition from alien species, mortality from diseases and pollution all contribute.

The last 15 years have shown an increase in the quantity of exported honeybush as the market has expanded (McGregor, 2017a). From the total production of honeybush, there is an 85% export rate to countries such as Germany, the Netherlands and the United Kingdom (McGregor, 2017a). Other markets are emerging in America where a honeybush tea extract is used as a sugar-free lunchtime drink for scholars. The demand for tea in the overseas market has caused an expansion of the honeybush sector locally, which in its current form cannot meet the requirements of this market (Polak & Snowball, 2017).

Figure 1-3 Honeybush tea as packaged product (Shoup, 2016)

The export market for honeybush has grown considerably in the last 20 years. What started as a locally used commodity, with a value of 2c per kilogram in the 1930s, has grown into a 350 ton per year export market at R70 per kilogram in the past six years (Polak *et al.,* 2017). The success of honeybush commercialisation has been driven by research done at the Agricultural Research Council (ARC), which proved that it is truly a herbal tea.

The honeybush industry is progressing towards a more structured means of production through cultivation rather than wild harvesting for its major supply. Honeybush production has many factors that affect the quality of the product: fire, plant competition, fermentation and drying (Joubert *et al.,* 2011). Due to the high proportion of honeybush exports, the market requires that quality remains constant in order for the product to be acceptable overseas (Joubert *et al.,* 2011).

Overview of Existing Honeybush Research

Joubert *et al*. (2017) and Joubert *et al.,* (2011) extensively reviewed the history of the crop and its use in the industry. Additionally, Hannes de Lange has pioneered the ability to cultivate the wild honeybush plants (Pers Comms. McGregor, June 2018). *Cyclopia* species contain a medically significant compound, mangiferin, which along with isomangiferin, xanthones, flavanones, dihydrochalcones and benzophenones has been found in numerous *Cyclopia* species (De Nysschen *et al.,* 1996; Joubert *et al.,* (2011); Schulze *et al.,* 2015). Research done on the anti-cancer properties of honeybush extracts and phenolic compounds (Joubert *et al.,* 2008), skin photo-protection and skin cell viability (Petrova *et al.,* 2011; Magcwebeba *et al.,* 2016), as well as anti-obesity (Dudhia *et al.,* 2013) and anti-diabetic properties of *Cyclopia* extracts (Muller *et al.,* 2013; Chellan *et al.,* 2014; Schulze *et al.,* 2015) will likely aid in the commercialisation of honeybush teas in the future.

Joubert *et al.* (2011) summarised the honeybush market in the South African and international context and along with highlighting information about the honeybush market, they looked at plant biology and the lack of scientific analysis of the harvesting and selling of the plant. Due to the unknown quantity and extent of the wild honeybush resource, wild harvesting needs to be studied in order to ensure sustainability (Schippmann *et al.*, 2002). In order to resolve this dearth of knowledge, McGregor provided wild honeybush harvesting guidelines (McGregor, 2017a) and a field guide for wild harvesting (McGregor, 2017c). This field guide contains a contribution by Van der Walt on the best practice for harvesting of *C. subternata.*

Only 10% of the annual average of 732 tons of green honeybush crop that is processed is *C. subternata* (McGregor, 2017a). Along with the low quantity of crop used, this species also has a lower green harvested price of R9.00 to R10.00 per kilogram (McGregor 2017a). The lower cost is due to the crop not having a desirable taste, not producing the right colour for the tea or having a high moisture loss compared with *Cyclopia intermedia* (Joubert *et al.,* 2011).

Due to the lack of data, the decline of medicinal plants in the wild has often been overlooked. In order to establish relevant policy and conserve plant populations, but still allow for their use, an extensive study into the state of wild populations had to be conducted. Therefore, this study established where conservation efforts must be directed. Cultivation could be put in place to supplement and conserve the wild populations (Moyo, Aremu & Van Staden, 2015). Along with the benefits of growing the market through commercial cultivation, there may be negative effects such as genetic diversity loss due to a lack of local adaptation, hybridisation and the phenology of the plants (Joubert *et al.,* 2011). These aspects have all been overlooked in the cultivation of *Cyclopia* due to the desire for rapid expansion in response to demand for the product.

The growth in demand for honeybush has raised questions about sustainability because 85% of the crop originates from wild harvesting (Joubert *et al.* 2011; Schutte, 1995; Du Toit *et al.,* 1998). A resource assessment of wild populations, as proposed by Schippmann (2002) and Cunningham (2001), is a first step towards sustainable management and use. It will also contribute to improved implementation of the Eastern Cape permit system, which maintains the protected status of *C. subternata* and *C. intermedia.* Resolving issues of sustainability will clear the way for organic certification, which can bring a higher price on the market. However, due to the high cost of getting this certification, many smaller farms cannot afford this process (Polak & Snowball, 2017).

While research has been done to understand the plant in the wild, it is clear that there are still areas which are not fully understood. In order for the plant to remain sustainable, there needs to be a better understanding of cultivation and management of the wild resource, which is the focus of this research. This lack of knowledge was highlighted at workshops carried out by McGregor (2017a) and led to the call for sustainability and the harvesting guidelines established by McGregor (2017a).

In the South African and more specifically the Langkloof context where the main industry is fruit production, labour is not available in the latter part of the year. Due to the need for workers to be involved in the fruit picking industry, it is not viable to harvest the crop when it is the best regrowth period. Harvesting at this time will in the long term affect the suitability of the crop (North *et al.,* 2017)[2]. A dedicated honeybush harvesting workforce should be established in order for harvesting to occur at the correct period with sustainable practices. With the current harvesting practice of July harvests, records show that a plant can be harvested for six to eight years before it will no longer produce the desired crop (North *et al.* 2017). North *et al.* (2017) suggest that harvests should take place in September before flowering occurs.

Harvesting of buchu, another wild-harvested medicinal crop in the South African context, has encountered many of the same hurdles experienced in the wild harvesting honeybush industry. While the buchu industry has started moving towards small-scale cultivation, there have been concerns with regard to harvesting methods, harvesting intervals, alien invasion and fire (Street & Prinsloo, 2013). These issues, much like those in the honeybush industry, have led to a halt in progress in the cultivation of buchu. Incorrect farming practices have led to cultivated plants not producing seed or sufficient yields, which kept the primary focus on the wild harvesting of buchu. With a price of R35 per kilogram (Williams & Kepe, 2008), there is a strong economic incentive for harvesting the plant and potentially overharvesting if a permitting system and regulations are not established correctly (Street & Prinsloo, 2013). Lessons learnt from the buchu industry can aid in understanding the difficulties in the honeybush industry and can help avoid the same mistakes. One of these lessons is that harvesting guidelines need to be established to ensure the longevity and sustainability of the crop.

Belcher and Schreckenberg (2007), Peters *et al.* (1989) and Ticktin and Shackleton (2011) provide extensive literature on non-timber forest products (NTFP), which provides useful insights into natural resource use relating to conservation and resource control, nature of livelihoods and the economic value for local communities. Many of these ideas are useful in developing an approach to sustainable harvesting of the *C. subternata* resource. The increased promotion of non-timber forest products stems from a conservation effort which will allow local communities to trade goods in order to ensure their livelihoods (Belcher &

[2] This does not take into account the harvest teams who are dedicated to wild harvesting and do not take part in fruit picking, which is common in the Langkloof.

Schreckenberg, 2007; Ticktin & Shackleton, 2011). This conservation effort not only establishes an income for locals but also acts as an incentive for individuals to use the forest areas sustainably. The definition of NTFP is so broad and does not give criteria of exactly what these products are but rather a list of what they are not, which may lead to confusion. Additionally, *C. subternata* is referred to as a wild crop and as a NTFP throughout the referenced literature. Thus the reference to NTFP or wild crops throughout the research stems from the source of the information presented. Harvesters refer to *C. subternata* as a wild crop which allowed for the choice of words in the guidelines created in this research.

Belcher and Schreckenberg (2007) state that there are two principal objectives for the cultivation of NTFP. From a livelihood perspective, commercialisation will increase job opportunities and income for the poor. From a conservation perspective, there could be an increase in the number of protected areas due to a single species which can be found there (Ticktin & Shackleton, 2011). This idea stems from Peters *et al.* (1989), who state that the value derived from one hectare of NTFP can far exceed that of an equivalent area's timber output.

In order for NTFP to be economically successful, there are seven key steps which need to be considered (Belcher & Schreckenberg, 2007): production, collection, processing, storage, transport, marketing and sales. These steps encompass the value chain of the entire system and can give an idea of what is required for successful commercialisation. While there may be an individual make-up of this system for each crop, the principles can be applied to any product.

Wild Resource Harvesting and how this relates to honeybush

Harvest teams in general have a depth of knowledge and experience when carry out the wild harvesting of honeybush. Due to a lack of formal monitoring, there are concerns that in areas which are easily accessible, e.g. state or municipal land or land with absent landowners, degradation of the resource is taking place (Joubert *et al.,* 2011). In the wildflower industry, Bek, Binns and Nel (2013) report that there are concerns about the removal of plants and the effect this has on ecosystems and the plants themselves. There is often incongruence between the scientific knowledge and the knowledge which harvesters have when it comes to sustainable harvesting practices (Bek *et al.,* 2013). Trashing of the landscape, as described by Bek *et al.* (2013) in the wildflower harvesting industry, can occur while harvesting the wild honeybush with damaging effects on the landscape.

Poverty has contributed to the high level of overharvesting in the honeybush industry. Harvesting of the wild plants is typically an easy source of income for impoverished local communities (Williams & Kepe, 2008). Much like wild harvesting of other cash crops and NTFP's (Bek *et al.,* 2013), honeybush can be harvested wild because it is easily accessible and thus individuals can easily make money. This not only harms the growth cycle of the plant but it also causes juvenile plants to be included in honeybush tea production (Joubert *et al.* 2011) if not harvested in a sustainable manner. Due to the demand for honeybush tea in the international markets there has been increased harvesting pressure. This situation worsens as the demand goes up and prices increase (Polak & Snowball, 2017).

Figure 1-4 Harvested *C. subternata* plant material in a processing factory (McGregor, 2017a)

Some harvest teams gain access to private lands through working with the landowners. These teams will generally pay the landowner one third of the crop value and the individuals who harvest the crop receive between R1.50 and R3.50 per kilogram depending on the difficulty of harvesting (McGregor, 2017a). A harvester can typically bring in between 50 to 180 kg of crop in a day depending on the ease of access to the site (McGregor, 2017a). More experienced middle-aged harvesters will often bring in more crop than inexperienced harvesters. Each harvester is paid individually, according to how much they crop.

Two harvesting methods are widely used; the first is for cutting *C. intermedia* and is not suitable for cutting *C. subternata.* This method uses a sickle, which is favoured by most harvesters because a large amount of material can be cut quickly. The second harvesting method, which is suited to *C. subternata,* involves secateurs, a slower harvesting method, which enables the harvesters to be selective in harvesting. This leads to a cleaner cut and causes less damage to surrounding plant material.

In order to ensure the sustainability of the *C. subternata* crop, it is important to look at what enables the natural seeding process to occur and which harvesting practices allow the plants to recover. North *et al.* (2017) state that *C. subternata* recovers faster after harvesting in the wetter, warm spring months than at any other harvesting period. This could be due to *C. subternata* having a shallow root system compared with other *Cyclopia spp.* (e.g. *C. intermedia*) and requiring more moisture to sustain its growth (North *et al.,* 2017).

The methods used by Privett, Krug, Forbes and Gaertner (2014) to test for medium-term sustainability could be adapted in order to establish the sustainability of harvesting wild honeybush. The Privett *et al.* (2014) study looked at two sets of resprouters and reseeders of fynbos which are harvested in order to establish the effect of different cutting methods and cutting heights. The principle of using 75 plants, which are grouped into sets of 25 and cut at different heights, can be used as a means to study the sustainable harvesting techniques for honeybush. In order to establish whether the use of a sickle or secateurs is more suitable for harvesting honeybush, the methodology of Privett *et al.* (2014) can be adapted to apply the different cutting methods at a standard height so that they can be compared and sustainability of the harvesting methods can be established.

While the increased cultivation of a product can lead to decreased stress on wild populations, commercialisation of a product can have the opposite effect. A distinction between cultivation and commercialisation must be made. Commercialisation encourages better marketing and scaling of product use, which can lead to incentivising the harvesting of wild crops. This can lead to the destruction of wild populations and a reduction in biodiversity (Joubert *et al*., 2011).

Understanding the relationship of fire to fynbos is key to the survival of the wild honeybush crop. Cowling *et al.* (1996) explore the idea that the early growth and flowering cycles are crucial in establishing a soil seed store after a fire event. Therefore, if harvesting takes place within this early period, it would be damaging to the long-term sustainability of the plant due to the lack of a seed bank being established (Enright & Lamont, 2008). *Cyclopia spp.* are described as pioneer plants which regenerate quickly after a fire has affected an area (Vlok & Schutte, 2010). Scarification from a fire event allows seeds to germinate and emerge as seedlings (Le Maitre & Midgley, 1992). Later there is a stage where the honeybush plants are outcompeted by other species as the fire interval increases. Therefore, fire is required to ensure the species can coexist in the wild populations.

Honeybush and Rooibos Similarities

Rooibos tea made from the fynbos plant *Aspalathus linearis* has a long history as a medicinal plant in South Africa and has been used for refreshing drinks, health improvement and as a cure for restlessness and vomiting (Ajuwon *et al.,* 2018). There is a wide market for rooibos and as such it has become very lucrative in the international market (Mahomoodally, 2013). As a fynbos plant, similar to honeybush, rooibos has been affected by harvesting and conservation issues. Rooibos has already faced many of the challenges which now appear in the honeybush industry in the transition from a wild-harvested product to a cultivated crop (Pretorius, Harley & Ryser, 2011). The rooibos market has already progressed through the market stages which honeybush is currently in. The honeybush market can draw on the knowledge gained in the rooibos industry to inform and develop the market and avoid potential mistakes.

The rooibos and honeybush industries have parallels with regard to skills developed in the harvesting of the crops. Both crops are harvested by selecting branches for harvest and then cutting these, using a set of secateurs (Malgas & Oettle, 2007; Pretorius *et al.,* 2011). Therefore, plants can be individually judged for a sustainable harvesting quantity. Much like the cultivation of honeybush, rooibos (*A. linearis*) is harvested by small- and large-scale farmers to produce organic tea for the local and international markets. The rooibos crop also has a limited range in the Cape Floristic Region and faces similar growth, harvesting and production problems to the honeybush industry.

Three problems which have been associated with the rooibos industry are rapid habitat loss because of virgin land clearing for rooibos cultivation, loss of unprotected ecotypes of wild rooibos, and finally, potential loss of genetic resources for both biodiversity and long-term successful cultivation (Hawkins, Malgas & Biénabe, 2011). The honeybush industry has been less affected by land clearing because many of the cultivated stands are in old lands (Beyers, 2016). However, there have been threats to wild populations due to poaching, overharvesting, development of settlements and invasive plants (McGregor, 2017b). Not all of the harvested species of honeybush are protected or listed as endangered species, which creates difficulty for monitoring sustainable harvesting. While the rooibos industry depends on one species for cultivation, honeybush has several species used in cultivation, which creates genetic diversity due to the use of seeds from a wide range of populations (Cowling *et al.,* 1996). With foreknowledge of the type of problems the rooibos industry experienced, the honeybush industry can avoid similar problems.

Western Science, Local Ecological Knowledge and Traditional Ecological Knowledge

Honeybush harvesting has been a skill passed on from harvester to harvester and thus falls into the category of indigenous knowledge or traditional knowledge. The Convention on Biological Diversity (CBD) is a globally accepted treatise on conserving global biodiversity. Various sections in the CBD deal with the protection of biocultural heritage, which includes preserving and respecting traditional knowledge, using that knowledge more widely for sustainable management and conservation and sharing the benefits from industries that use and depend on traditional ecological knowledge (TEK) with the holders of that knowledge (CBD, 1992).

South Africa is a signatory to the CBD. Moreover, in August 2019, *Protection, Promotion, Development and Management of Indigenous Knowledge Systems Act 6, 2019* was signed into law as a landmark achievement in South Africa.

Figure 1-5 Group of harvesters discussing where *C. subternata* plants occur on a map (McGregor, 2017)

Indigenous knowledge, also known as traditional knowledge or aboriginal knowledge (Bruchac, 2014) as well as traditional ecological knowledge (Chamberlain, Emery & Ginger, 2019), is recognised as a valuable source of knowledge in sustainable resource management. It may include information dealing with techniques for planting and harvesting, hunting and gathering skills as well as particular knowledge and understanding of local ecosystems (Ballard & Huntsinger, 2006).

This kind of knowledge is accumulated through real observations and experience in the local environment and is essential to subsistence and survival (Ballard & Huntsinger, 2006). The authors refer to local ecological knowledge as "local expertise of peoples that may not have a long-term relationship with the local environment, but nevertheless has local wisdom, experience and practices adapted to local ecosystems". The value of local ecological knowledge (and traditional ecological knowledge) for sustainability has been documented for commercially harvested NTFPs (Emery, 2000; Emery & Barron, 2010). Both local ecological knowledge and traditional ecological knowledge can be found in the honeybush context. There are older harvesters who have experience and younger harvesters who have learnt how to work in these specific conditions. Additionally, local ecological knowledge is present with farmers and processors who have gained specialised skills through working with the plants.

There is a growing body of evidence that shows how traditional knowledge is being aligned with the best available scientific knowledge to manage and protect natural resources. A United Nations Environmental Program report (2017) lists many examples of how indigenous people have used their traditional knowledge to protect their resources against destructive and exploitative development schemes, such as mining and damming. A report on "The Future We Want" (United Nations, 2012) state that: "…the traditional knowledge, innovations and practices of indigenous peoples and local communities make an important contribution to the conservation and sustainable use of biodiversity, and their wider application can support social well-being and sustainable livelihoods".

Cyclopia species are endemic to areas inhabited by the Khoi and San for over 2 000 years and that knowledge of its use has been passed down for 300 years. Research presented in the TEK document supports the community's perception that traditional ecological knowledge for rooibos and honeybush rests with the communities who originated in these areas (DEA, 2014). Interviews conducted for this research with farmers, harvesters and processors provided extensive evidence of these individuals possessing local ecological knowledge. They have gained specialist skills through long-term work with the crop and have shared knowledge among those involved in the industry. This knowledge is especially important in the understanding of wild honeybush growth because there has been no formal long-term monitoring, formal recording of harvesting processes or changes in yield over time. Therefore, by combining local ecological knowledge and scientific research, a holistic understanding of the industry can be achieved.

CURRENT FEATURES AND ISSUES OF CULTIVATION IN THE INDUSTRY

The Department of Agriculture, Forestry and Fishery (DAFF) in its most recent biennial report gives an overview of the honeybush value chain from 2006 to 2011 (DAFF, 2011; DAFF, 2016). The department promotes commercialisation in order to aid local harvesters with income. The overview provides outlines of the amount of cultivation which has taken place. When compared with other studies and estimates, their values appear to be incorrect, according to McGregor (2017a). Their suggested strategy of giving individuals plots of larger farms does not consider the ideas of Schippmann *et al.* (2002) to maintain biodiversity and create sustainability within cultivation. Due to high startup costs, there is little incentive for harvesters to move away from wild harvesting because profits would be reduced.

State-subsidised initiatives such as supplying land for the cultivation of honeybush will financially support individuals living in rural areas. Allowing people in these areas to cultivate honeybush can reduce the perception that rural areas are unproductive and require welfare (Shackleton, Shackleton & Cousins, 2001). Direct use value from land-based activity is high and can support multiple individuals through extended farming practices. Shackleton *et al.* (2001) refer to agriculture within close boundaries to rural homes as major contributors to the wealth of these regions. In the honeybush industry, this is not the case due to the need for individuals to move great distances in order to find wild crops which are suitable for harvesting. This increases labour costs and production time (DAFF, 2011).

In their research on rural livelihoods, Shackleton *et al*. (2001) conclude that rural farmers manage to live off selling very little of what they produce in their local areas. Most of the crops, wild or cultivated, are used within the homes and are not sold; yet they still add to the economy of the area. In the rural context, the Shackleton *et al.* (2001) study estimates that 57.5% of the total annual value per household originated from land-based activities. In order for increased yields to occur, the Green Paper by the Ministry of Agricultural and Land Affairs (1998) suggests that demands on the land be increased due to the idea that the recovery rate of cultivated land is much higher than previously thought. However, this idea needs further exploration as the main focus of this research is the conservation of *Cyclopia spp.*

Cultivation allows for the entire growth process to be standardised. From seed to harvesting to post-harvest processing and distribution, the entire process can be monitored. This can simplify the organic certification process and ensure that farmers receive the best prices for their crops (Schippmann *et al.,* 2002). As cultivation becomes refined, the pressure on the wild resource is reduced (Schippmann *et al*., 2002). The size of the wild populations currently does not make provision for the honeybush market to expand – there is not enough plant material to meet today's demand for tea sustainability (McGregor, 2017).

Local dispersal of plants is often poor due to a lack of seed dispersal, which can lead to sympatric speciation (Cowling *et al.,* 1996). While *C. subternata* is the most widely used crop in the cultivated sector, it does not grow abundantly throughout its distribution. This creates a risk of future genetic problems if a monocrop system is used (Cowling *et al.,* 1996).

Cultivation allows for the harvesting of the intended crop without damaging or including unwanted plant material (Schippmann *et al*., 2002). Unmonitored wild harvesting of plant material can lead to uncertainty of future crop yields, which may cause overharvesting in the wild. Having cultivated stands of honeybush will produce a constant product with a guaranteed quality, which can aid in price negotiations and a growing market.

Due to the rapidly increasing demand that outstrips supply, cultivation of honeybush must be established in order to meet market demands (Joubert *et al.,* 2011). However, there are a number of concerns related to cultivating the wild plant, which can lead to costly and time-consuming startups. While there has been growth in the cultivated sector, McGregor (2017b) found that 85% of honeybush supply consists of wild-harvested crop. This increase in demand creates concern that inexperienced harvesters will overharvest populations on private and public land for financial gain (Potts, 2017). Overharvesting has already led to the destruction of natural populations in some areas (Joubert *et al*., 2011).

Cultivation is a good alternative for honeybush production because it brings economic benefits such as job creation, reduced pressure on the wild populations and can promote the use of old unused lands for cultivation, while creating a standardised crop (Potts, 2017).

Little is known about the genetic diversity of *Cyclopia spp.* and it is evident that more research needs to be done in order to establish whether there is a threat of hybridisation and species contamination during cultivation. (These ideas are not the focus of this research and will not be dealt with in this research). Plant genetic diversity is essential in 'domestication'; it aids in the overall diversity of the system and in creating the best possible building blocks for the plant species itself (Potts, 2017). In order to establish a population which is resistant to climate change and diseases, inbreeding must be avoided (Potts, 2017).

While increased domestic cultivation of food crops has led to better food security, using this same principle for medicinal plants can be detrimental. A monocrop culture could potentially lead to a loss in biodiversity (Schippmann *et al*., 2002). Many cultures believe that a plant which is cultivated does not harbour the same medicinal qualities as that of a wild plant – thus making it less desirable for consumption (Schippmann *et al*., 2002). Potts (2017) also notes that while wild crops may be commercially viable, the information required about population size, regrowth and sustainable harvesting is lacking. Under a controlled cultivation environment, less external stress is placed on the plants and there is reduced competition, which could reduce the quality of the harvested material (Schippmann *et al.,* 2002; Uniyal, Uniyal & Jain*,* 2000).

Figure 1-6 Typical wild *C. subternata* growth site (McGregor, 2017)

In general, with a wild crop, there is no capital investment for harvesters, the cost of production is low and the income that harvest teams make is mostly profit (Schippmann *et al.,* 2002). However, it is well documented that these harvesting teams do not receive the full potential pay for their product (Schippmann *et al.,* 2002). Low payment to harvesters reduces the cost of the product on the market. Low product costs do not allow for economically viable cultivation to take place because the cost of production will be too high (Schippmann *et al.,* 2002).

Climate Change Assessments

Anthropogenic climate change raises many questions in terms of conservation and protection of biodiversity. It was the general assumption in terms of conservation efforts that climate was a constant feature of an environment. However, this is not the case because range shifts are now seen in plant populations as climatic change occurs (Midgley, Hannah, Millar, Rutherford & Powrie*,* 2002; MacKellar, New & Jack, 2014). If species' range shifts are the most likely result of climate change, conservation efforts will have to extend conservation into areas where these shifts could occur. Therefore, a modelling system is required to show where these possible areas are, how the plants (or animals) will migrate, and if the areas they inhabit will indeed be able to support the new species (Midgley *et al.,* 2002).

In order to understand climate change and the effect it will have on a variety of plant populations, it must be understood from a spatial and temporal perspective (Midgley *et al.,* 2003). Models can effectively be used to determine the spatial distribution of plants not only as they stand currently but also as climate change affects them (Phillips, Andersonb & Schapired, 2006). Models can show early warning signs for global warming, which can aid in ensuring conservation for a species and biomes as a whole. To best evaluate what effect climate change will have, there is a need to do both species- and biome-specific studies (Phillips *et al.,* 2006). This is because there is variability between species and these factors must be considered. Having a holistic understanding of the situation is the only way to ensure conservation.

With regard to biome relocation, the following factors have to be considered for the survival of these species: species relocation, how previous land transformation will impact movement, which species are under the highest threat to climate change, and finally, what implications this will have for conservation planning (Midgley & Bond, 2015). Concerning specific species, the three major risks they face are range elimination, range reduction and range shifts. The biome modelling which Midgley *et al.* (2002) conducted for their study shows that the fynbos region will lose large parts of its range in the coastal forelands and inland plains along the west coast, with a rough increase of 1.8 ^{o}C mean annual regional temperature. Midgley *et al.* (2002) predict there will be a migration towards the Cape Fold

Belt Mountains and that areas to the west of this will not be able to support the necessary bioclimates for fynbos growth.

Midgley *et al.* (2002) predict a loss of 65% of the fynbos biome area due to climate change by the year 2050. Again, the regions to the north and west coast are those affected the most with an estimated survival area of 10% of the current growth area. This massive loss in biodiversity area can be attributed to the dependence of these biomes on altitude (Midgley *et al*., 2002). Survival of species will rely on the speciation that has occurred in the south due to topographical variances. Areas such as the Cape Fold Belt will act as safe zones during climate change and need to be protected accordingly. Within this time period, the heightened ambient temperature could increase the fire interval in the fynbos regions (Midgley *et al.,* 2002). This would alter fundamental growth cycles, adding to the destruction of biodiversity in the area.

Midgley *et al.* (2002) state that fynbos species are vulnerable to the effects of climate change in the future. This leads to a need for harvesting guidelines to consider these affects and the long-term impacts harvesting will have on the honeybush plants. Methods used by Midgley *et al.* (2003) to assess the effect of climate change on the CFR were considered throughout this research in order to ensure the sustainability of the plants.

METHODOLOGY OF THE RESEARCH

This research aimed to investigate the nature and state of the *C. subternata* wild resource with a view to develop guidelines for the sustainable harvest thereof. This was achieved through creating 5 objectives which were addressed in individual chapters. These chapters addressed their own set of aims and should be viewed as components that add to the overall knowledge about *C. subternata.*

Both quantitative and qualitative methods were used in order to fully explore the extent of this study. The *International Encyclopaedia of Geography* (Castree *et al.,* 2017) suggests using multiple methods to explore a complex research question. According to Timans, Wouters, and Heilbron (2019), the use of mixed methods has become increasingly popular in the social and behavioural sciences. It is a research approach that involves collecting, analysing and integrating quantitative (e.g. experiments and surveys) and qualitative (e.g.

focus groups and interviews) research and analysis techniques (Cresswell, 2014). This method includes measuring the physical environment and accommodating human use and knowledge about the plant. The combination of different methods (Cresswell, 2014) allows the researcher to manage not only the plants used in the wild but also the individuals who are using the plants.

The mixed methods used in this study followed both the positivist and interpretivist approach, with these being the two main research philosophes used in science today. Positivism states that reality is stable and observable can be described objectively and in a way that is repeatable (Cohen, Manion & Morrison, 2011). In addition to dealing with measurable phenomena, the research relied on the use of interviews; transect walks and observations with honeybush harvesters and experts (i.e. interpretivism). These methods allowed for the research to be understood contextually and how interaction between researcher and subject can affect the outcomes (Schwartz, Shea & Yanow, 2011).

This research used the positivist approach because it dealt with measurable phenomena. However, it also included an interpretivist approach due to the use of interviews, transect walks and observation for data collection through the guidance of harvesters and experts in the research process. Mixed methods were used to create the best understanding of the plant.

Chapter 2 used an overall approach of positivist because the aim was to quantify the resource. Existing GIS data sets and modelling were used to achieve this. However, this data was supplemented by expert mapping based on interviews and focus groups producing qualitative information, which was used to quantify the data.

Chapters 3 and 4 described interviews, transect walks and observation to collect and record the harvesters' knowledge of harvesting and the honeybush environment. The results were subjected to thematic analysis (qualitative method). The data was confirmed with measurements of the physical environment and surveys of the harvested as well as non-harvested plants. Therefore, the harvesting taking place was quantified to verify what the harvesters said about the harvesting process. While chapter 5 combined the knowledge gained from the previous chapters to create the guidelines for harvesting.

CONCLUSION

The honeybush industry is set for an expansion due to the popularity of the product across a range of uses. For it to remain viable, the product must be harvested with sustainable use in mind. Using information gathered from other areas of research which relate to the wild harvesting of honeybush will result in the best understanding of the crop and how to use it into the future. The industry has an opportunity to become aware of and implement sustainable practices as well as the opportunity to support livelihoods of local communities through these practices.

The industry is still relatively young and this is the ideal time to create awareness and to spread knowledge about sustainable harvesting practices. The sooner these conservation ideas are implemented, the greater effect they will have on the wild populations of *C. subternata.*

Because this study aimed to create a set of best practices for harvesting, many facets of the industry such as the growing, harvesting, conservation and processing of the wild plant were investigated. These ideas were all developed together with ideas from other industries to establish the most sustainable practice for the harvesting of wild *C. subternata.* This was achieved by using the objectives stated in this chapter as a step by step process to create a sustainable harvesting guide (as seen in chapter 5).

Chapter 2

MAPPING OF CYCLOPIA SUBTERNATA

AIM

The aim of this chapter was to investigate and map the extent of the distribution and range of *C. subternata* populations by combining information from multiple sources.

INTRODUCTION

While mapping plays a crucial role in the ability to conduct a resource assessment of wild crops (Schippmann *et al.,* 2002), no such detailed mapping exercise has been conducted for *C. subternata*. A mapping exercise was required to establish the extent of *C. subternata* (vleitee) distribution and to enable conservation and resource management of the plant. Maps such as those created by Schutte (1995) for her thesis and subsequent paper (Schutte, 1997), generalised online maps such as those by South African Honeybush Tea Association (SAHTA), Joubert *et al.* (2011) and the Red List (IUCN, 2017) show rough population distributions. Beyers (2016) refined the mapping criteria by creating a map based on botanical descriptions of the species in the Cape Floristic Region (Manning & Goldblatt, 2012). Finally, McGregor (2017a) produced a single medium-resolution distribution map of the *Cyclopia spp.,* which is commercially important, including *C. subternata,* as well as a second detailed distribution map of *C. intermedia.* While these are the most accurate distribution maps created to date there is no detailed *C. subternata* map.

Therefore, the aim of this chapter of the research was to create a new, accurate and detailed distribution map of the extent of the wild *C. subternata* resource. The information depicted in the maps was intended to provide a basis for establishing a resource management and conservation plan to ensure the future of not only the honeybush crop but also the future of the market.

The mapping exercises done by McGregor (2017a) and Beyers (2016) established which variables were required in order to accurately depict the population distributions. Their mapping exercises formed the basic methodology for the resource assessment which was conducted for this research. The distribution of *C. subternata* is influenced by a number of environmental variables, namely geology, rainfall, vegetation community, agricultural land-use class, land cover and aspect. Mapping also enables a researcher to identify areas which will be of interest in terms of threats to the population such as climate change, poaching, overharvesting and unnatural fire intervals (Franklin, 2009).

OBJECTIVES

The objective of chapter 2 – creating a new *C. subternata* distribution map resource through modelling, expert mapping and field mapping – was achieved through carrying out the following steps:

1) to compile all existing data on *C. subternata* from various sources such as experts (harvesters, botanists and farmers) and available literature in a spatial database.
2) to use multiple criteria selection in GIS to create a map of where *C. subternata* should occur based on existing secondary digital spatial data layers.
3) to conduct field mapping.
4) to create a modelled probability of distribution map using the MAXENT modelling software.
5) to combine the data from the previous objectives in order to create a distribution map for *C. subternata.*

REVIEW OF LITERATURE AND METHODOLOGY

In order to have a data set that was usable and reliable, two sources of data should be combined, namely primary and secondary data. Primary data such as expert mapping, vegetation sampling and field mapping create building blocks for developing a potential distribution model. Secondary data such as the GIS modelling from multiple criteria selection (MCS), species distribution maps and primary data from SANBI and PERCIS (Preserved Context Index System) co-ordinate data were used to further gain knowledge and refine the data. Along with the distribution range of the plant, the patterns of population distribution were considered: the distribution of the plants can either be uniform dispersal, random dispersal or clumped dispersal (Mucina & Rutherford, 2006).

Expert Mapping data collection

Experts were an important source of knowledge in a specific field based on experience and education. Experts play a crucial role in understanding specific situations were not well understood in the past (Clevenger *et al.,* 2002; Garthwaite & Al-Awadhi Shafiqah*,* 2006). Expert mapping or spatial prioritisation define areas of interest due to the knowledge which individuals have in the field (Knight, Cowling & Campbell, 2006). Tubbs and Blackwood (1971) suggest that experts should be used to highlight areas of interest or rank areas for comparison. The method of expert mapping has been used extensively by biologists and ecologists in order to determine where protected areas should be established (Soulé, 2007). While a systematic approach may reveal more detailed information about an area, the ability of experts to draw on experience can save time and money in identifying areas of interest for research. Using expert knowledge in order to map protected areas, habitats, species-specific information and identifying threats to biodiversity has been widely used (Smith, Goodman & Matthews*,* 2006).

Kuhnert, Martin and Griffiths (2010) warn that expert knowledge is a useful tool in refining and creating precision within a model but should not be looked at in isolation and must be treated with the same scrutiny as empirical data.

Field Mapping

Vegetation and soil sampling are key aspects to field mapping and methods described by Mueller-Dombois (1974) were used. These included using belt transects to establish the distribution of populations in an area. The soil sampling used criteria described by Carter and Gregorich (2007) as the method for collecting samples within and outside the belt transects used for vegetation sampling. (These sampling methods are described in detail in Chapter 3.)

Vegetation mapping

Vegetation mapping has been used extensively throughout South Africa and the world as a tool for conservation and management. In order to create valid distribution maps, there are seven key elements which need to be considered, according to Mucina and Rutherford (2006). Firstly, vegetation is a tangible object and needs to be studied. Secondly, due to vegetation being an object, these objects should be classified into vegetation types. Thirdly, classification reduces the complexities that are apparent in all vegetation types. Fourthly, creating a hierarchy rank of individual characteristics allowed for the analysis of patterns in the vegetation. Fifthly, the environmental conditions where the vegetation can be found will determine the complexity of the system. Sixthly, there are a large variety of plants making up a vegetation type and which will individually respond to ecological factors. These dynamics thus create a complex system, which were considered when classifying vegetation types. Lastly, vegetation occurs within time and space and was mapped to represent this data.

GIS Modelling (Multiple criteria selection)

Multiple criteria selection (MCS) in a GIS context enables the user to make decisions based on multiple criteria (the use of many different variables and input data) in a spatial context; thereby geographical data can be manipulated to either solve a problem or create an output (Rikalovic, Cosic & Lazarevic *,* 2014. Based on this definition (Rikalovic *et al.,* 2014), MCS was used as a first step in creating an output in the form of a new map for the distribution of *C. subternata.* MCS was used to establish a model of possible population distribution based on selecting the extent of individual criteria and combining these extents to establish a predicted distribution. Empirical as well as expert knowledge data was used to create these models through the selection of specific criteria based on the needs of the study (Store & Kanga*s,* 2001). The selection process was limited by the available data and its scale, resolution and age.

Models which depict habitat suitability are used to represent the possibility of species occurrence in an area due to their preference for certain landscapes (Pausas, Braithwaite & Austin*,* 1995). While empirical data gave the most accurate representation of population distributions, these data sets are often not available or have not been created. Using a GIS modelling system along with the information gathered from experts enables the researcher to produce data which is numerical and has spatial relevance (Shaw & Atkinson*,* 1988). Store *et al*. (2001) describe using a classification system based on Boolean logic which will confirm or reject a specific location due to a preset value (determined by the user). Once this classification method was completed, the map will only show areas which fulfil all the criteria which have been selected (Carver, 1991). While the Boolean logic forms the basis for selection criteria, it does have flaws which were resolved by using multi-criteria evaluation methods. These methods considered areas which were best suited to the criteria outside the feasible areas and thus alternative areas of interest can be evaluated.

In order to create an MCS model, Store *et al.* (2001) recommend using the following approach:

1. identifying environmental variable criteria suitable for growth of the plant (i.e. choosing the habitat requirements);
2. producing map layers: gathering data from multiple sources such as expert knowledge, ground truth data and species distribution;
3. cartographic modelling: defining the feasible area and combining the habitat requirements;
4. analysing sensitivity: the effect of changing the weighting of certain criteria on the suitability of the habitat.

These steps were used to create a model which will accurately show a possible distribution without the use of empirical data (which was not available in the case of *C. subternata*) and can save time by using expert knowledge to narrow down study areas. Using a GIS and overlaying raster images in order to determine the suitability of an area through objective classification created a map which was used to help describe the extent of the population due to specific criteria suitable for honeybush growth.

Species distribution and MAXENT

Guisan and Zimmermann (2000, p. 47) define species distribution modelling (SDM) as: "The production of empirical models relating field observations to environmental predictor variables, based on statistically or theoretically derived response surfaces." Therefore, by using SDM, distributional changes were predicted. Understanding the change in plant distributions and how these changes interacted with the environment around them has become crucial due to the potential climate change effects on the planet. SDM developed in three stages (Guisan & Thuiller, 2005): firstly, non-spatial statistical quantification of species-environment relationship based on empirical data; secondly, expert-based (non-statistical, non-empirical) spatial modelling of species distribution; thirdly, spatially explicit statistical and empirical modelling of species distribution.

A changing environment will have direct and indirect effects on species across a distribution. The main factors which affect these distributions are regulators such as temperature, water and soil composition; disturbances such as man-made or non-man-made problems affecting the environment; and resources, which are used by the species to survive (energy and water) (Guisan & Thuiller, 2005). These three factors interact with the environment's spatial distributions and when altered affect the species at different scales.

While many different methods are used for determining species distribution, the ability to not only predict species location but also predict migration of species due to climatic change is essential to understand how species can be protected in the future. Habitat conservation plants, environmental risk assessments, invasive species management and ecosystem modelling will all aid in the broader understanding of species distribution and sustainability (Franklin, 2009).

The ability to model population distributions with climate change is aided by the use of maximum entropy methods such as MAXENT when there is a lack of detailed distribution data (Phillips *et al.,* 2006). Species distribution modelling using presence-only data, as is done with MAXENT, can help to identify the distributions of species of which we know little such as *C. subternata.* Phillips *et al.* (2006) state that using these modelling methods better defines areas which are suitable and unsuitable for species migration than would other modelling systems such as the genetic algorithm for rule-set predictions (GARP). The use of bioclimatic variables which are derived from temperature and rainfall values on a monthly basis creates a base of biologically meaningful data to model population distributions (WorldClim, 2019). Used in the MAXENT modelling software, these variables aided the model in predicting population distributions while taking into consideration seasonality and extreme climatic events, for example, the warmest or wettest months (WorldClim, 2019). The success of the use of these variables was attributed to the fact that multiple climatic models were used and compared to create the best possible representation of what can be expected in the future.

MAXENT can be used to model population distributions while taking into consideration changes in climatic condition (WorldClim, 2019). The use of the MAXENT modelling system is beneficial because it creates multiple climatic models which are compared and thus provide the best possible representation of population distributions (Phillips *et al.*, 2006). In order to achieve the best possible results, species-specific niche modelling must be done (Pearson & Dawson, 2003). The diverse nature of each vegetiation type can then be taken into consideration and effectivly modelled. However, there are limitations to the success of MAXENT modelling, which can cause bias within the results (Slingsby *et al.,* 2017). Hannah *et al.* (2005) also advise that populations rather than range should be modelled to avoid inaccuracies at fine scales of population distibution.

Species distribution modelling can be used to help with conservation efforts and to understand how plants will migrate due to climate change. However, there are limitations to the models which are created. Due to the diverse nature of all vegetation and the variations in microclimates, the effects of climate change will vary extensively at individual species level (Mucina & Rutherford, 2006). While large-scale reponse to climate change modelling has been used extensivly, modelling at a niche or species level can be more useful. Firstly, species variation in response to climate change can be considered, and secondly, this modelling can then be used as a potential impact assessment rather than a prediciton of occurance (Pearson & Dawson, 2003).

Additonally, occurance bias were considered within modelling. Factors such as access to sites, sampling methods, level of detail in recording data, sample sizes and the avalability of bioclimatic variables (Slingsby *et al.,* 2017) can all influece the validity and realiability of the models created. Another limitation which was considered during modelling was the modelling range rather than populations (Hannah *et al.,* 2005). The range of a species consists of its geographical extent where it actually occurs. However, some bioclimatic models assign a probablity of occurance which can be converted to presence-absence value. While this shows the potential occurance of a species at a coarse scale, the resultant map will not accurately depict the predicted localities of a habitat at a fine scale (Hannah *et al.,* 2005). There is thus a loss in accuracy of actual area of occurance when the scale is reduced in these models.

Existing data contributing to the Mapping of honeybush

To aid in creating population distribution maps of potential *C. subternata* growth locality records from previous honeybush work were used. Location information gathered from research done by SANBI, the National Herbarium Computer Information System (PRECIS), iSpot and other researchers such as G.K. McGregor and N Galuszynski (personal communication, August 2017) provided reliable records for sites which could not be ground truthed during this study. These researchers conducted extensive work on *Cyclopia spp.* as a whole in terms of population distributions, wild harvesting and plant genetics. The information that was gathered was recent and could be trusted and was therefore suitable for use in the mapping of the *C. subternata* population distribution. This data was included in the creation of subsequent distribution maps.

Methods

Given the aim of the research, mapping must occur using the criteria mentioned above. Mucina and Rutherford (2006) described an approach for consistent mapping of vegetation classes. Most of the available literature deals with broader-scale community mapping. The standards which must be determined are as follows: mapping theme, mapping scale, mapping element and unit hierarchy. This research focused on mapping populations of a single species, rather than a community, and therefore, the approach was simplified. Vegetation mapping is a complicated system, which needed to first identify specific vegetation characteristics and how these characteristics interact and then a mapping exercise was completed as explained below:

1) All existing data on *C. subternata* from various sources such as experts (harvesters, botanists and farmers) and available literature were compiled in a spatial database.

From the expert knowledge gathered through focus groups, interviews and informal discussions while in the field, a map of the likely distribution of *C. subternata* was drawn. The questions asked in the informal interviews were based on a questionnaire, which is provided in Appendix 1. The map was created from the information which harvesters, farmers and experts in the field provided for the researchers (see Appendix 1). The points were all plotted on a map and a standard set of variables was measured at each site (see

Appendix 2). Data was recorded as point and polygon features on a physical map and digitised into ArcGIS, where data analysis and map making could be done.

2) A multiple criteria selection map of where *C. subternata* should occur based on existing secondary digital environmental and spatial data layers was modelled.

Select environmental variables were extracted from individual sites which were identified by expert mapping and from literature (Joubert *et al.,* 2011; Schutte, Vlok & Van Wyk*,* 1995) in order to determine possible site characteristics for *C. subternata.* The following variables were considered: elevation, aspect, slope, biome, vegetation and land cover. These variables formed the basis for selecting areas of possible growth and were used due to the availability of data across the entire population range.

Along with the above data, information from the literature and expert knowledge were considered in the selection process. Renosterveld vegetation communities, for example, were excluded from the selection because they did not support honeybush populations. Table 2-1 details the variables considered in the MCS process.

Table 2-1 MCS inclusion and exclusion criteria

Variable	Included in selection	Excluded from selection	Source	Data set
Elevation	0 – 1 000m	Greater than 1 000m		DEM SRTM 30m CD: (NGI 2016)
Aspect	WNW to ENE	NNW to NNE	Barnardo, Vlok & Kemineth (personal communication, , 2017), Joubert (2011)	DEM SRTM 30m CD: (NGI 2016)
Biome	Fynbos	All other biomes	Mucina & Rutherford (2006), Joubert *et al.* (2011)	National vegetation map (SANBI, 2012)
Vegetation types	All fynbos communities	All other communities	Mucina & Rutherford (2006), Joubert *et al.* (2011)	National vegetation map (SANBI, 2010), McGregor (2017)
Land cover	Natural fynbos	Pastures, orchards, ploughed lands, waterbodies, settlements, mines and degraded land.	DEA (2014)	NLC (2013-2014)

3) A field mapping exercise was conducted.

Field sites were chosen according to a number of factors such as land access, harvestability, fire history, distribution of plant material and harvest history. The sites were chosen to show the spread of the population distribution as well as to show plants in a variety of conditions and ages. This provided a better understanding of the entire population distribution because multiple growth conditions were taken into consideration.

Field mapping consisted of a vegetation sampling survey and soil sampling at each site. The vegetation sampling included creating a defined area in which the survey would take place. In this sample site, multiple measurements were taken of each plant. These measurements were the height of the plant, the base diameter of the stem, the length of four harvestable stems, the diameter of those harvestable stems, the length of two unharvestable stems, the diameter of those unharvestable stems, and finally, a note on the condition of the plant. A general summary of each sample site was also recorded, which included the slope, aspect, elevation, presence of moisture, and other vegetation in the area. Finally, soil samples were taken within and outside the distribution for comparison purposes.

4) MAXENT modelling software was used to create a probability of distribution maps

To predict the potential distribution of *C. subternata,* the MAXENT modelling programme was used (see Appendix 3 for data used). By using the point locations for the known *C. subternata* populations, a distribution model of *C. subternata* linked to climatic variables was created. These locations are represented as probability of occurrence estimates and are useful because they can aid in refining the distribution models created, as represented in this chapter.

Of the location samples, 105 were used from throughout the Eastern and Western Cape regions. The data used was a combination of localities from all available data sources. In order to create a prediction for the distribution of *C. subternata,* presence-only data was used in the form of point locations. These locations indicated the full extent of the distribution range and allowed for a reasonable prediction of presence of the plant. Importantly, the MAXENT model had to be confined to the fynbos extent in the Eastern and Western Cape because these were the only suitable environments for growth in the CFR (this also increased the accuracy of the prediction). The model was run using the default settings and a probability of distribution map was created as the final output.

5) The data from the previous objectives were combined in order to create a distribution map for *C. subternata.*

In order to establish a new distribution map for the growth of *C. subternata,* all the previous mapping results were combined. The preferred environmental setting gathered from the expert mapping exercise aided in creating a multiple criteria selection map. It was possible to overlay the known locations of *C. subternata* with the MCS map in order to establish a range of where *C. subternata* should be occurring in the wild. Areas which did not align with the MCS and the known locations of *C. subternata* were excluded from the final distribution map because *C. subternata* was unlikely to grow in these areas.

RESULTS

EXPERT MAPPING

Expert mapping data was collected at several sessions (listed in Table 2-2 as well as in Appendices 4 and 5) at which the researcher was a member of the team responsible for facilitating discussions and recording information. Material on *C. subternata* distribution was also collected in the process of developing the wild honeybush harvesting guidelines for *C. intermedia* (McGregor, 2017c) and this data was also used for the research.

Table 2-2 Description of expert knowledge used for expert mapping

Meeting type	Expert	Description of data captured
Contribution to EADP 696, Wild harvesting guidelines for C. intermedia (McGregor, 2017c)	Mr J. Vlok, botanist	Polygons of *C. subternata* distribution across full extent at 1: 250 000
Interview (McGregor, 2019)	Mr Sam van der Merwe, retired agric. ext. officer	Polygons of *C. subternata* populations in the Langkloof and Tsitsikamma at 1: 50 000
Interview (McGregor, 2019)	Mr S. Scheepers, farmer	Polygons of *C. subternata* populations in the Elands Valley at 1: 50 000
Interview (McGregor, 2019)	Mr Pieter van Rensburg	*C. subternata* populations in the Langkloof and Tsitsikamma at 1: 50 000
Interview (Van der Walt, 2018)	Mr Edward Bornado	*C. subternata* populations in the MTO forestry plantation at 1: 10 000
Interview (Van der Walt, 2018)	Ms Ilse Kemineth	*C. subternata* populations in the MTO forestry plantation, Witelsbos and Woodlands at 1: 10 000
Interview (Van der Walt, 2018)	Mr Seun Godfree	*C. subternata* populations in the Langkloof at 1: 10 000
Workshop – MTO (Van der Walt, 2018)	(See Appendix 6 for workshop attendance)	Polygons of *C. subternata* populations in the Langkloof and Tsitsikamma specific to each individual's knowledge at 1: 50 000
Information session EADP 817 (McGregor, 2018)	Mr Justin Bramford Mr Gerard Botha	Polygons of *C. subternata* populations on farms in the Tsitsikamma at 1: 10 000

The areas which the experts highlighted were digitised as shown in Figure 2-1 as 55 uniquely occurring polygons. In order to establish the possible parameters of growth for *C. subternata,* the following variables were extracted from the locations provided by the experts: elevation, aspect and land use. The distribution extent which was highlighted by experts covered 1 641,96 km^2.

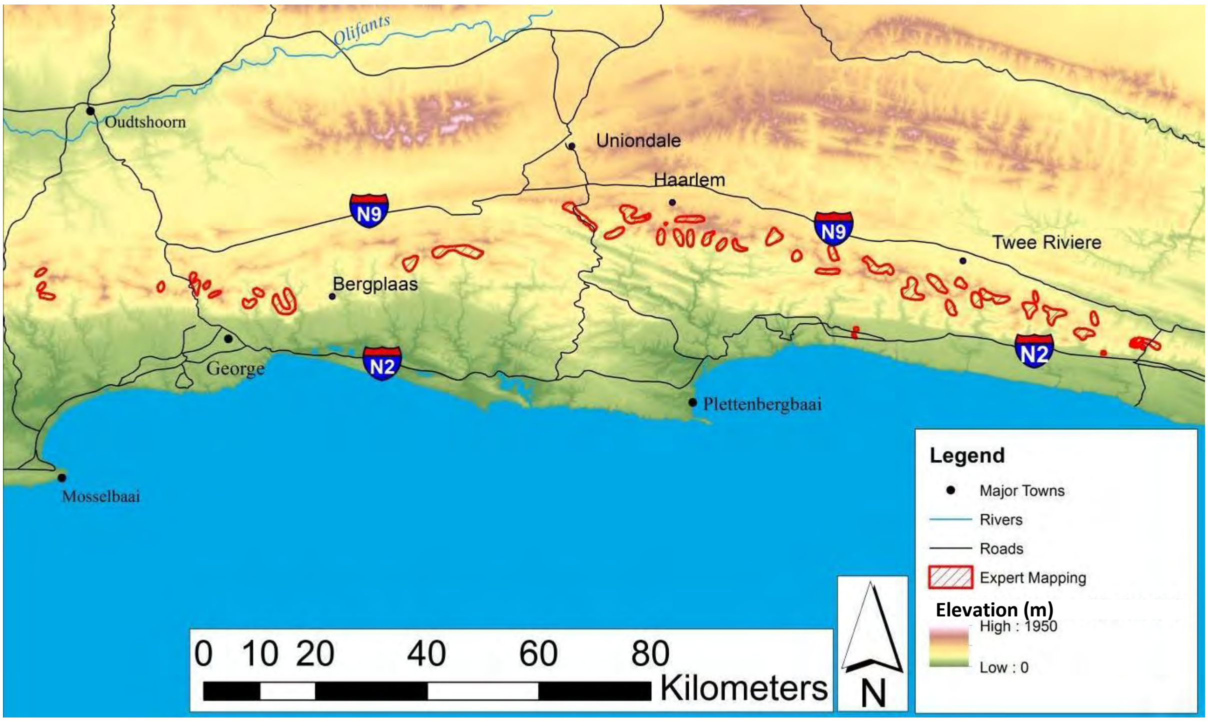


Figure 2-1 *C. subternata* populations identified through expert mapping polygons

Locality records mapping

Figure 2-2 shows known point locations of *C. subternata*. These individual points are a combination of multiple sources of data, which include personally recorded sites, harvesting sites, expert knowledge, research sites, PRECIS sites and iSpot sites.

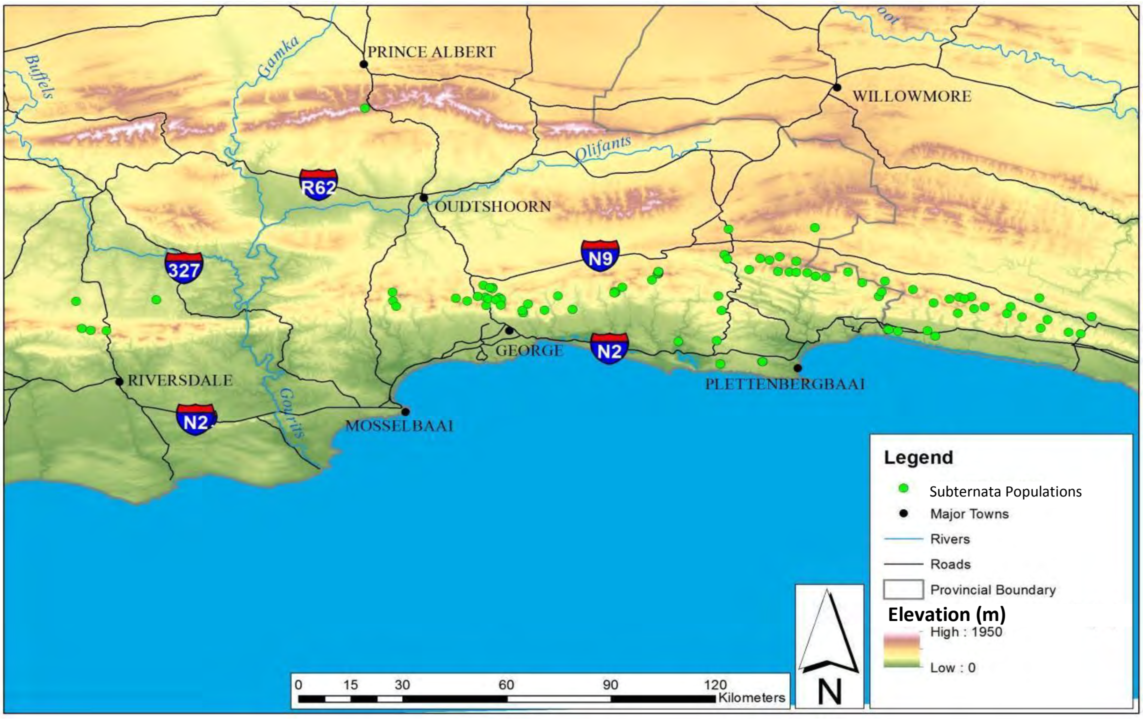


Figure 2-2 Map of known *C. subternata* points

Multiple criteria selection modelling

In order to define the potential distribution of the plants, transformed landcover areas were excluded, namely dams, rivers, commercial farming land, forestry lands, renosterveld, urban areas and subsistence farming. The area was further refined by selecting areas which meet the requirements for aspect and rainfall. As can be seen in Figure 2-3, the area which is highlighted is the potential distribution of *C. subternata*. The area which was selected by using the MCS method generated a potential distribution of 9 832,5 km^2. When comparing the map in Figure 2-3 with recorded plant localities and expert mapping in Figure 2-2, it is evident that there are areas of potential populations in the modelled MCS map that do not feature on the other maps, in particular, areas north of the R62 in the Langkloof and an area near Oudtshoorn.

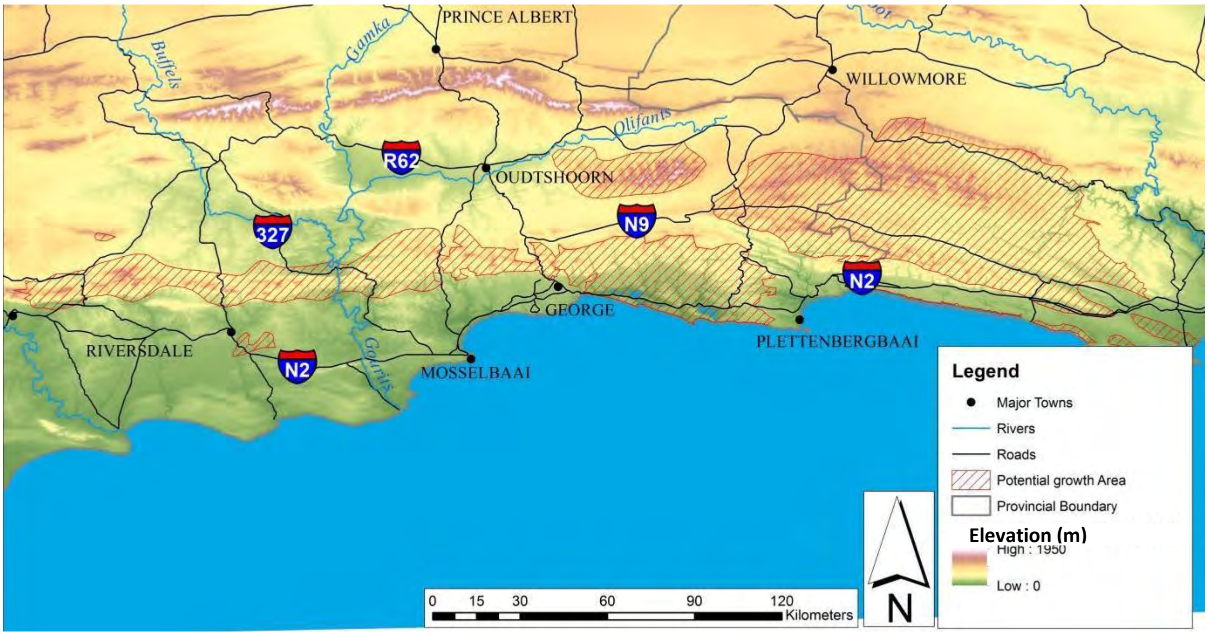


Figure 2-3 Map of the potential distribution of *C. subternata* as polygons

Field mapping sites

Sites were visited with harvest teams who knew the area well and had harvested the area previously. This enabled ease of access onto the farms as well as informal interviews to take place during the search and harvesting of honeybush plants. Figure 2-5 shows an example of a transect which was done on the Landman farm near Storms River. The transects were done at 13 sites (as indicated in Figure 2-4) in order to map the population at the field site as well as to measure the individual plants. The transects aided the researcher in gaining an understanding of the state of the population.

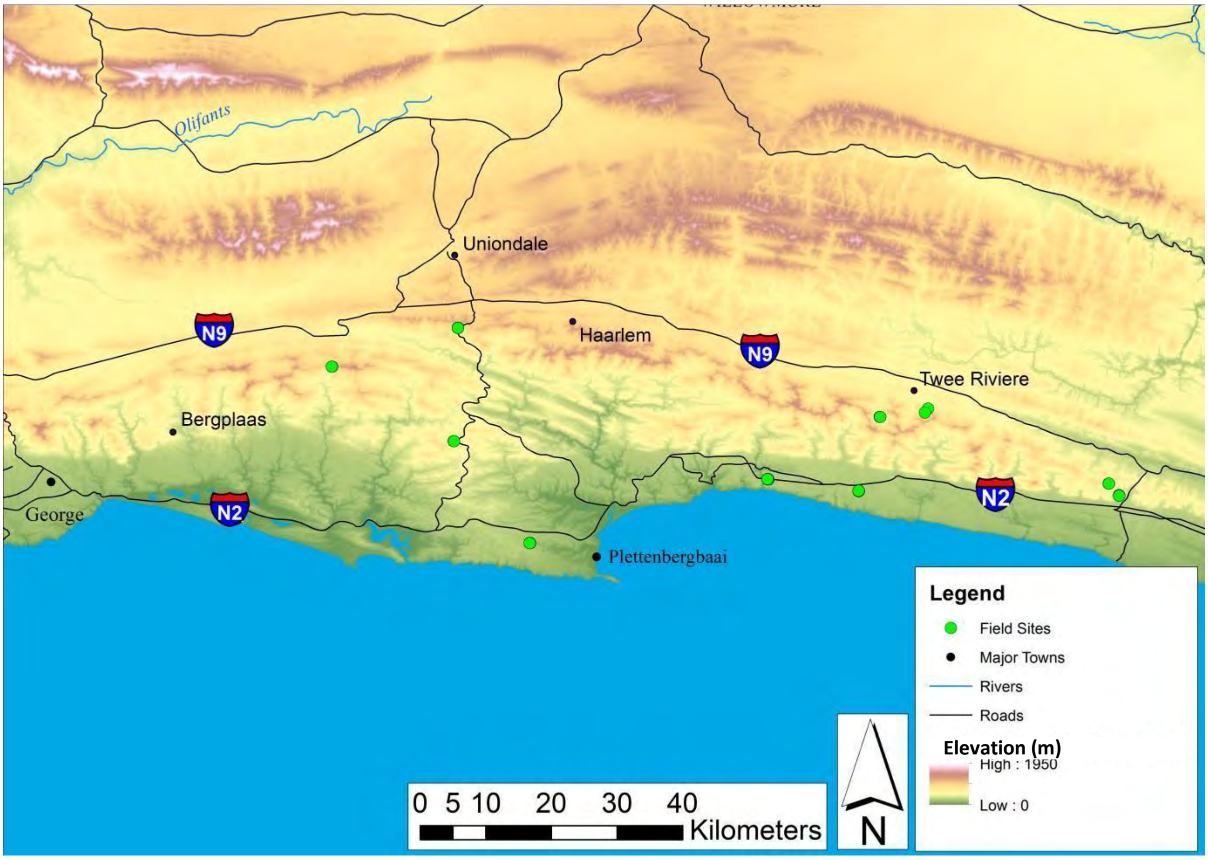


Figure 2-4 Sites where population surveys were carried out

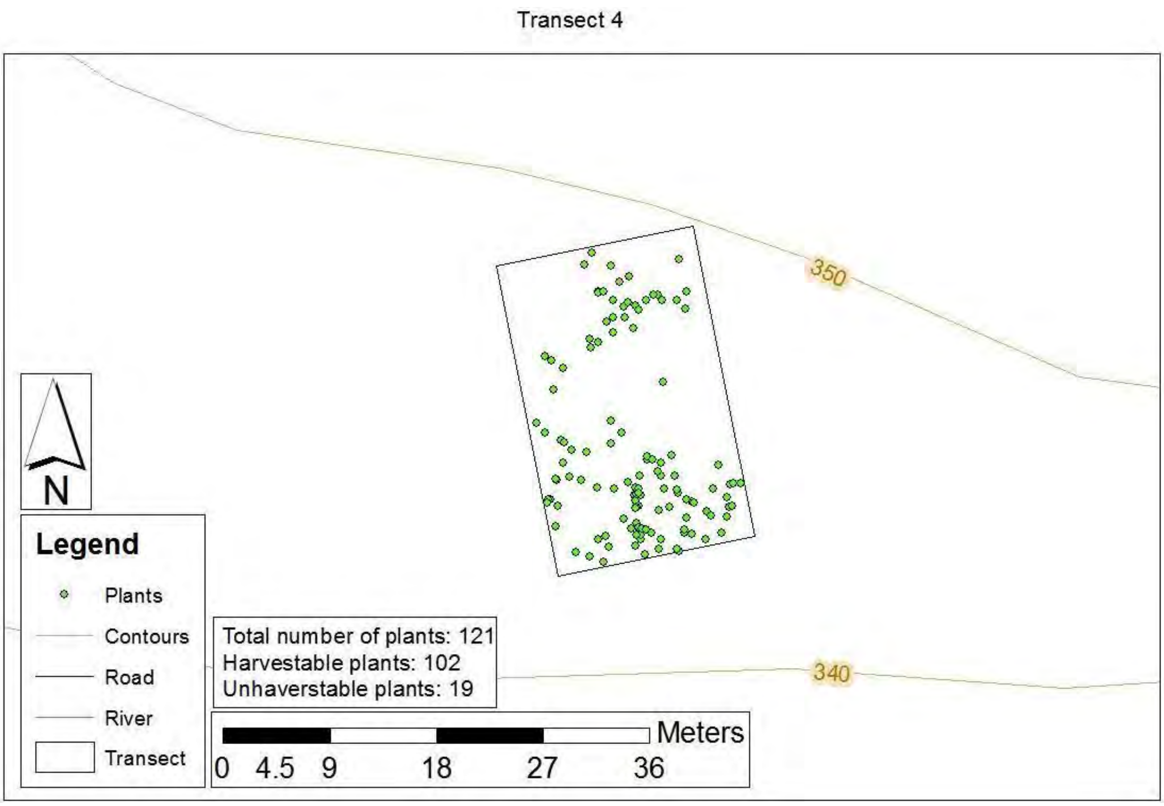


Figure 2-5 Example of a detailed field site transect of the Landman farm (Site 3)

SPECIES DISTRIBUTION AND MAXENT MODELLING

The model used climatic variables at a 2.5 minute (±4.5 km by 4.5 km) spatial resolution in order to create a probability of distribution map. This map was compared with the other distribution maps presented in this chapter. The variables (WorldClim, 2019) used in this probability of distribution map included the monthly average minimum temperature, monthly average maximum temperature, monthly total precipitation, and other derived bioclimatic variables (provided in Appendix 3). The results of the analysis are shown in Figure 2-6. The map uses a logarithmic scale to produce the distribution model for *C. subternata* where green represents the highest likelihood of presence (roughly 8 400 km^2), while blue shows the least likely locations for growth.

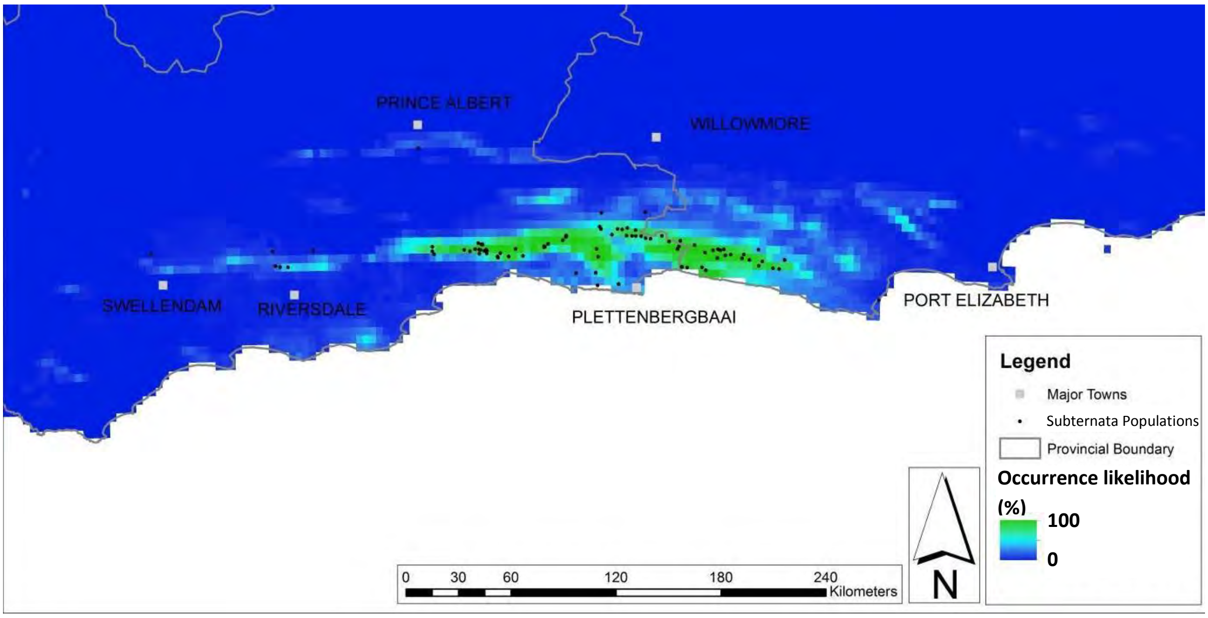


Figure 2-6 Map showing the probability of distribution of *C. subternata* using MAXENT modelling

COMBINED POTENTIAL DISTRIBUTION MAPS

By using the information gathered through the previous mapping exercises, the possible population distribution of *C. subternata* throughout its range could be narrowed down. By combining the expert knowledge, the MCS methods and the known populations of *C. subternata,* a more refined distribution map was created. This was done by creating an intersection map from the above maps. At the intersection between all three maps, there was a 100% likelihood of a plant population, whereas areas outside the intersections could be removed. Figure 2-7 shows the comparison between the MCS map and the known locations of the plant. Sightings which fell outside the MCS distribution map were limited to areas which were being used for either forestry land or sheep farming. These areas were not continuously used or disturbed and could support honeybush populations. A single plant sighting (from data collected from iSpot) occurred in the Prince Alfred area, which was not included in any of the possible distribution maps.

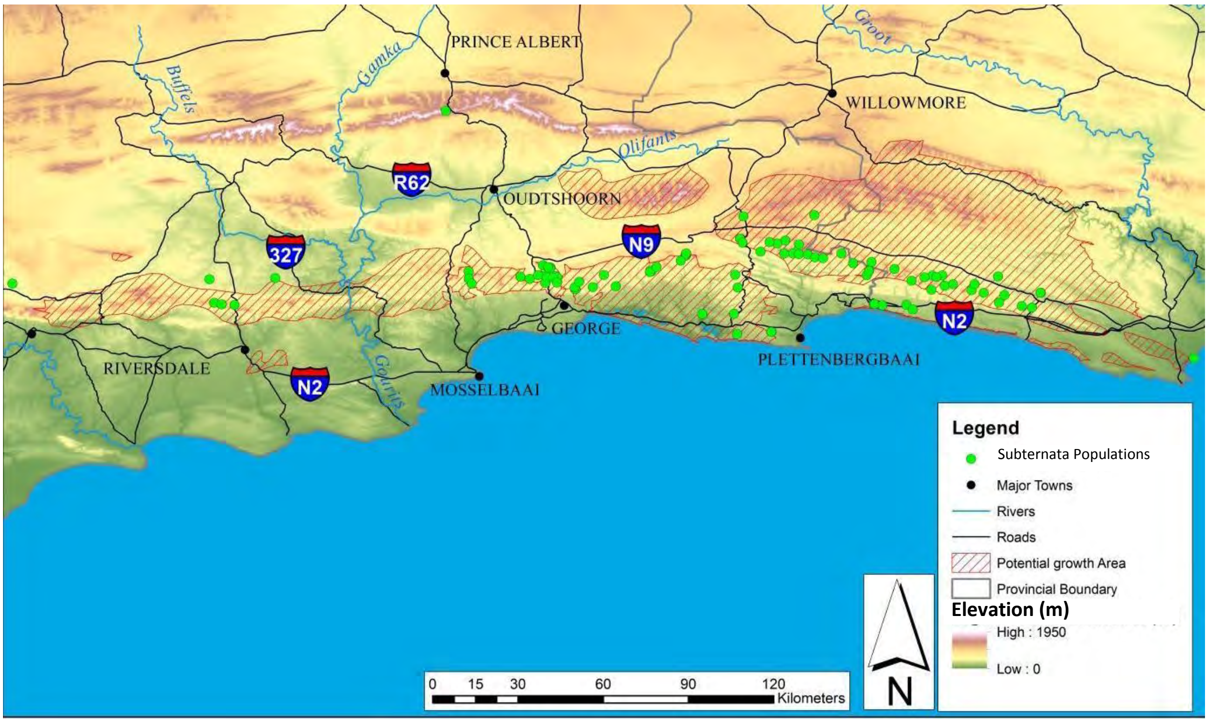


Figure 2-7 Map overlaying the possible distribution of *C. subternata* with known locations

Figure 2-8 shows the likely distribution of *C. subternata* across its range. This distribution is smaller than the MCS distribution because it combines all the distribution maps created to give a refined distribution of the plant. The map shows an area of 4 541,9 km^2 as the likely distribution extent of *C. subternata.* Figure 2-9 shows a detail of part of the *C. subternata* extent, aspect is taken into account (only a selected area is shown to illustrate the detail). When aspect criteria are included as one of the variables, the distribution area is reduced by a third to 1 513.97km^2.

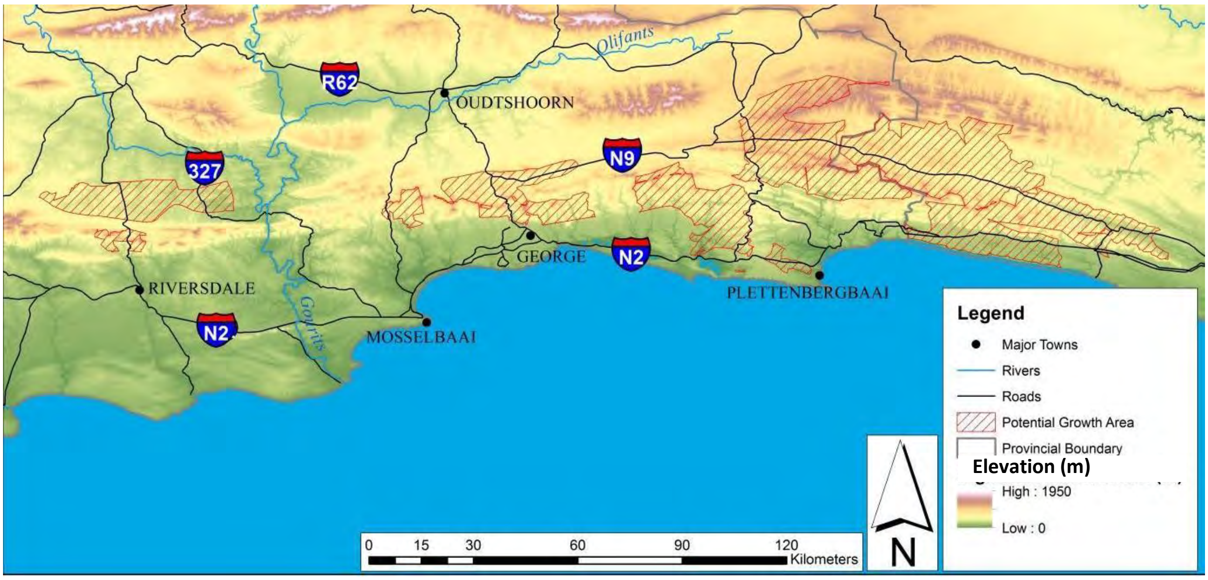


Figure 2-8 Map showing the likely distribution of *C. subternata*

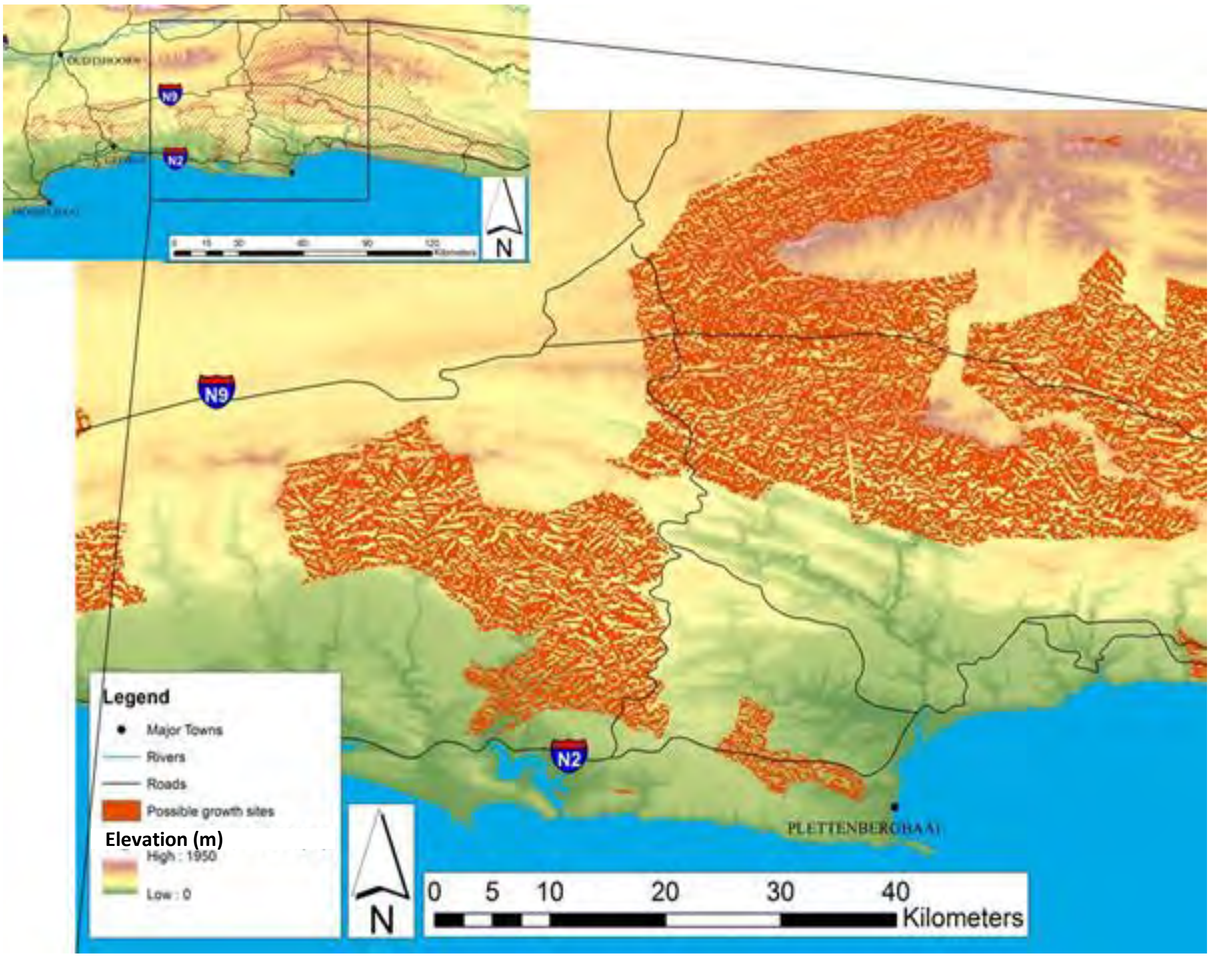


Figure 2-9 Map showing a detailed view of the potential areas where *C. subternata* could grow based on aspect

DISCUSSION

In order to achieve the aim of this part of the research, various existing sources of potential data on *C. subternata* were identified, namely SANBI, PRECIS, iSPOT, McGregor (2017a), as well as field data collection and expert interviews as sources of data for the map compilation exercise (Godínez-Alvarez *et al.,* 2009). As highlighted by Schippmann (1997), mapping of the resource is an essential step towards suitable management. GIS is a powerful tool for integrating data from many sources, in various formats and at different scales (Clevenger *et al.,* 2002; Mucina & Rutherford, 2006). The data was brought together to compile a new *C. subternata* distribution map in addition to a MAXENT probability of distribution map.

The results presented here represent the most comprehensive and recent spatial data set showing the distribution of *C. subternata*. Table 2-3 shows how different mapping methods created different distribution ranges for *C. subternata.*

Table 2-3 Differences in *C. subternata* distribution with different mapping methods

Mapping method	***C. subternata* distribution (km^2)**
Expert mapping	1 641.96
Multiple criteria selection	9 832.5
MAXENT modelling (above 75% probability)	6 952
Combined potential distribution	4 541.9

The use of expert mapping was crucial in aiding the researcher to understand the population distributions of the plant and the potential for harvest given the lack of scientific information (Store & Kangas, 2001; Tubbs & Blackwood, 1971). Most importantly, harvesters' knowledge was used to highlight areas of interest and site-specific growth conditions were described. Data validity was ensured by comparing both expert knowledge and ground truthing at specific sites.

Because a variety of models were used, the drawbacks of some could be considered in others. Kuhnert *et al.* (2010) identify the following benefits of expert mapping: the knowledge is current, it is quickly accessible, both local and broad scale can be identified. According to Kuhnert *et al.* (2010), there could be gaps in the knowledge and multiple sources are required in order to build a complete picture. It may also be difficult to find experts in the required field.

Generalised existing maps lack detail such as the map by Beyers (2016) and maps created for South African Honeybush Tea Association (SAHTA) by Du Toit *et al.* (1998). While these maps created a useful starting point, a better map was required to do resource assessments. As indicated in Figure 2-1, small select areas were highlighted based on expert knowledge. This consisted of mapping from many experts and included an overarching map of knowledge from a botanist, Jan Vlok (personal communication, July 2017), at a 1:250 000 resolution. The information gathered from previous literature also aided in determining the outer extent of the distribution. Literature and point data were used to estimate the environmental variables required for growth, recommended by Mucina and Rutherford (2006).

The data extracted from previous literature aided in understanding characteristics for the growth of *C. subternata* such as aspect, altitude, rainfall, geology, vegetation, harvesting history sites and land use. These variables were available as secondary digital data sets. Primary data sets (existing locality records) were added to data collected during this research project from expert mapping and ground truthing. The variables which were chosen to create the basic maps for the distribution of *C. subternata* were taken from the Mucina and Rutherford (2006) description for data sourcing and processing. According to Mucina and Rutherford (2006), both environmental and physical features which could influence plant growth. Therefore, a distribution map could be created, taking into consideration the physical and environmental elements required for the growth of the plant.

Information gathered formed the basis of selecting criteria for identifying suitable areas for *C. subternata* from secondary spatial data of environmental themes (WorldClim, 2019). While the MCS model created a distribution map meeting all the criteria determined from the characteristics in Objective 1, areas which had known *C. subternata* populations were not represented. The MCS model created a refined distribution map, but it was limited by the available data and BIOCLIM data resolution. Based on field visits, it was apparent that these plants could establish in conditions that did not meet all the criteria required for the optimal growth or represented in the available data sets.

Schippmann *et al.* (2003) warn that the MCS model should not be used in isolation to try and predict the potential distribution of *C. subternata*. Therefore, several approaches to distribution mapping had to be followed to cover all the likely distributions of *C. subternata.* Farming land or forestry land could not be excluded from the map where *C. subternata* populations did occur because the land was not totally transformed at the local scale. To refine the MCS model further, aspect was included. As determined from the literature, the *C. subternata* plants prefer south-facing slopes and can grow on both west- and east-facing slopes (Joubert *et al.,* 2011; Schutte, 1995). This criterion decreases the likely distribution of the plant throughout the mountainous terrain in the Western and Eastern Cape. It reduces the area where *C subternata* may occur by a third but may not be a perfect reflection of where the plants do occur.

The field mapping exercise revealed sites that lacked any *C. subternata* growth where there once had been populations. These sites were identified by harvesters as areas that had easy access and little or no enforced restrictions on harvesting. It was thus possible that these sites had been overharvested in recent history and the population disappeared. One such area was near Louterwater Dam, which once had a healthy population of plants (McGregor, personal communication, June 2018).

Rikalovic *et al.* (2014) state that with MCS, broad-scale modelling can be done quickly and easily. However, the modelling is limited to the data scale and the availability of the data (Rikalovic *et al.,* 2014). Field mapping allows for accurate, fine-scale modelling of actually occurring plants to take place. However, it does have limitations with the extent which can be covered. In this study, time and capital limited visits to field sites. However, some of these limitations were overcome by the use of expert knowledge (Kuhnert *et al.,* 2010). Expert mapping identified 1 641.96 km^2 of known honeybush populations, which formed part of the potential distribution map.

Creating a MAXENT model for the predicted distribution of *C. subternata* was the next step in creating a new distribution map. Using the BIOCLIM bioclimatic variables based on temperature and rainfall with *C. subternata* location data, the MAXENT mapping software produced a predicted distribution range for *C. subternata.* While the use of MAXENT modelling can help predict the overall occurrence of plants, it does not take into consideration the extreme topographical and microclimate variations which are seen across the CFR (Allsopp, Colville & Verboom, 2014). Moreover, Mucina and Rutherford (2006) comment on the highly diverse nature of the flora across different biomes and the inability of MAXENT modelling to accuratly account for these differences. The combination of location, climate, substrate and species affects the actual location of plant species which cannot be captured by MAXENT modelling (Mucina & Rutherford, 2006; Allsopp *et al.,* 2014; Kraaij & Van Wilgen, 2014).

When comparing the MAXENT model with the MCS model, there is considerable overlap. Areas predicted to have a high possibility of plant growth (highlighted in green) coincide with the larger MCS areas. Both maps show a small corridor of growth extending west from Plettenberg Bay through Riversdale and both maps focus on the region between Plettenberg Bay and Willowmore as the area with the highest potential for honeybush growth. It must be noted that the MAXENT map does not take aspect into consideration when predicting the possible localities of plant populations. This explains the difference in the possible distribution extent between the MAXENT model and the combined potential distribution map (6 952 km^2 and 4 541,9 km^2 respectively).

Finally, by combining all the distribution maps, a composite map was created representing the most accurate distribution map yet for *C. subternata.* The MCS model along with the known populations of *C. subternata,* field mapping and the MAXENT prediction created a distribution map, indicated in Figure 2-8. This final distribution map excluded the aspect distribution map in order to give an outer limit to the potential for growth. The map served as a possible distribution map rather than as an exact location map. While not all sites could physically be visited to verify the presence of the plant, the potential for growth, depicted on the map, was the most accurate distribution which could be created.

CONCLUSION

By using GIS software, many different data sets were compared. This allowed for the mapping of the distribution and range of *C. subternata* populations. The new maps which were created illustrate the size of the potential population. While previous models did not highlight the extent of *C. subternata* specifically, this research shows just how small the population extent is (final estimated distribution of 4 541.9 km^2 not accounting for aspect). Models should not be used in isolation because there are many variables which cannot be accounted for in each model and which will determine the potential distribution of the species.

A new and improved *C. subternata* distribution map was created through the integration of new and old information. This map can form the basis for future conservation and vegetation management programmes. These maps need to be used in conjunction with sustainable harvesting practices and permits from local authorities in order to ensure that the honeybush market continues to thrive locally and internationally.

LIMITATIONS

There were clear limitations affecting this research such as the use of mixed scales due to the different data sources. This could alter the accuracy of the data set created. The limited time and capital for field work did not allow for the entire population to be surveyed and could create errors in the prediction of sites which were not ground truthed.

Chapter 3

UNDERSTANDING WILD SUBTERNATA POPULATIONS

AIM

The aim of this chapter was to characterise the extent of the wild *C. subternata* resource in terms of its density and environmental requirements for growth and use.

INTRODUCTION

In order to describe the state of the wild resource and establish a set of best practices for harvesting, it is essential to understand the plant and its distribution. This can be achieved by using a standard set of measurements consisting of a population survey and an environmental survey to compare different populations. The plant survey for this research consisted of a location (GPS point), height, stem base diameter, stem lengths and stem diameters to determine the state of the plant. The environmental survey determined the soil surveys, aspect, slope, average rainfall and vegetation community. After determining the extent of the populations and the state of the resource, a set of harvesting guidelines for the sustainable use of the plant could be established. Creating a population distribution map and characterising the physical environment for growth will help to understand the use of the resource throughout the distribution area.

It is also crucial to understand the harvesting practices which are taking place and how these practices affect the plant. Harvesters' knowledge forms the foundation of the best practices for harvest due to the specific knowledge that they have gained through experience in the field (Cunningham, 2001; Ticktin & Shackleton, 2011). Empirical data on harvesting has been insufficient and this research represents a step towards formalising information on harvesting practices. The harvest quantities taken by the harvesters and their knowledge were documented in order to create a best practice harvesting guide to promote a balance between sustainability of the crop and production for the market.

OBJECTIVES

The following objectives were explored in this chapter:

1) to characterise the *C. subternata* resource and its physical environment.
2) to document the use of the resource in terms of typical harvesting practices.

REVIEW OF LITERATURE

FYNBOS ECOLOGY

All species of *Cyclopia* occur within the fynbos biome, which is the largest biome in the Cape Floristic Region. The geology stems from the Table Mountain group, which has sandstone and quartzite as its main components leading to nutrient-poor soils. As mentioned by Witkowski and Mitchell (2018), soils play a major role in the distribution of species within the fynbos biome. The distribution is also affected by factors such as rainfall, fire, the phenology of the plant and the ability to adapt to climatic conditions. These criteria are explored further in the next section.

ECOLOGY OF CYCLOPIA SUBTERNATA

Cyclopia species occur in the fynbos biome, the largest biome in the Cape Floristic Region (CFR), and knowledge of the genus for this research was based on the doctoral research by Schutte (1995). There is a lack of extensive knowledge about the genus and additional research is required to understand the distribution and growth of the plant. The CFR is dominated by the geology of the Table Mountain group containing sandstone and quartzite, which give rise to nutrient-poor soils (Mucina & Rutherford, 2006). *C. subternata* specifically has a restricted distribution compared with its more widely harvested relative *C. intermedia.* Distribution ranges from the coastal side of Kareedouw west along the Tsitsikamma, Outeniqua and Langeberg mountains, mainly on the southern slopes (Vlok & Schutte, 2010). *C. subternata* is a shrub which under the right environmental conditions can reach up to 3 m in height (Joubert *et al.,* 2011). Honeybush has trifoliate fine leaves, which have a low stem-to-flower ratio. It has sweet-smelling, bright yellow flowers which are up to 12 mm in length and feel leathery to the touch (Vlok & Schutte, 2010).

Fynbos species are fire adapted and require regular fire intervals in order for the system to maintain itself. Fire prevents colonisation by thicket and forest on the lower mountain slopes. *Cyclopia* spp. are described as pioneer plants which over time will be outcompeted (McGregor, 2017b) by other fynbos species. Without anthropogenic influences, the fire return interval in fynbos areas varies from 10 to 50 years and is influenced by normal climatic variables such as rainfall and temperatures. A fire regime is described according to its typical frequency, seasonality, intensity and size of fires (Allsopp *et al.,* 2014).

Phenology, the study of a plant's phenophases, needs to be considered when establishing a sustainable harvesting regimen. Locality will affect the phenology of a plant due to the fact that it is dependent on specific environmental conditions such as site, aspect, rainfall, seasonal variability and the type of plant (Cramer, West, Power, SkeltonStock, 2014). In the case of *C. subternata* in the Lottering and Witelsbos areas (on the MTO forestry plantation), budding can start as early as April or May and flowering can last late into October (Motsa *et al.,* 2017). Plants that are reseeders, such as *C. subternata,* invest much energy in flowering and seed production, because this is required to maintain the population (Cramer *et al*., 2014). Therefore, if plants are compromised, for example, by harvesting during this period, they might not have the required resources for long-term persistence.

Resprouters and reseeders

In fire-prone ecosystems, the ability of plants to either reseed or resprout is a crucial element in maintaining survival. Pausas and Keeley (2014) refer to three growth forms: obligate resprouters, obligate seeders (non-resprouters) and facultative seeders. Once a fire event has occurred, obligate seeders will die back completely and rely on the seedbank for their regeneration. On the other hand, resprouters survive a fire event by maintaining their below-ground energy stores in the forms of bulbs or lignotubers. Facultative seeders have the ability to act as both a resprouter and seeder in that they can survive a fire event and produce seedlings for regeneration after a fire event. In terms of this definition, *C. intermedia* is a typical facultative seeder (but is commonly called a resprouter) and *C. subternata* is an obligate seeder.

Resprouters can use recruitment from seeds in order to establish new plants, which will occur in the inter-fire period in well-sheltered areas. Seeders will require a fire event as well as an open environment for their seedling recruitment to take place. In general, seeders will have less access to water after a fire event and have adapted physiological traits which better deal with a limited water supply and highly variable growth conditions (Vilagrosa, Hernández, Luis, Cochard & Pausas, 2014). Due to the deeper root systems of resprouters, they have adapted to environmental conditions with a stable water supply.

While seeders do not have deep root systems, they have adapted to use water more efficiently in their leaves, they have higher leaf mass per branch and their seeds can handle heat shock better in order to increase post-heat exposure germination (Pausas *et al.,* 2014). These characteristics enable the plants to thrive in areas with relatively short fire intervals. It is important to note that when referring to resprouters and seeders, these reproduction methods focus on the ability of the plant to regenerate after a fire event. In the inter-fire periods, seeders can sustain regrowth if damage is done to the branches of the plants and resprouters can use seed requirement to establish new plants (Marais *et al.,* 2014).

C. SUBTERNATA AS A RESEEDER

The earliest mention of honeybush is in a 1705 botanical piece cited in Joubert *et al.* (2011), stating that germination was poor if scarification did not take place. Du Toit *et al.* (1998) also state that scarification is essential for the re-establishment of populations. Plant reseeding is one of the most common re-establishment methods in fire-prone areas and a fire moving through an area triggers germination (Ojeda, 1998). When a fire moves through an area, the adult plants are killed while the seeds which lie dormant in the soil are scarified and have the potential to germinate. One problem that occurs with reseeders is that a short fire interval does not allow the seed bank to be restored, which creates the potential for a post-fire collapse of the species (Ojeda, 1998).

The most common method of cultivation is the use of seedlings in the form of seeds prepared through sulphuric acid scarification to break dormancy in *Cyclopia* seeds. Dry and wet heat or microwave treatments can also be applied in order to use less environmentally damaging methods (Joubert, De Beer & Malherbe, 2017). Cuttings have been used as an alternative method for propagation. Cuttings taken during the months of March and November have the best regrowth rate and produce viable plant harvests (Mabizela, Slabbert & Bester, 2017 and Bester, 2013). *Cyclopia spp.* also require particular communities of rhizobial bacteria in the soil to fix nitrogen for the plant to survive (Mabizela *et al.,* 2017).

Both methods of propagation, namely the use of seedlings and cuttings, will ensure population security in the future.

Fire and its effects on fynbos

While fires occur throughout the year in the fynbos regions, most fires are concentrated within the dry summer months of November to March. The western regions experience most of their fires in this period. The eastern coastal regions experience a more aseasonal fire regimen due to the decreased climatic variability of these regions (Kraaiji & Van Wilgen, 2014) with a tendency for winter fires to be associated with hot bergwind conditions (McGregor, 2017b). However, due to anthropogenic influences, fire intervals have changed dramatically. To increase grazing capacity, fires are used and veld is set alight more frequently (McGregor, 2017b). There is an increasing frequency of fires in the Langkloof where most of the honeybush lands can be found and it is likely that fire frequency will impact the population persistence.

Field Vegetation Sampling data collection

To establish a sampling method which will provide the best representation of the quantity of honeybush in the wild as well as a graphical population distribution, multiple factors and methods need to be considered. These include previous proven sampling methods, the accessibility of the terrain and the age of the veld itself. According to Mueller-Dombois (1974), it is essential to familiarise oneself with the veld before sampling is done in order to establish natural growth patterns and plant densities. Mueller-Dombois (1974) provides three criteria which must be met when sampling is done:

1) The area should be large enough so that all plant species can be represented fairly.
2) The habitat should be uniform within the stand to the best knowledge of the surveyor.
3) Plant cover should be as homogeneous as possible. There should not be areas which are dominated by one species or open areas of land.

These criteria form the basis for a sampling approach. The approach can be refined to suit a particular context, including environmental questions such as: 1) What is the slope of the site? 2) When last was the veld burnt? 3) When was the crop last harvested? These factors will provide the best representation of what the actual population is (Schippmann *et al.,* 2002). A standard sampling method is required in order to have not only comparable data but also comparable mapping criteria, which will provide more accurate distribution mapping. While the Mueller-Dombois (1974) sampling method aided in refining the methods of this study, the sampling methods used by McGregor (2017a) for vegetation sampling of *C. intermedia* formed the basis for the methods used. It is important to note that the criteria of Mueller-Dombois (1974) for sampling were based on forest surveys and therefore modification was required.

The minimum sampling area must be chosen next. The minimum area is seen as the area where the species is represented adequately and is thus an indicator of the quadrant size which can be used for sampling (Mueller-Dombois, 1974). The area which is selected depends greatly on the type of population and the climate region (Mueller-Dombois, 1974; Stehman & Salzer, 2000), for example, areas such as dry grassland require an area of 50 to 100 m^2 while moss communities require areas of 1 to 4 m^2 (Mueller-Dombois, 1974). By mapping individual transects, the population at a specific site can be estimated. While there are some basic criteria which need to be followed in order to determine the area for sampling, there is no objective guide for determining the size of the area (Mueller-Dombois, 1974). The sampling area must be mapped at an adequate size to predict the population distribution of the field site. An estimation of vegetation quantities will provide a basic classification of the sample sites, which can then be extended to predict the potential bushes that occur in a hectare on the farm (Stehman & Salzer, 2000).

When sampling for specific species, it is more desirable to use belt transects as they offer a method which is easy to use, practical and can be more accurate than quadrat sampling (Stehman & Salzer, 2000). In the context of this study, belt transects were chosen for these advantages. Belt transects offer greater accuracy when dealing with large slopes because the belt transects can be laid to the slope (Stehman & Salzer, 2000). This was particularly suitable with honeybush due to the steepness of slopes. A problem which has been noted with using belt transects is that if the natural growth of the plant is not within the rectangular area, then there will be lost data (Stehman & Salzer, 2000). Mueller-Dombois (1974) states that the researcher must become familiar with the field before placing the transects, which will give the greatest accuracy.

Stehman and Salzer (2000) proved through statistical analysis of 10 000 simple sample sites that placing sampling sites randomly or having systematic sampling did not affect the outcome of the sampling to an extent where data was not valid. It was thus possible to map the extent of the population from the samples which were taken in the field.

Soil Sampling

Soil samples are used to determine the characteristics of the soil and aid in understanding why a particular species grows in its unique location. Soil samples aid in analysing the chemical and physical characteristics such as nutrients, pH and possibly the rhizobial bacteria that are present in the soil. Carter and Gregorich (2007) set out multiple methods of soil sampling depending on the nature of the survey. These include sampling of mechanically disturbed and undisturbed soils, exploratory sampling, random sampling, systematic sampling, composite sampling and sampling for linear disturbances.

Carter and Gregorich (2007) state that sampling can be 'judgmental' when the soil is uniform and is within the same area. Therefore, the study sites which were used could have a single soil sample taken randomly on the site to determine the average throughout the 10 by 100 metre area.

Soil plays a role in the unique distributions which occur within the fynbos biome. Factors such as soil pH, organic matter, total nutrient content and soil moisture contribute to separation of communities within the biome (Witkowski & Mitchell, 2018). Therefore, nutrient requirements for the plant affect the spatial distributions due to the correlation between soil nutrients and individual species distribution (Witkowski & Mitchell, 2018).

Soil Nutrition within the Study Area

While the area around the Cape Floristic Region has a Mediterranean climate, the soils do not match those of Mediterranean climates around the globe (Richards, Stock & Cowling, 1997). Rather, these soils appear more acidic and nutrient poor much like those of the Western Australian Heathlands (Kwongan). This poor soil quality is attributed to summer droughts, low winter temperatures and nutrient-poor geology. Therefore, both the fynbos and the Kwongan regions have developed specialised nutrient uptake systems in order to survive in these extreme conditions. Richards *et al.* (1997) showed that vegetation patterns are strongly correlated with environmental factors such as pH and physical soil factors (texture and depths). Therefore, soil type is key to understanding any fynbos plants, and *cyclopia* spp. in particular.

To achieve the best possible growth for the plants within the cultivated setting, natural conditions must be replicated. Witkowski and Mitchell (2018) state that fynbos plants have adapted to nutrient-poor soil conditions and is unable to compete on soils which have been fertilised. Due to the change in soil properties, fynbos species can become outcompeted in an altered environment (Witkowski & Mitchell*,* 2018). Nutrient demand needs to be researched further in order to understand its impact on the plants not only in a cultivated setting but also in its wild distribution.

USE OF THE WILD RESOURCE

In the context of harvesting wild plant species, there are gaps in the research into the use of non-timber forest products (of which there are tens of thousands) in a sustainable manner on the local scale (Ticktin & Shackleton, 2011). Ticktin and Shackleton (2011, p. 155) also state that due to this lack of data, there are assumptions that need to be made from the known "patterns of species attributes, harvesting systems, and nature of demand" in order to begin to grasp the scale at which sustainable methods need to be implemented. This lack of data can be troublesome for those dependent on the use of NTFP for their income because there is little or no research to see whether their methods are sustainable and will continue to support them into the future (Ticktin, 2004).

While there is much concern about the state of the resource itself, there is a larger scope which also needs to be considered. Both papers by Ticktin and Shackleton (2011) and Ticktin (2004) highlight the fact that social, political, economic and ecological factors affect the use of NTFPs. Ticktin and Shackleton, (2011) state that to holistically understand the honeybush industry, one must not only understand when, where and how the plant material is collected but one must also understand why harvesters choose the areas of harvest. When these factors are explored, one can holistically understand the use of honeybush as a wild resource and then explore the best possible solutions to ensure sustainability.

Adaptive management is a common theme among articles on community-based resource use associated with traditional knowledge systems (Armitage, 2005). Communities share knowledge with existing members plus newcomers and this traditional ecological knowledge and local ecological knowledge can provide a wealth of information on sustainable management of the resources used (Chamberlain *et al.*, 2019). It is thus crucial to use traditional ecological knowledge and local ecological knowledge in the creation of guidelines for best practices for harvesting due to the lack of long-term scientific studies in this field (Ballard & Huntsinger, 2006). Williams and Brown (2016, p. 263) define adaptive management in the context of natural resource management as a "structured process of learning by doing, and adapting based on what is learnt". Adaptive management is a way of allowing for using what is learnt in the course of management to inform and adjust the management approach. Adaptive management is useful because it acknowledges the incompleteness of a management approach at the outset.

Interviews to gather Information from Harvesters

Interviews are face-to-face communications, which can lead to the exchange of information from one person to another (Rowley, 2012). Questions are prepared beforehand by the researcher in order to guide the conversation and gain information. Interviews should be structured around gaining quantitative facts and subjective ideas about the topic from each individual's experiences. The combination of multiple interviews gives a holistic factual understanding of the research question (Rowley, 2012). Using both structured questions as well as allowing the conversation to flow to areas which the interviewee is interested in enables the researcher to gain more information. Questions should also be open ended to facilitate a conversation.

Much like an interview, a focus group is used to have a group of participants express their opinion. In order for focus groups to be successful, the researcher must facilitate an environment in which participants can speak freely and can be understood (Halcomb, Gholizadeh, DiGiacomo & Phillips, 2007). A conversation is guided by a set of questions which the researcher has designed and allows the researcher to gain information in a group setting. This method allows for good time management and large amounts of information can be gathered at once (Halcomb *et al.,* 2007).

Rainfall within the study area

The south-west and western parts of the fynbos region receive roughly 60% of their rainfall during winter (Cowling *et al.,* 1996). To the east, the regions experience year-round rainfall with the highest rainfall in spring and autumn. The biggest part of the region where most *Cyclopia* spp. grow experiences bimodal rainfall (McGregor, 2017b).

METHODS

1a. Reviewing previous literature on *C. subternata*

To understand the characteristics of the wild resource, it was essential to take into account all the previous research which has been conducted on the plant. Not only did this provide a better overall understanding, but it gave an idea of what variables needed to be considered to understand the plant's growth parameters. Key pieces of literature such as papers by Joubert *et al.* (2011), Schutte *et al.* (1995) and McGregor (2017a; 2017b) were considered in understanding the growth of the plant and the need for sustainable use guidelines, as stated by Schippmann *et al.* (2002).

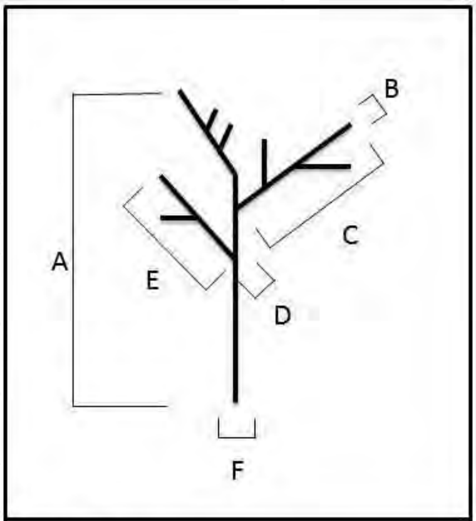
Information such as the honeybush industry, descriptions of the plant, the harvesting process, distribution, threats and cultivation were areas focused on throughout the literature.

b. Populations surveys

Table 3-1 Breakdown of the steps involved in a site survey

Task	Methods
i) Environmental variables	Extracted through desktop analysis.
ii) Field surveys	Environmental variables such as slope, aspect, road access, fire history, soil surveys and vegetation community were sampled.
iii) Population survey	Growth stage, location and plant allometry were measured.
iv) Site maps	Transects showing plant locations and plant harvestability were compiled.

As recommended by Mueller-Dombois (1974), field surveys were carried out with belt transects, which were either 10 by 50 m or 10 by 100 m depending on the size and nature of the field site. Each plant was individually mapped with a GPS and measured for a standard set of variables (Figure 3-1). The measured variables for each plant included the height of the plant, the base stem diameter, stem diameter and stem length of four harvestable



A – Height
B – Harvestable branch diameter
C – Harvestable branch length
D – Unharvestable branch diameter
E – Unharvestable branch length
F – Base diameter

Figure 3-1 Schematic for measuring *C. subternata* plants

stems, stem diameter and stem length of four unharvestable stems, and finally, if the plants were previously harvested, the weights of the harvested stems (see Appendix 2).

Along with the belt transects, each site was visually inspected for signs of previous harvesting and previous fires. This gave an indication of the plant age and the period of regrowth. Next, two sets of soil samples were taken at each site. These samples were taken within the honeybush distribution and outside this area for comparison. The samples were taken by first removing any organic material at the surface of the sample site. Next, the top 5 cm of soil was removed and soil was collected below this line up to 35 cm down where possible (Carter & Gregorich, 2007). A spike was also used to measure soil depth at each site.

For each field site, a descriptive note based on observations was made regarding access, health, roads, paths, suitability for harvest, growth conditions at each site such as the availability of water and shade, the state of the surrounding vegetation and the health of the population as a whole.

A set of maps were created using ArcGIS to cartographically represent each study site. Data collected in the first three steps were used to represent the plant populations. The maps created show the density of growth for the plants and the distribution of the population within a rectangular transect. This data can be used to determine whether or not a site is suitable for harvesting as well as the environmental characteristics of each site.

2a. Interviews with harvesters

Both formal and informal interviews were used to document typical harvesting practices. Informal interviews were conducted with harvest teams while in the field. This included a set of questions to gauge what the harvesters' ideas on harvesting, sustainability, and their knowledge of the veld was. The questionnaire covered methods of harvest, criteria for an acceptable harvest or not, knowledge of the veld, and where they gained this knowledge. Notes were made on the demonstrations which the harvesters gave, followed up with measurements of acceptable plants and stems (this process aided in verifying qualitative information with quantitative surveys).

One of the approaches available for handling interview data is that of thematic analysis. It is the process of identifying patterns or themes in qualitative data (Maguire & Delahun, 2017) in a structured way. Good thematic analysis goes beyond merely summarising interview data: it can be used to interpret and make sense of the data in order to answer the research question (Maguire & Delahun, 2017). Mortensen (2019) outlines the steps taken in a typical thematic analysis as follows: familiarise oneself with one's data; assign preliminary codes to one's data in order to describe the content; search for patterns or themes in one's codes across the different interviews; review themes; define and name themes; produce one's report.

Formal interviews were conducted in workshop settings where questionnaires were used to guide the conversations. Interviews were conducted at the Louterwater workshop (January 2017) (McGregor, 2018, Workshop report) as well as at a workshop at the MTO field site (September 2018). The questionnaire which was used is provided in Appendix 1.

b. Field surveys of harvests

The field surveys of the harvests were conducted with the assistance of the harvesters. Harvesters were tracked for an hour during a harvest period. Harvested and unharvested plants within a 5 m belt of the harvest path were given a GPS point and measured according to the measurements shown in Figure 3-1. Once the harvest was completed, the harvested material was weighed and the information documented. Once all the plants in the area were marked, the harvested material was collected and measured (branch length, diameter and weight).

RESULTS

Potential survey sites were identified through consultation with harvesters and processors in the industry and through mapping, as discussed in Chapter 2. The sites were chosen to show populations of different ages, fire intervals, rainfall and harvest intervals for a holistic representation. Multiple sites were visited in the Haarlem, Twee Rivieren, Kareedouw, Noll, Plettenberg Bay and Tsitsikamma areas to represent the population within the greater *C. subternata* range. An overview of each site is given in Figure 3-2 and Table 3-3.

SURVEY OF C. SUBTERNATA POPULATIONS

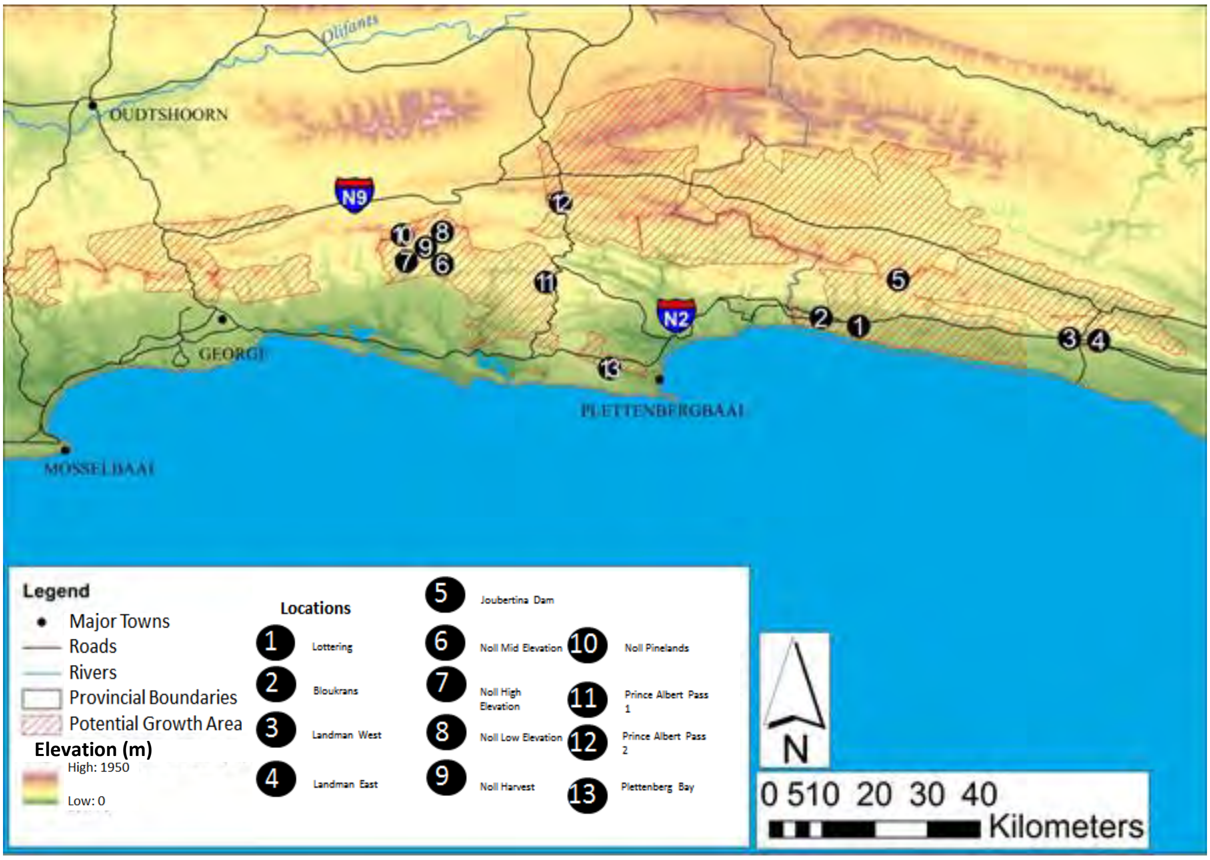


Figure 3-2 *Cyclopia subternata* distribution map with population survey sites

Soil samplings were done at each site in order to show a comparison between soils inside and outside the distribution site for *C. subternata*. While there was a range of .5 of pH in soil samples within the distribution and of .8 of pH outside the distribution area, there was little difference in the variables between sites, as indicated in table 3-2.

Table 3-2 Highlighting the similarity in soil sample averages for sites which have *C. subternata* growth and sites which do not.

	% moisture loss	Temp	pH	% organic material
Within distribution	15.6	20.8	3.3	8.0
Outside distribution	16.2	20.0	3.5	7.7

All Sites Visited:

Table 3-3 Overview of field survey sites

Site Location & Map no.	No. of Transects	Site Characteristics		Rainfall and Veld Age	Field Site Description
1. Lottering plantation (MTO Forestry)	17 (2 full block, 1 harvest)	Specific site characteristics can be found in the MTO case study in Chapter 4		Rainfall: 900 – 1 050 mm	Harvested populations, forestry lands. Mostly in pine plantation understorey, some natural sites.
2. Bloukrans Bridge (Tsitsikamma)	1	Aspect: South facing Slope: 5 degrees Elevation: 220m	Soil moisture: Medium Vegetation type: Tsitsikamma Sandstone fynbos	Rainfall: 900 – 1 050 mm Last fire: +10 years	Unharvested wild population, old fynbos veld next to the N2 highway. Pristine fynbos
3. Landman farm west (Tsitsikamma)	2 (One harvest transect)	Aspect: South-east facing Slope: 45 degrees Elevation: 460m	Soil moisture: High Vegetation type: Tsitsikamma Sandstone fynbos	Rainfall: 900 – 1 050 mm Last fire: 6-7 years	Unharvested population, old fynbos veld on a rocky outcrop. Pristine fynbos
4. Landman farm east (Tsitsikamma)	2	Aspect: South facing Slope: 30 degrees Elevation: 650m	Soil moisture: High Vegetation type: Tsitsikamma Sandstone fynbos	Rainfall: 900 – 1 050 mm Last fire: 6-7 years	Harvested population, old fynbos veld, which was overhead. Pristine fynbos
5. Joubertina Dam	1	Aspect: North-east facing Slope: 45 degrees Elevation: 610m	Soil moisture: High Vegetation type: Tsitsikamma Sandstone fynbos	Rainfall: 500 – 650 mm Last fire: 2 years	Unharvested population, old fynbos veld on the edges of a river bank. Lacking other fynbos growth
6. Noll (Pinelands)	1	Aspect: South-east facing Slope: 10 degrees Elevation: 903m	Soil moisture: Low Vegetation type: North Outeniqua Sandstone fynbos	Rainfall: 650 – 750 mm Last fire: 8 years	Unharvested population between invaded pinelands. Single stream running through the middle of the transect
7. Noll (low elevation)	1	Aspect: North-east facing Slope: 12 degrees Elevation: 882m	Soil moisture: Medium Vegetation type: North Outeniqua Sandstone fynbos	Rainfall: 650 – 750 mm Last fire: 5 years	Unharvested population, hip-high pristine fynbos. Harvester tracks lead through the transect
8. Noll (medium elevation)	1	Aspect: North-east facing Slope: 20 degrees Elevation: 920m	Soil moisture: Medium Vegetation type: North Outeniqua Sandstone fynbos	Rainfall: 650 – 750 mm Last fire: 10 years	Unharvested population in very dense pristine fynbos veld with head-high plants
9. Noll (high elevation)	1	Aspect: North facing Slope: 5 degrees Elevation: 1 000m	Soil moisture: Low Vegetation type: North Outeniqua Sandstone fynbos	Rainfall: 750 – 900 mm Last fire: 6-7 years	Unharvested population in low-growing grassy fynbos on a flat mountain top on the boundary of the Tsitsikamma area
10. Noll (harvest)	1 (One harvest transect)	Aspect: South to north facing Slope: 10 degrees to 35 degrees Elevation: 940m	Soil moisture: High initially, then low Vegetation type: North Outeniqua Sandstone fynbos	Rainfall: 650 – 750 mm Last fire: 10 years	Unharvested population in a valley bottom, invasive pines, very dense overhead fynbos veld. Harvest conducted through a stream
11. Prince Alfred Pass (1)	1	Aspect: South-east facing Slope: 35 degrees Elevation: 717m	Soil moisture: High Vegetation type: Tsitsikamma Sandstone fynbos	Rainfall: 750 – 900 mm Last fire: +- 5 years	Harvested population in head-high fynbos veld in a valley. Pristine fynbos
12. Prince Alfred Pass (2)	1	Aspect: South-west facing Slope: 10 degrees Elevation: 913m	Soil moisture: Low Vegetation type: Tsitsikamma Sandstone fynbos	Rainfall: 750 – 900 mm. Last fire: 2 years	Unharvested population, hip-high growth. Many seedlings present with signs of burnt older plants. Lacking other fynbos growth
13. Plettenberg Bay	1	Aspect: South-west facing Slope: 15 degrees Elevation: 210m	Soil moisture: Medium Vegetation type: South Outeniqua Sandstone fynbos	Rainfall: 750 – 900 mm Last fire: 5 years	Unharvested population in land cleared of invasive plants. Overhead natural fynbos veld

C. SUBTERNATA SITE CHARACTERISTICS

1. LOTTERING PLANTATION

Full results of the MTO plantation surveys are presented in Chapter 4.

2. BLOUKRANS BRIDGE

The Bloukrans Bridge site is an old fynbos veld site, which has not been harvested due to its location within the 'Face Adrenalin' compound (a bungee jump company on the Bloukrans Bridge). It has also been protected from any recent fire (in the last 15 years). Additionally, the veld was dense and tall. Honeybush plants were discovered on the fringes of the road where there was space free from competitors.

Table 3-4 Transect data for plants surveyed at the Bloukrans site

	Average
Height (cm)	198.7
Base diameter (mm)	21.1

Table 3-4 shows the average height and base diameter for the 14 plants which were surveyed at the Bloukrans site. This was a small population, which had plants growing with long single stems. The plants appeared dark brown and had mostly single stems and were growing in-between dense fynbos plants including *Protea* spp. and *Lucadendron* spp. None of the branches on these plants were considered harvestable as they were mostly single thick stem plants which did not have potential for regrowth and were undesirable for processing. Figure 3-3 shows the distribution of the plants along the road edge in the compound. The site had a density of 13 plants per 1 000 m^2.

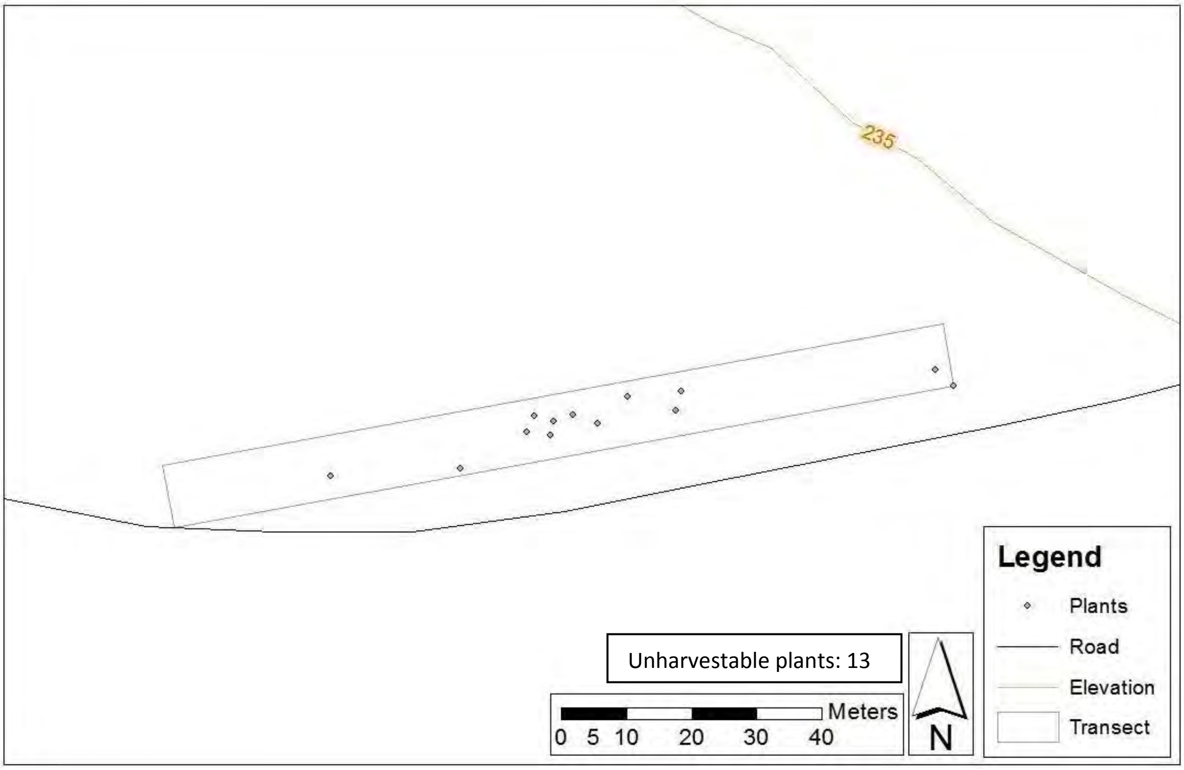


Figure 3-3 Transect of 100 m by 10 m at Bloukrans Bridge (2)

3. Landman Farm (West)

The Landman farm is located in the Tsitsikamma region next to the Kareedouw pass and receives 900 to 1 050 mm rainfall. The site was far from the valley bottom and did not appear to have a source of water close by.

The harvest site was at the top of a mountain with a gentle slope, rocky outcrops and sparse other vegetation. *Brunia spp.* were present as well as sedges, which were growing in a vlei on the side of the mountain. The harvest, shown in Figure 3-4, was done by following a harvester through the field and measuring the plants which she selected for harvest and which had a plant density of 583 per 1 000 m^2. The measurements represented in Table 3-5 were only taken on the plants which were harvested. Plants that were not harvested were of the same size but only had a single stem and were therefore judged to be unsuitable for harvest because they had no potential for regrowth. Table 3-5 shows that there is little difference between the harvestable and unharvestable branch sizes.

Table 3-5 Transect 1 data showing averages for plants harvested on the Landman west farm (3)

	Averages
(A) Height (cm)	148.4
(B) Harvestable branch diameter (mm)	8.6
(C) Harvestable branch length (cm)	66.7
Weight (g)	99.8
(D) Unharvestable branch diameter (mm)	8.0
(E) Unharvestable branch length (cm)	70.8
(F) Base diameter (mm)	16.8

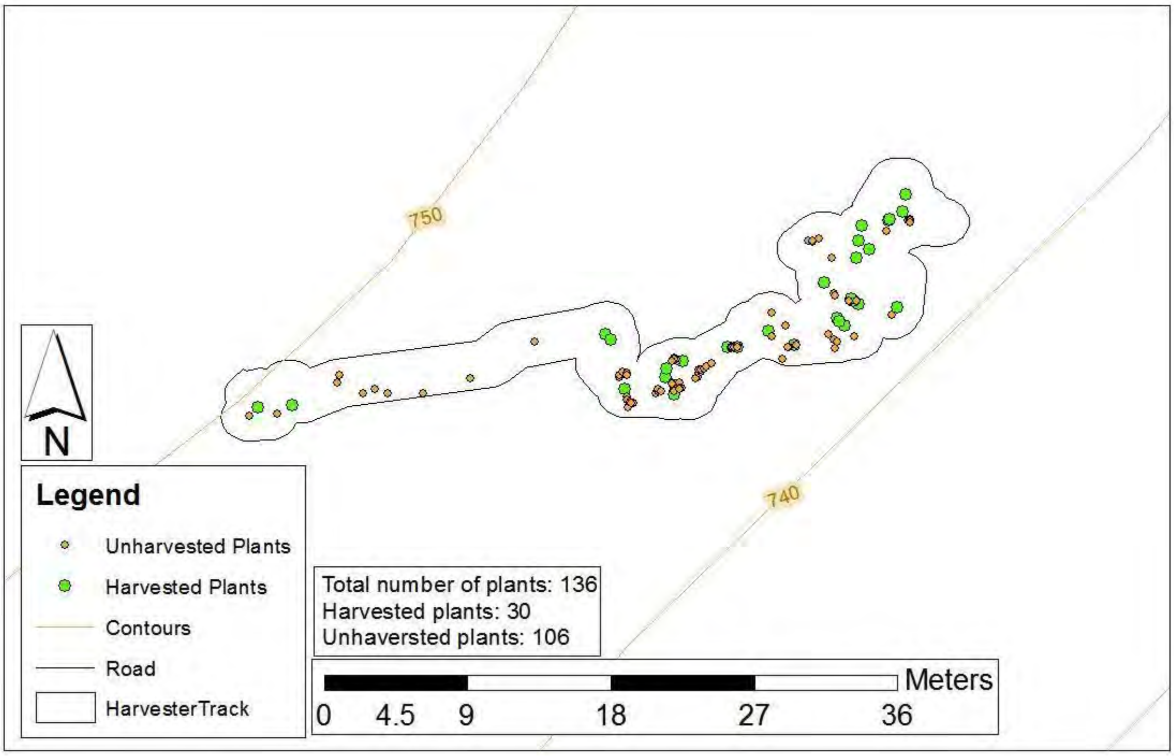


Figure 3-4 Harvest transect with a 3 m buffer around the harvested area on the Landman west farm (3)

Table 3-6 shows survey data for another 25 m by 10 m transect (Site 3), which was at a lower altitude. The transect had a density of 328 plants per 1 000 m$^{2.}$ The slope was roughly 45 degrees and was sparsely vegetated. The honeybush plants were the most commonly occurring species in this transect. A full 100 m transect could not be carried out due to the mountainous conditions. Again, the unharvestable branch lengths were greater than those of the harvestable branches.

Table 3-6 Transect 2 data for plants surveyed at the Landman west site (3)

	Averages
(A) Height (cm)	103.9
(B) Harvestable branch diameter (mm)	8.5
(C) Harvestable branch length (cm)	49.8
(D) Unharvestable branch diameter (mm)	8.0
(E) Unharvestable branch length (cm)	71.9
(F) Base diameter (mm)	9.7

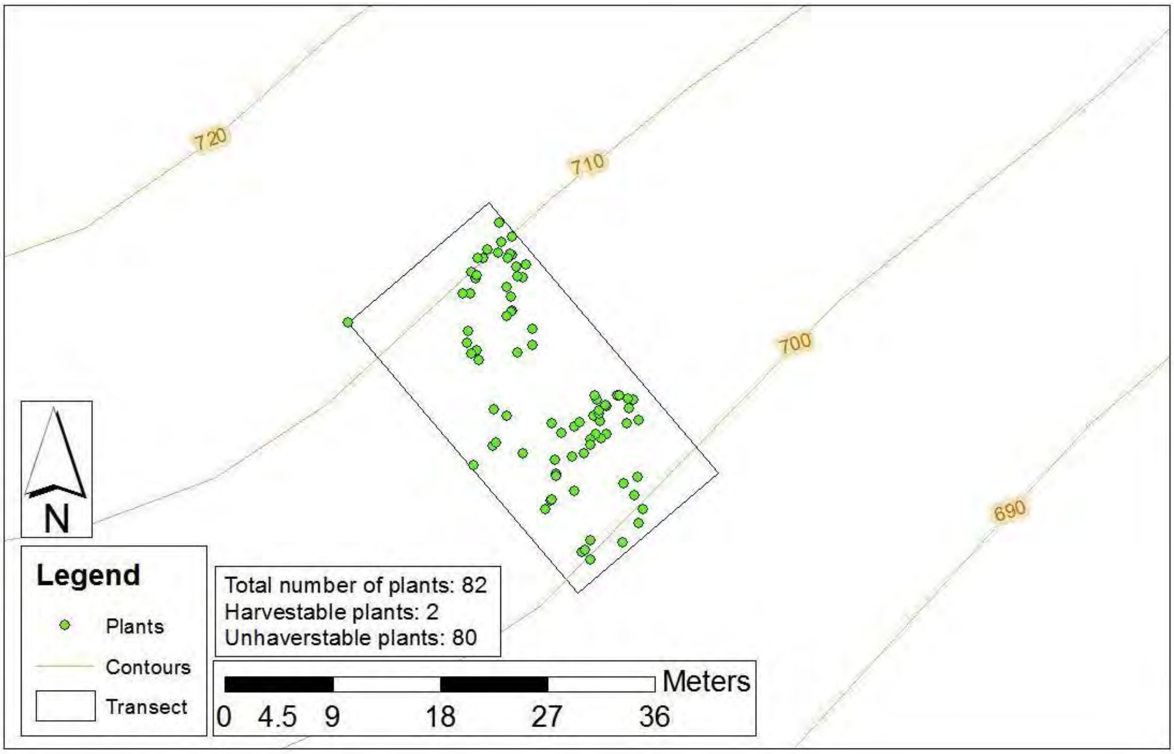


Figure 3-5 Transect of 25 m by 10 m of the Landman west farm (3)

4. Landman Farm (East)

Two transects were conducted at this site at two different altitudes along the slope. The initial transect (Figure 3-6) was done in an area of knee-high fynbos veld growth with a slope of roughly 30 degrees with a density of 28 plants per 1 000 m^2. It had signs of invasive pines but was dominated by *Restio* spp. and sedges. The second transect was laid out further down the slope in an area of overhead fynbos growth with a density of 484 plants per 1 000 m^2. This area was previously harvested and had many harvester tracks leading to individual clusters of plants.

Table 3-7 shows the data collected from the first transect done on the eastern side of the Landman farm. There were a total of seven plants in this transect with three plants suitable for harvest. The initial transect (Figure 3-6) had a soil moisture content of 15.7%, a pH of 3.15 and 7.09% organic matter in the transect. Outside the distribution, the moisture content was 23.3%, pH was 3.61 and organic matter was 7.33%.

Table 3-7 Transect data for plants surveyed at the Landman east site (4)

	Averages
(A) Height (cm)	122
(B) Harvestable branch diameter (mm)	8.6
(C) Harvestable branch length (cm)	71.0
(D) Unharvestable branch diameter (mm)	7.2
(E) Unharvestable branch length (cm)	56.5
(F) Base diameter (mm)	9.2

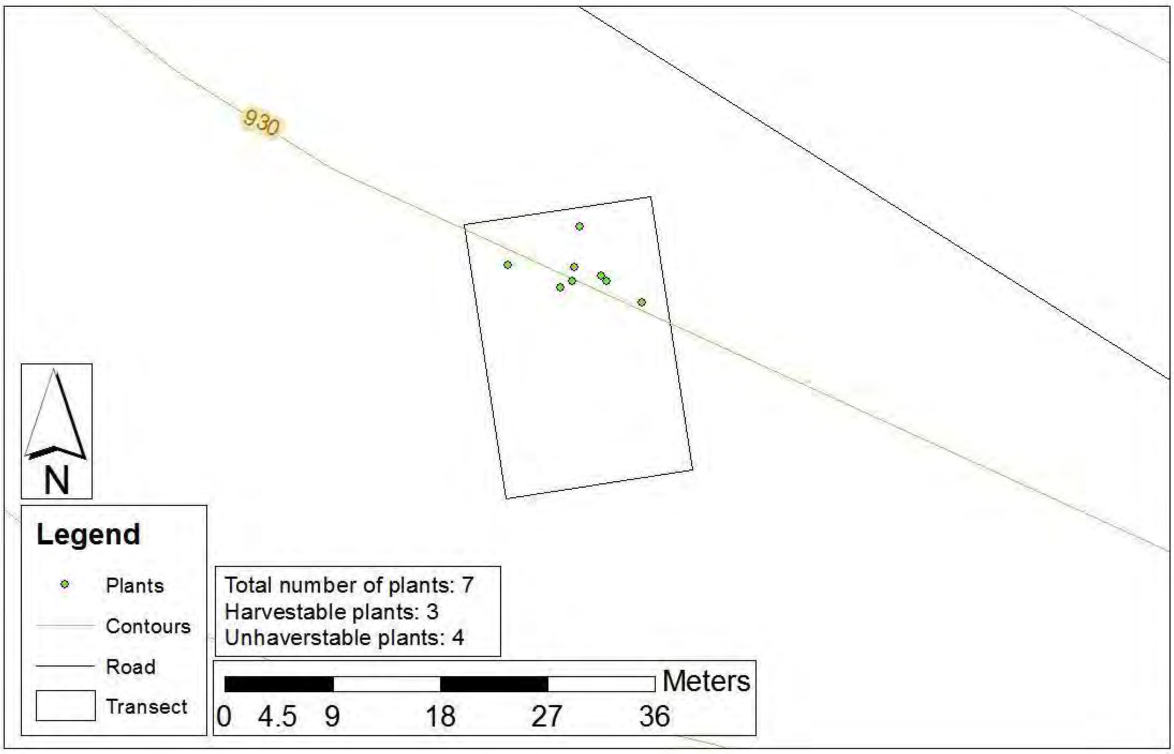


Figure 3-6 Transect of 50 m by 10 m of the Landman east farm (4)

Table 3-8 along with Figure 3-7 shows the data from the second transect, which was carried out on the eastern slope of the Landman farm. This transect had a total of 102 plants of which 64 were harvestable plants. Table 3-8 indicates a clear difference between the harvestable and unharvestable stems measured at this site. The second transect (Figure 3-7) had a soil moisture content of 18.2%, a pH of 3.16 and organic matter of 6.67% in the transect. Outside the transect and the distribution, the soil had a moisture content of 25.19%, a pH of 3.07 and 10.25% organic matter.

Table 3-8 Transect data for plants surveyed at the Landman east site (4)

	Averages
(A) Height (cm)	152
(B) Harvestable branch diameter (mm)	8.5
(C) Harvestable branch length (cm)	90.6
(D) Unharvestable branch diameter (mm)	6.4
(E) Unharvestable branch length (cm)	74.6
(F) Base diameter (mm)	16.6

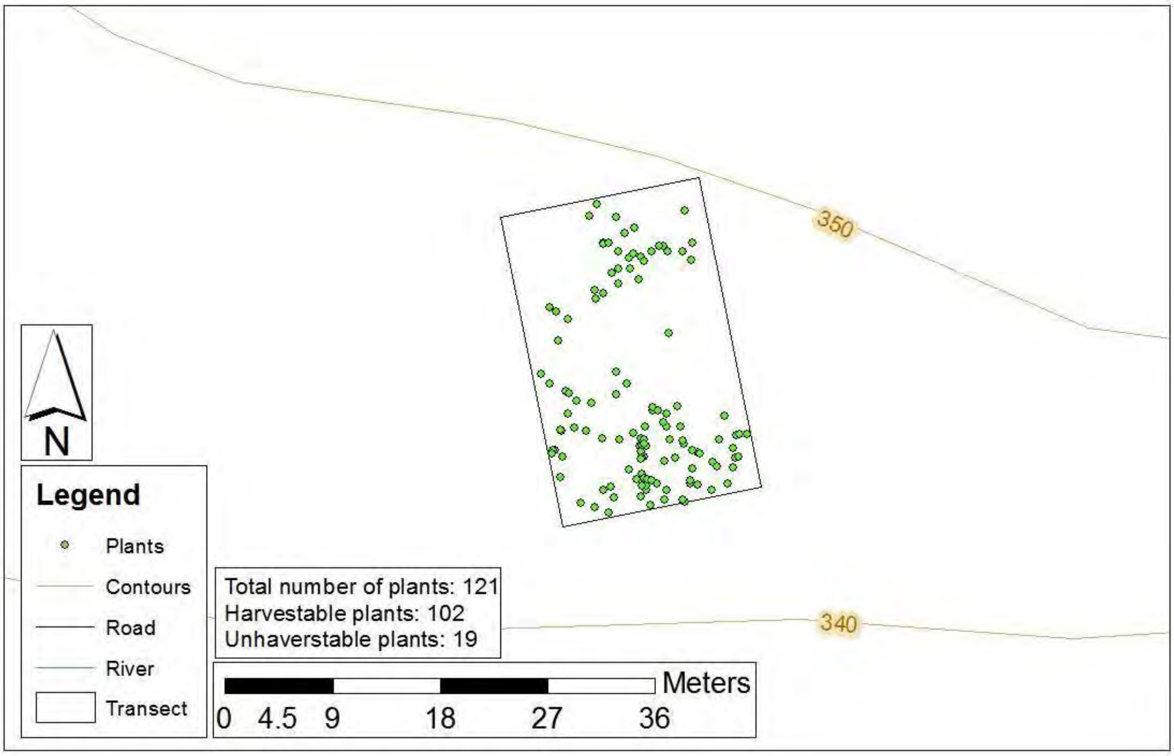


Figure 3-7 Transect of 50 m by 25 m of the Landman east site (4) – Transect 2

5. Joubertina Dam

A single transect, as indicated in Figure 3-8, was conducted along the banks of a stream leading into the Joubertina Dam. The plants were located on a steep bank of the floodplain of the stream but not where water was flowing. The sparse vegetation growth along the banks of the river was shoulder to head high. There were mostly *Restio* spp., *Brunia* spp. and some *Protea* spp. The soil was also very rocky and appeared shallow. Table 3-9 shows the average plant measurements at this site. The transect at Joubertina Dam had a soil moisture content of 30.5%, a pH of 3.27 and 14.7% organic matter. Outside the transect and the distribution, the soil had a moisture content of 10.08%, a pH of 3.82 and 2.49% organic matter. The site had a density of 40 plants per 1 000 m^{2}.

Table 3-9 Transect data for plants surveyed at the Joubertina Dam site (5)

	Average
(A) Height (cm)	169.8
(B) Harvestable branch diameter (mm)	10.1
(C) Harvestable branch length (cm)	130.3
(D) Unharvestable branch diameter (mm)	8.9
(E) Unharvestable branch length (cm)	108.3
(F) Base diameter (mm)	38.7

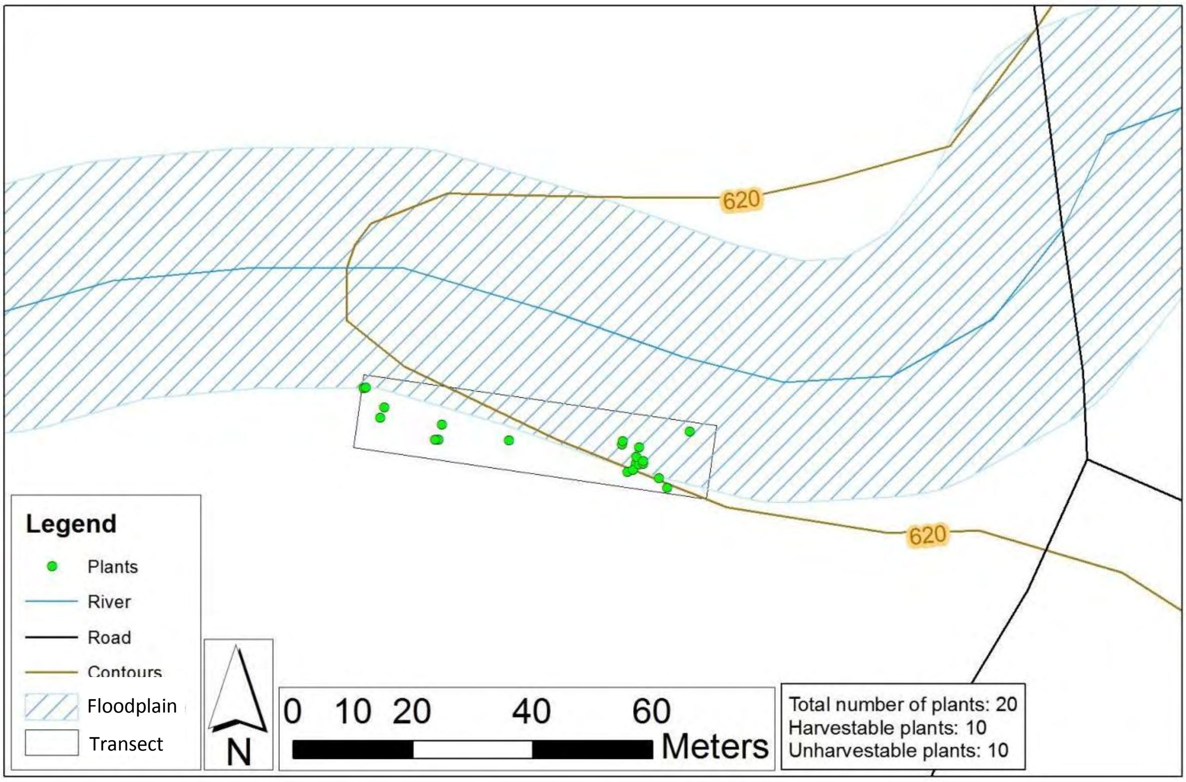


Figure 3-8 Transect of 10 m by 50 m at Joubertina Dam (5)

6. *Noll Pinelands*

A single 50 m by 10 m transect was conducted in this study area, as indicated in Figure 3-9. The area was mainly invaded pineland leading into and across a stream, which had some natural head-high fynbos growth. Many of the pines were over 5 m tall and had a dense growth pattern, which allowed little or no sunlight to reach the ground. This did not allow for plant growth which was sufficient for harvest. The soil was very deep (more than 55 cm). The area also appeared to be very dry. The Noll Pinelands site had a soil moisture content of 10.76%, a pH of 3.53 and 6.57% organic matter in the transect. Outside the transect and the distribution, the soil had a moisture content of 22.81%, a pH of 3.43 and 14.14% organic matter. The site had a density of 178 plants per 1 000 m^2.

Table 3-10 Transect data for plants surveyed at the Noll Pinelands site (6)

	Averages:
(A) Height (cm)	206.6
(F) Base diameter (mm)	21.8

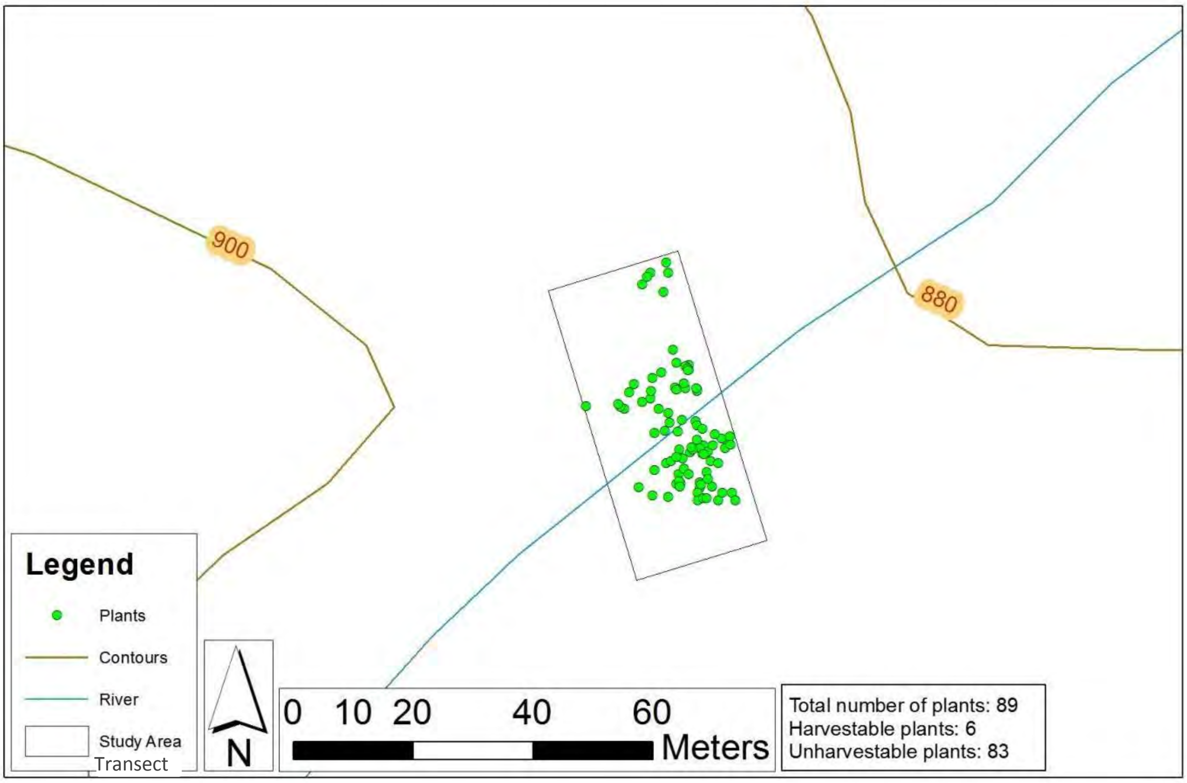


Figure 3-9 Transect of 50 m by 10 m of Noll Pinelands (6)

7. Noll (Valley bottom open area)

A single transect, as indicated in Figure 3-10, was conducted in hip- to head-high fynbos. The site ran along a harvester track on a slight east-facing slope with moist soils. While the slope was east facing, it was a relatively flat area leading down to a stream in the valley bottom. The site had a density of 186 plants per 1 000 m^2.

Table 3-11 Transect data for plants surveyed at the Noll low-elevation site (7)

	Average
(A) Height (cm)	156.3
(F) Base diameter (mm)	11.1

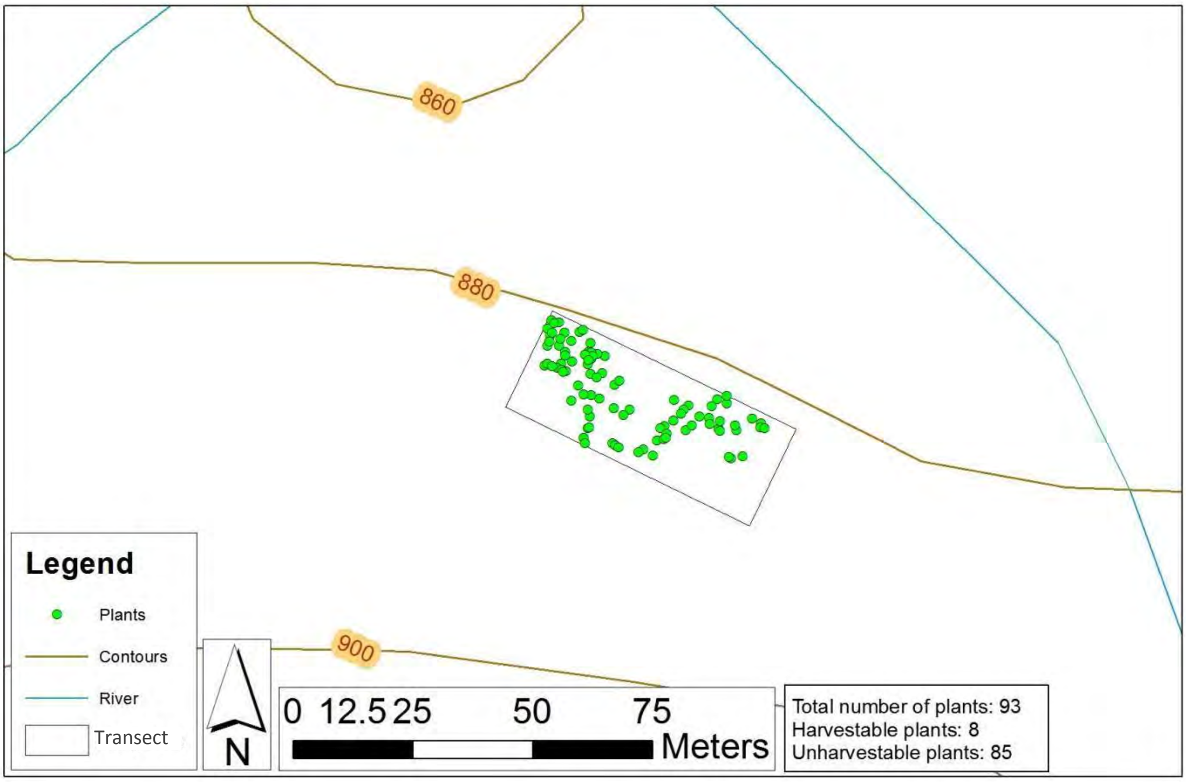


Figure 3-10 Transect of 50 m by 10 m at Noll low site (7)

8. NOLL (MID ELEVATION)

A single transect, as indicated in Figure 3-11, was conducted on the edge of a road which had a north-east-facing slope. The vegetation was dense overhead fynbos, which created an abundance of organic matter at ground level. There were *Brunia* spp., *Protea* spp. and *Restio* spp. present. The Noll mid-elevation site had a soil moisture content of 13.2%, a pH of 3.36 and 8.47% organic matter in the transect. Outside the transect and the distribution, the soil had a moisture content of 12.8%, a pH of 3.3 and 9.42% organic matter. The site had a density of 934 plants per 1 000 m^2.

Table 3-12 Transect data for plants surveyed at the Noll mid-elevation site (8)

	Average
(A) Height (cm)	141.7
(F) Base diameter (mm)	12.01

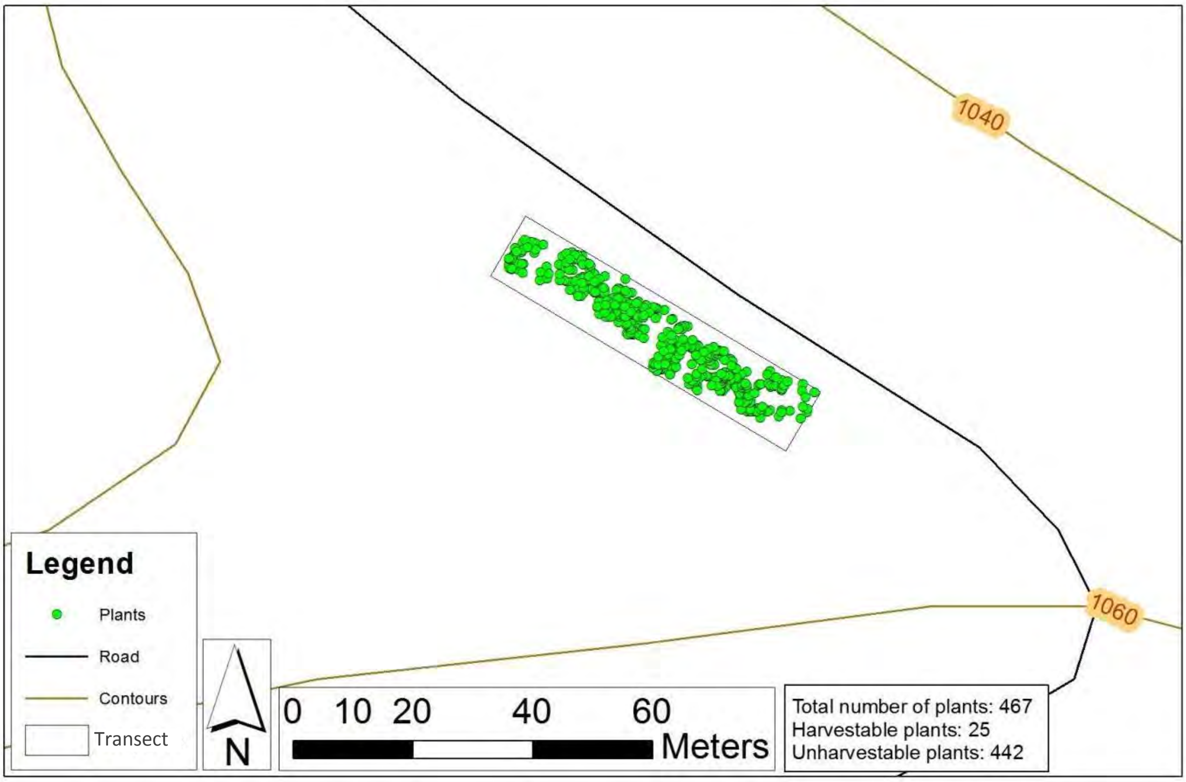


Figure 3-11 Transect of 50 m by 10 m of Noll mid-elevation site (8)

9. Noll (high elevation)

This transect, as indicated in Figure 3-12, was conducted at the peak of the mountains bordering the Tsitsikamma region. The area bordered on ECPTA (Eastern Cape Parks and Tourism Agency) land and was very difficult to access. The area had knee- to hip-high grassland with scattered *Protea* spp. on the flat peak of the mountain. The average plant size for the entire population can be seen in Table 3-13. The south side of the transect was much wetter than the north side and the soil was shallow (10-15 cm). The Noll high-elevation site had a soil moisture content of 11.03%, a pH of 3.01 and 10.73% organic matter in the transect. Outside the transect and the distribution, the soil had a moisture content of 3.14%, a pH of 3.27 and 6.6% organic matter. The site had a density of 294 plants per 1 000 m^2.

Table 3-13 Transect data for plants surveyed at the Noll high-elevation site (9)

	Average
(A) Height (cm)	99.8
(B) Harvestable branch diameter (mm)	12.6
(C) Harvestable branch length (cm)	87.2
(D) Unharvestable branch diameter (mm)	10.8
(E) Unharvestable branch length (cm)	70.9
(F) Base diameter (mm)	13.3

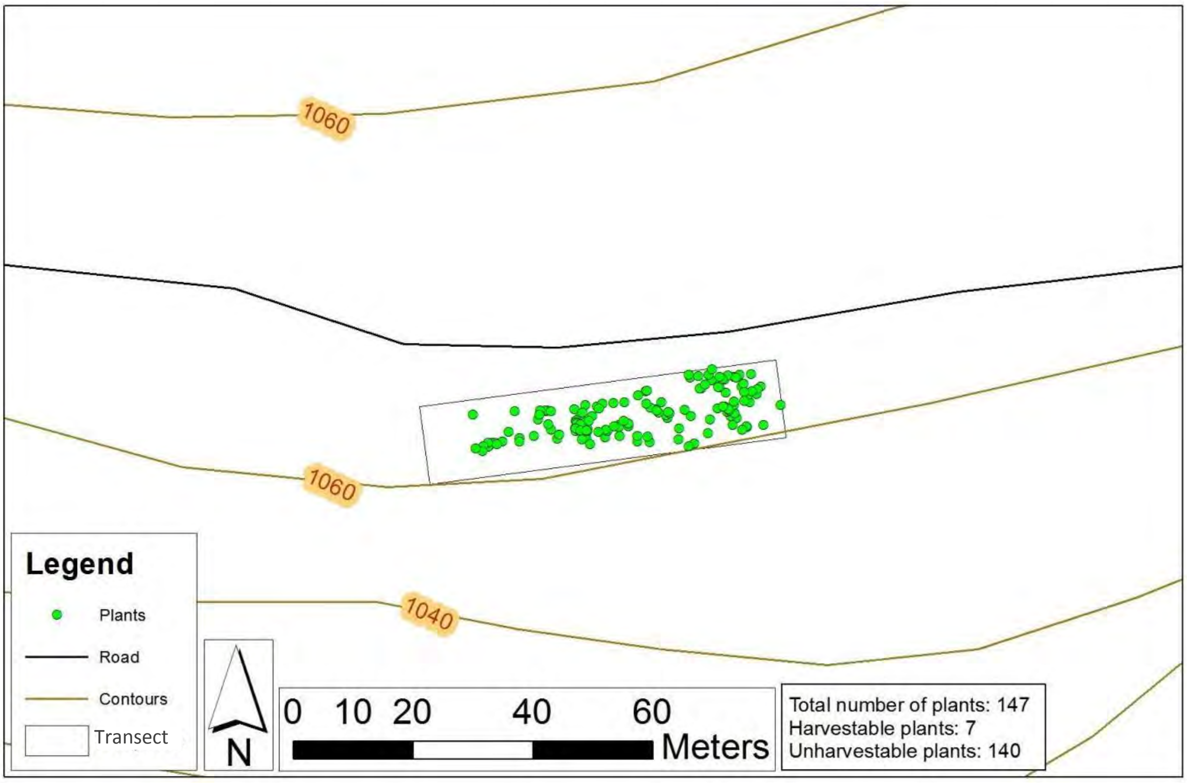


Figure 3-12 Transect of 50 m by 10 m of Noll high-elevation site (9)

10. Noll Harvest transect

The harvest transect was conducted in an area which ran through a valley bottom and a stream, as indicated in Figure 3-13. Initially, the slope faced south and as the harvest moved through the valley, it changed to north facing. Many of the plants that were harvested were well over 2 m tall and a single branch was left unharvested. The harvested plant measurements are indicated in Table 3-14. The vegetation was dense overhead fynbos with scattered pines. The valley bottom had flowing water and there were deep wet soils (55cm). The site had a density of 148 plants per 1 000 m^2.

Table 3-14 Transect data for plants surveyed at the Noll harvest site (10)

	Average
(A) Height (cm)	273.1
(B) Harvestable branch diameter (mm)	10.5
(C) Harvestable branch length (cm)	120.8
Harvested branch weight (g)	179.8
(D) Unharvestable branch diameter (mm)	4.3
(E) Unharvestable branch length (cm)	82.6
(F) Base diameter (mm)	17.5

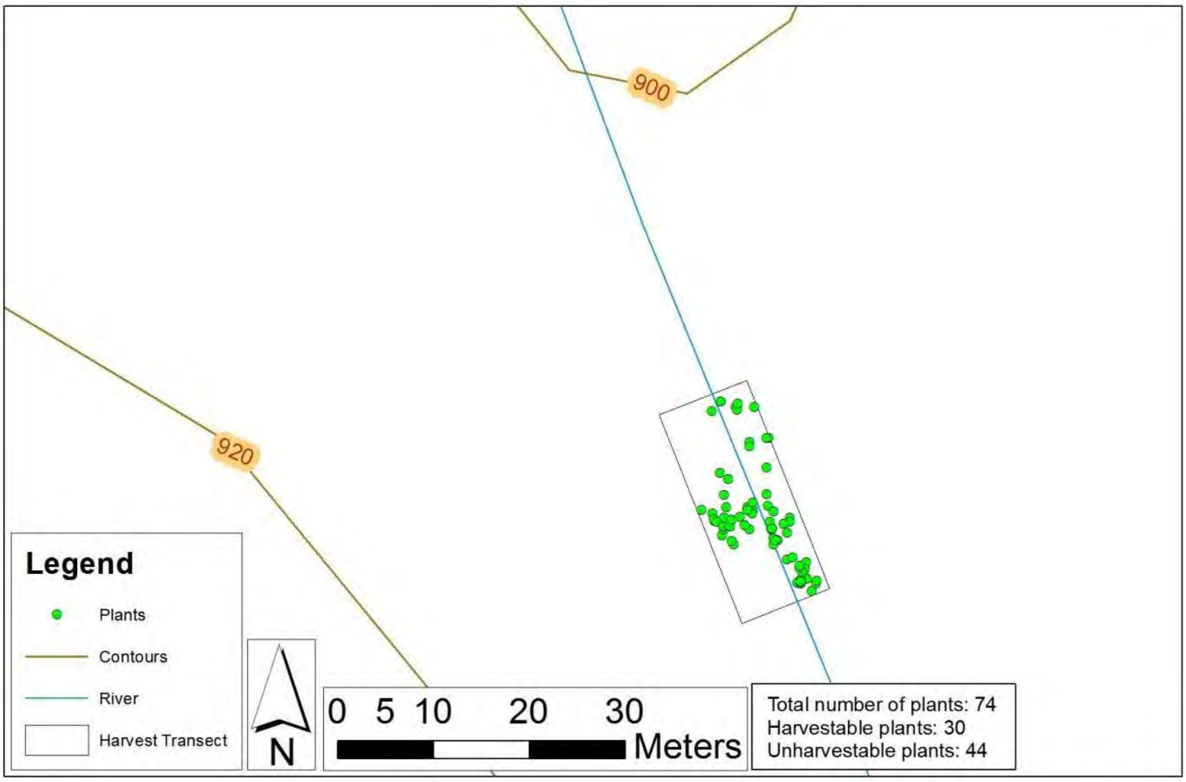


Figure 3-13 Transect of 50 m by 10 m of Noll harvest site (10)

11. *Prince Alfred Pass (site 1)*

Along the Prince Alfred Pass road, the site was located in a valley leading down the mountain, as indicated in Figure 3-14. It was a south-east-facing slope with damp soils and signs of previous harvests. The site had a slope of roughly 25 degrees and the honeybush stopped growing where the aspect changed to south facing. The averages for the plants which were measured are indicated in Table 3-15. There were *Brunia* spp., *Lucadendron* spp. and *Erica* spp. present on the site. The Prince Alfred Pass site had a soil moisture content of 22.51%, a pH of 3.48 and 8.08% organic matter in the transect. Outside the transect and the distribution, the soil had a moisture content of 23.07%, a pH of 3.32 and 7.45% organic matter. The site had a density of 370 plants per 1 000 m^2.

Table 3-15 Transect data for plants surveyed at the Prince Alfred Pass site (11)

	Average
(A) Height (cm)	134.7
(B) Harvestable branch diameter (mm)	10.9
(C) Harvestable branch length (cm)	94.6
(D) Unharvestable branch diameter (mm)	8.4
(E) Unharvestable branch length (cm)	82.4
(F) Base diameter (mm)	8.1

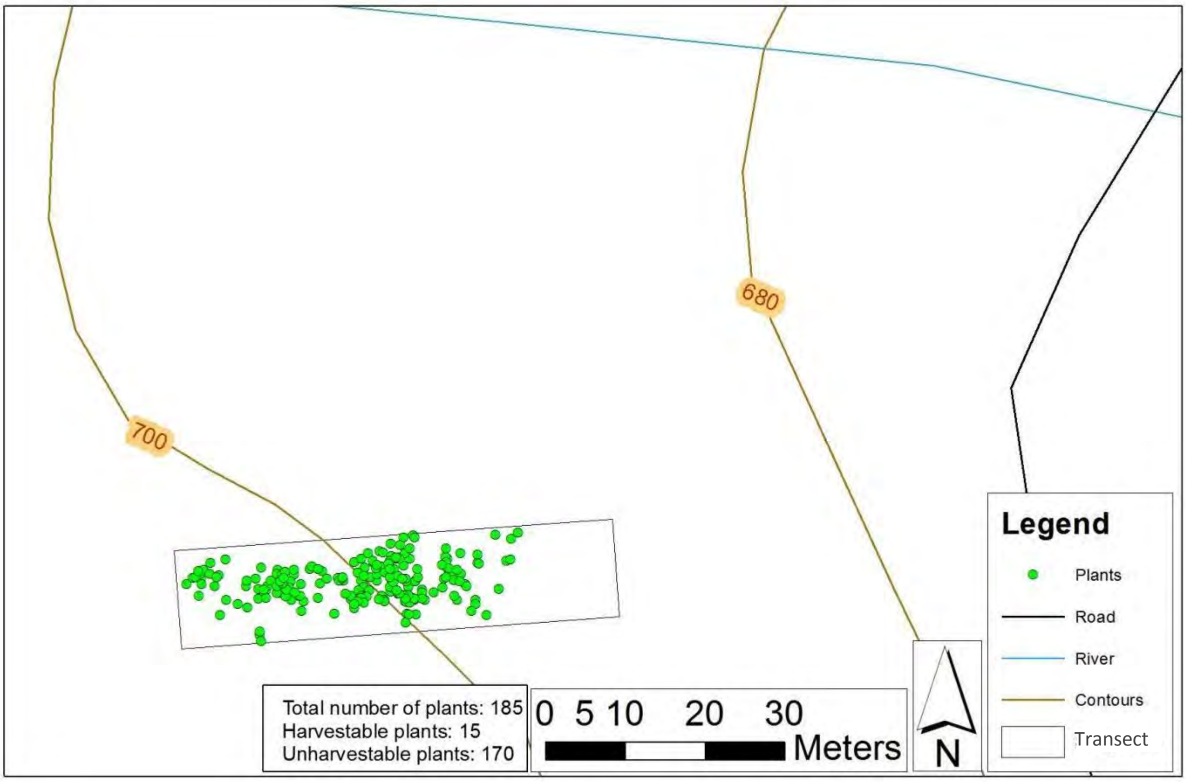


Figure 3-14 Transect of 50 m by 10 m of the Prince Alfred Pass site (11)

12. Prince Alfred Pass (Site 2)

Another site along the Prince Alfred Pass, as indicated in Figure 3-15, had a south-east-facing slope. The area appeared to have been burnt within the last two years and seedlings were abundant. Table 3-15 shows that these plants were smaller than the plants indicated in Table 3-16 due to them mostly being seedlings. The sparse vegetation consisted of knee- to hip-high sedges and pines with shallow hard soils. The seedlings were all under 60 cm tall and had base diameters of less than 5 mm. The Prince Alfred Pass site had a soil moisture content of 5.14%, a pH of 3.94 and 8.83% organic matter in the transect. Outside the transect and the distribution, the soil had a moisture content of 4.71%, a pH of 3.89 and 5.25% organic matter. The site had a density of 550 plants per 1 000 m^2.

Table 3-16 Transect data for plants surveyed at the Prince Alfred Pass site (12)

	Average
(A) Height (cm)	111.2
(B) Harvestable branch diameter (mm)	8.4
(C) Harvestable branch length (cm)	105.5
(D) Unharvestable branch diameter (mm)	9.95
(E) Unharvestable branch length (cm)	150
(F) Base diameter (mm)	9.7

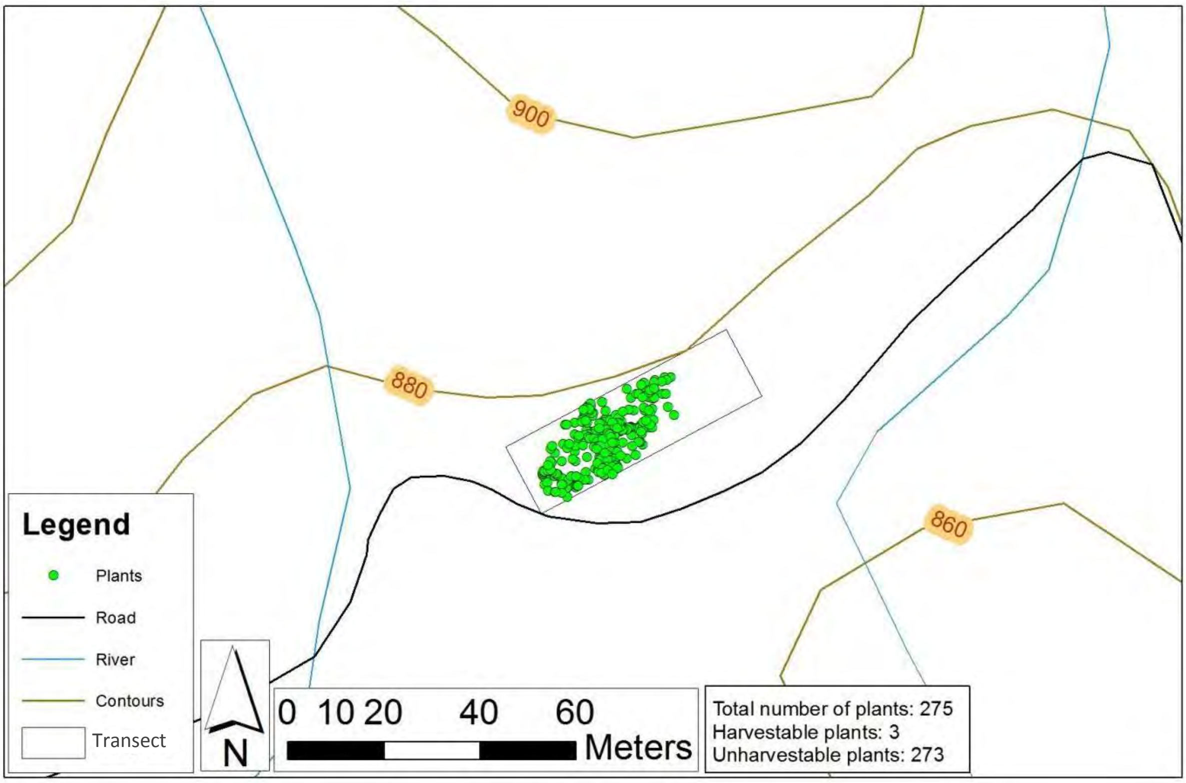


Figure 3-15 Transect of 50 m by 10 m of the Prince Alfred Pass site (12)

13. Plettenberg Bay

The transect, as indicated in Figure 3-16, fell within old pine and bluegum lands, which had been cleared of these alien plants five years ago and has since grown wildly. Within the last five years of growth, the plants have grown to the average sizes shown in Table 3-17. The gradual slope faced a south-easterly direction and was on the edge of a cliff leading down to the stream. The area had many protea bushes, sedges, pines and bluegums. The Plettenberg Bay site had a soil moisture content of 8.39%, a pH of 3.83 and 5.88% organic matter in the transect. Outside the transect and the distribution, the soil had a moisture content of 6.65%, a pH of 3.92 and 4.1% organic matter. The site had a density of 160 plants per 1 000 m^2.

Table 3-17 Transect data for plants surveyed at the Plettenberg Bay site (13)

	Average
(A) Height (cm)	122.9
(B) Harvestable branch diameter (mm)	7.8
(C) Harvestable branch length (cm)	91.7
(D) Unharvestable branch diameter (mm)	6.4
(E) Unharvestable branch length (cm)	85.3
(F) Base diameter (mm)	6.2

INTERVIEWS

Interviews conducted during the harvesting process and during focus group sessions aided in gathering information about the harvesting process and the knowledge that harvesters had about the honeybush industry. The questionnaire also led to discussions, which highlighted key concepts that should be known in order to understand the growth of honeybush plants. The interviews were recorded and from the recordings, themes were identified in order to tell a thematically structured story.

From the questionnaire, informal field interviews and workshops, the following data was collected (more than 23 individuals were engaged with):

Table 3-18 Summary of questionnaire responses

Questions	Answers
Earnings	R150 – R450 per day. Depending on harvest size
Team size	Range from 4 – 10 On average 4
Cutting methods	80% use secateurs - Selective, clean cuts which don't damage the plant 20% use sickle - Quick cutting method for large quantities
Why this cutting method?	
% of plant cropped	Range from 50% to 90% On average, 65% in good conditions
Why only harvest a percentage of the plant?	The harvesters are aware that *C. subternata* does not resprout and thus requires living biomass to maintain itself
Plant size suitable for cropping	Ranges from above knee height as a starting point to above hip height as starting point Harvesters note surrounding environment must be considered to determine cutting height
Harvest interval	Range from 18 months to 5 years On average 2-3 years
Harvest training	Most learn from experienced harvesters
Fire knowledge	Harvesters know it is needed for germination and to control competition from other plants
Processing	All harvesters have arrangements with a processing plant who buys the crop from them
Permit system	All agree it is required

DISCUSSION

Individual harvest surveys, population surveys and interviews aided in characterising the extent of the wild *C. subternata* resource in terms of its use and density and environmental requirements for growth. While each site was sampled in the same way, the state of each population was unique and depended on the surrounding environment. The description of each individual population adds to the broader understanding of where *C. subternata* grows. It became very apparent through this research that there was tremendous variability between sites. Therefore, in order to determine the suitability of harvest for a site, that specific site had to be considered individually.

HARVESTING PRACTICES AND OBSERVATIONS

A harvest transect took place at Site 3, which gave some insight into the selection of suitable harvest material. The results show a 7% (0.6 mm) difference in average branch diameters between harvested and non-harvested branches, which suggest that choice of branches was a highly subjective decision to harvest or not to harvest by the harvester[3]. While the size of the branches which were harvested or not harvested did not differ much, single-branch plants were never harvested. Plant density was high at this site, which is characteristic of a reseeder population. *C. subternata* is a pioneer and reseeder and produces quantities of seed for storage in the soil, which germinate after a fire (Cramer *et al*. 2014; North *et al.,* 2017; Bond *et al.,* 1984).

At the second sampling area at Site 3, only a 0.5 mm (7.5%) difference in branch diameter between harvestable and non-harvestable branches was recorded. Again, the harvester did not harvest plants with single branches as it would not be suitable.

The sample surveys conducted at the Landman west site (Site 3) showed remarkable density differences or 583 per 1 000 m^2at Transect 1 and 328 per 1 000 m^2 at Transect 2. A comparison of the survey data (Table 4 and Table 5) shows that plants which had the same growth period, fire interval and rainfall differed greatly in their physical characteristics. The plants found at the higher altitude had much greater heights (42.82% larger), branch lengths (33.9% larger) and base diameters (73.13% larger) than those of the plants on the lower slope. Conversely, at the Landman east site (Site 4), the opposite was true, the sample taken at the lower altitude had a much greater density and harvestability (24.6% larger height, 27.6% larger branch length and 79.9% larger base diameter). The plants at the lower altitude had base diameters roughly 7 mm larger and were 30 cm taller than those of the plants at the higher altitude. This could be due to unseen influences such as mist belts (Manning & Goldblatt*,* 2012).

The Noll Pinelands site (Site 6) was unique in that the harvest team decided not to harvest any plants. Due to the drought conditions, harvesters were of the opinion that the plants would not survive a harvest. They also explicitly noted that in order for this population to survive for future harvest, it would need another flowering event. Site 7 was deemed unfit for harvest due to the fact that most of the plants within the site had single-stem plants with little or no branches on the plants. Due to a lack of biomass, the plants would not have the resources available to them to survive after the harvest. While on average, the plant heights and diameters did not differ much from those of harvestable sites, the lack of

[3] Harvestable branch diameters had a range difference of 4.94 mm, while the unharvestable range difference was 6.9 mm. Overall, there was a 28.9% difference between harvestable and unharvestable branch diameters.

multiple branches caused the harvesters to avoid these sites. Hence the plants were not measured for harvestable branches, as indicated in Figure 3-9 and Figure 3-10.

Figure 3-16 Young single-branch *C. subternata* plant which should not be harvested

If a plant has a single main stem and appears suitable for harvest, it should be cropped above areas of new growth to allow these smaller branches to continue to grow (Barnado, personal communication, June 2017). This is often done at hip height and smaller shoots off the main branch are left intact. While colour can change due to age and health, it is not one of the first factors a harvester considers. If a plant is tall enough, has the right number of branches and is light green (a colour associated with a young plant), a harvester will still cut the plant. Plants which have turned brown will almost always be cut as they are considered old and at the end of their life span. Table 3-19 shows the average height and base diameter for all the plants measured in natural growing populations.

Table 3-19 Harvestable branches vs non-harvestable branches

	Height (cm)	Base Diameter (mm)
Harvestable	143.8	14.6
Non-harvestable	175.8	16.5

The harvest team was aware of the fact that their livelihoods depended on the survival of all the populations which they harvested. As they had harvested this site on at least three previous occasions in the last 10 years, they knew the environment well. The harvesters also knew that rain had not fallen in this area in recent history and that the plants would not have suitable resources to recover if harvested. The knowledge that the harvesters possessed not only about the plants but also about the variety of environments in which they grew allowed them to make informed decisions about sustainable harvesting of the plant (Chamberlain *et al.*, 2019; Ticktin & Shackleton, 2011). This adaptive management has been shown to happen in other areas of traditional resource use (Ticktin, 2004).

There were very few harvestable plants at Site 8 because they were outcompeted by other fynbos plants. Not only was this due to the nature of *C. subternata* as a pioneer species (Joubert *et al.,* 2011; Schutte *et al.,* 1995), but also due to the impact of competitive alien plants on its growth (Holmes & Newton, 2011; Kraaij & Van Wilgen, 2014). The honeybush plants did not have harvestable branch measurements, as indicated in Table 10. The plants that grew on the fringes of the road were much larger with more branches than those deeper into the transect due to less competition for growth. The harvesters decided to leave this site for another year before harvesting for the plants to flower, seed and grow larger.

Much like Site 8, Site 9 had plants growing at different rates throughout the sample area. The plants on the southern side of the transect were in wetter soil, while those on the northern edges were in drier soil (soil samples inside the transects had 13% moisture, while the samples outside the transect had 3% moisture). Moisture availability had a clear effect on plant size. As water availability decreased from south to north in the transect, so did the size of the plants to a point just beyond the transect where the north-facing slope had no honeybush plants growing on it.

The harvest survey at Site 10 recorded many plants which were well over 2 m tall (see Table 3-14). On these large plants, a single branch was left by the harvesters in order for the plant to survive. At this site, many smaller honeybush plants were being outcompeted by tall fynbos plants and pine trees. These small plants were judged to be dying by the harvesters and were fully harvested.

Site 12 had plants which had larger unharvestable branch lengths and diameter than those of the harvestable branches (150 cm vs. 105 cm and 9.95 mm vs. 8.4 mm respectively). This was unexpected and could be attributed to the fact that while these branches were larger, they were from single-stem plants, which should not be harvested as there would not be any biomass left to sustain the future growth of the plants. The plants with multiple branches would have been looked at individually to decide which branches were harvestable; plants which had multiple branches would have unharvestable stems, which have smaller lengths and diameters than those of the harvestable branches as seen at other sites.

In general, alien invasion is a problem in the fynbos and in the honeybush industry (Pretorius, Esler, Holmes& Prins*,* 2008; Blanchard & Holmes, 2008; McGregor, 2017a & 2018). Large areas of potential honeybush growth had been cleared of invasive pines at Site 13 in order to improve water resources and to re-establish the natural vegetation. At this site, honeybush had started growing alongside other fynbos plants, while new pine saplings were being removed every two years. Honeybush was absent at this site for 15 years due to the invasive pine growth, but the removal of pine trees and the recovery of a natural vegetation community showed that the honeybush seed bank was substantial enough to survive and re-establish the population. Outside the transect there were areas which had been burnt and produced many seedlings in the open veld.

ANALYSIS OF HARVESTER KNOWLEDGE

Experienced harvesters were chosen to do the harvest transects and to take part in the informal interviews in order to gain the most accurate representation of what was acceptable in the harvesting process. The most important information that came out of these discussions is summarised into five themes as follows:

Source of knowledge: Most of the harvesters who took part in the study were taught how to harvest honeybush from experienced harvesters in their harvest team. Experienced harvesters will constantly pass on knowledge to new members of the harvesting team to ensure that known methods are put into practice. In this way, individual harvest teams regularly harvest with the same methods, intervals, and have the same ideas about conservation of the plant. The harvesters also repeatedly noted that there was no central workshop or school to teach them how to harvest so they had to rely on knowledge passed down from expert harvesters.

Knowledge of the environment: Due to the variability of conditions (rainfall, soil type, aspect and climate), there were many ideas on what the harvest interval should be. In areas with high rainfall, harvesters had an interval of as little as 18 months whereas in drier areas which did not have good growing conditions, intervals as long as four years had been used. The Kareedouw area had an overall downward trend in rainfall since 1960 with their lowest year on record in 2017 (380 mm). Uniondale, on the other hand, had an upward trend in rainfall but had an all-time low in 2017 (100 mm). Lastly, Witelsbos had a downward trend with its lowest rainfall recorded in 2017 (650 mm) (GCBR, 2017). The harvesters are well aware of the conditions at each site which they harvest and alter their harvesting process to ensure sustainability of the crop. The decision of when to harvest a specific site is made by the harvest team leaders and the more experienced individuals in the teams.

Harvesters are aware of the role fire plays in the ability of the plant to regenerate and have a sustainable life cycle (Barnardo, personal communication, August 2018). Fire also aids the harvesters as it makes it easier for them to gain access to the plants and the quantities which they harvest are higher due to the lack of competition to the honeybush plants. They understand the mechanisms which are required for the plant to reseed, become scarified (through fire, wind or predators), and then germinate. Therefore, they agree that fire is necessary in populations every 10 to 15 years not only to allow for the germination of new plants but also to clear the natural fynbos, which can start to outcompete honeybush after extended periods without fire.

Knowledge of the plant: Harvesters agree that each plant must be individually assessed in order to determine whether it is suitable for harvest or not. While harvesters may not have a standard measure of what is acceptable to harvest, they will assess each plant individually to determine if it is suitable for harvest. The process of harvesting plants sustainably is subjective by nature. Harvesters are comfortable harvesting the plant during its flowering period as it makes the plants easier to identify and locate in thick bush. They are also aware of the fact that this might hinder the ability for the plant to seed and potentially reduce the population size in the long term (Cramer *et al*., 2014; Barnardo, personal communication, 2018). While most harvesters use secateurs to harvest the *C. subternata* plants because they can be more selective of which branches to cut, there is a lack of agreement on which variables are the most important in choosing which branches to cut.

Linking knowledge to practice: The need to understand how the honeybush plants should be harvested cannot be a one-size-fits-all approach. As the sampling has shown, each site and each individual plant in that environment need to be considered in order to make the best sustainable harvesting decision. While there are key harvesting features which must be maintained throughout the practice, there cannot be a designated measurement at which plants are suitable for growth due to the massive variety these plants show. It is essential to combine the harvester's knowledge with the scientific knowledge in order to create the best practices for sustainable harvesting. The key harvesting features which must be considered by the harvesters stem from the characteristics of both the plants and the environments they grow in, which the harvesters have highlighted. Their knowledge of rainfall, fire, invasive species, plant health and environmental suitability for growth must be formalised and spread to ensure sustainable harvesting practices.

Permitting and regulations: Finally, the harvesters all stated that they agreed with the permitting system and would like there to be a certification process to allow them to gain a qualification for the work which they do (Ticktin & Shackleton, 2011). The harvesters were of the opinion that this would reduce poaching and give them more opportunity to be respected in the community. The process of certification will result in a standardised harvesting practice and thus increase the possibility of sustainable harvesting methods to be used by more harvesters.

KEY CONCEPTS IN UNDERSTANDING SUSTAINABLE HARVESTING OF C. SUBTERNATA FROM LITERATURE

Table 3-20 Key concepts in and relevant sources of literature for understanding *C. subternata*

Concept	Value in context of sustainable harvesting	Source
Reseeders	In order to ensure survival, a plant cannot be fully harvested.	Mabizela *et al.* (2017), Pausas *et al.* (2014), Marais *et al.* (2014), Schutte *et al.* (1995), Midgely & Bond (2011)
Aspect	*C. subternata* favours moist cooler slopes on the edge of vleis, which are typically southerly in aspect.	Manning & Goldblatt (2012), Joubert *et al.* (2011), Schutte *et al.* (1995), Campbell (1986)
Fire	Fynbos plants require a fire interval of 10-50 years for normal growth.	(Kraaij & Van Wilgen, 2014), Slingsby *et al.* (2017)
Flowering	Plants must be allowed to flower and set seed to ensure renewal of soil and seed stores for the next germination event.	Motsa *et al.* (2017), McGregor (2017a; 2018), Schutte *et al.* (1995)
Vegetation type	Honeybush plants occur mostly in grassy fynbos communities.	Manning & Goldblatt (2012), Schutte *et al.* (1995), Mucina & Rutherford (2006)
Branches vs stems	*C. subternata* plants have a single stem emerging from the ground from which multiple branches grow.	Schutte (1995), McGregor (2018), Schutte *et al.* (1995)
General Fynbos ecology	Typical fynbos characteristics: nutrient poor sandy soils, soil microbes are important, fire-prone area and typically winter or aseasonal rainfall.	Mucina & Rutherford (2006), Campbell (1986), Richards *et al.* (1997), Privett *et al.* (2014)

CONCLUSION

The aim of this part of the research was to characterise the environment of the wild *C. subternata* resource. While growing conditions varied greatly throughout the expanse of *C. subternata's* distribution, it would still be possible to characterise a typical growth site, as suggested in Table 3-21.

Table 3-21 Typical *C. subternata* site

Typical growth site	
Slope	10-45 degrees
Aspect	Ranges from north-west to south and north-east-facing
Rainfall	Ranges between 500-1 000 mm
Geology	Does not grow with underlying shale. Grows well in sandstone substrates
Land use	Prefers pristine fynbos. Can re-establish itself in reclaimed land
Fire interval	Requires a regular fire interval (roughly 10-15 years) to maintain a healthy population
Vegetation community	Prefers to grow in grassy fynbos communities which do not have renosterveld present
Soil	Nutrient-poor sandy soils facilitate *C. subternata* growth

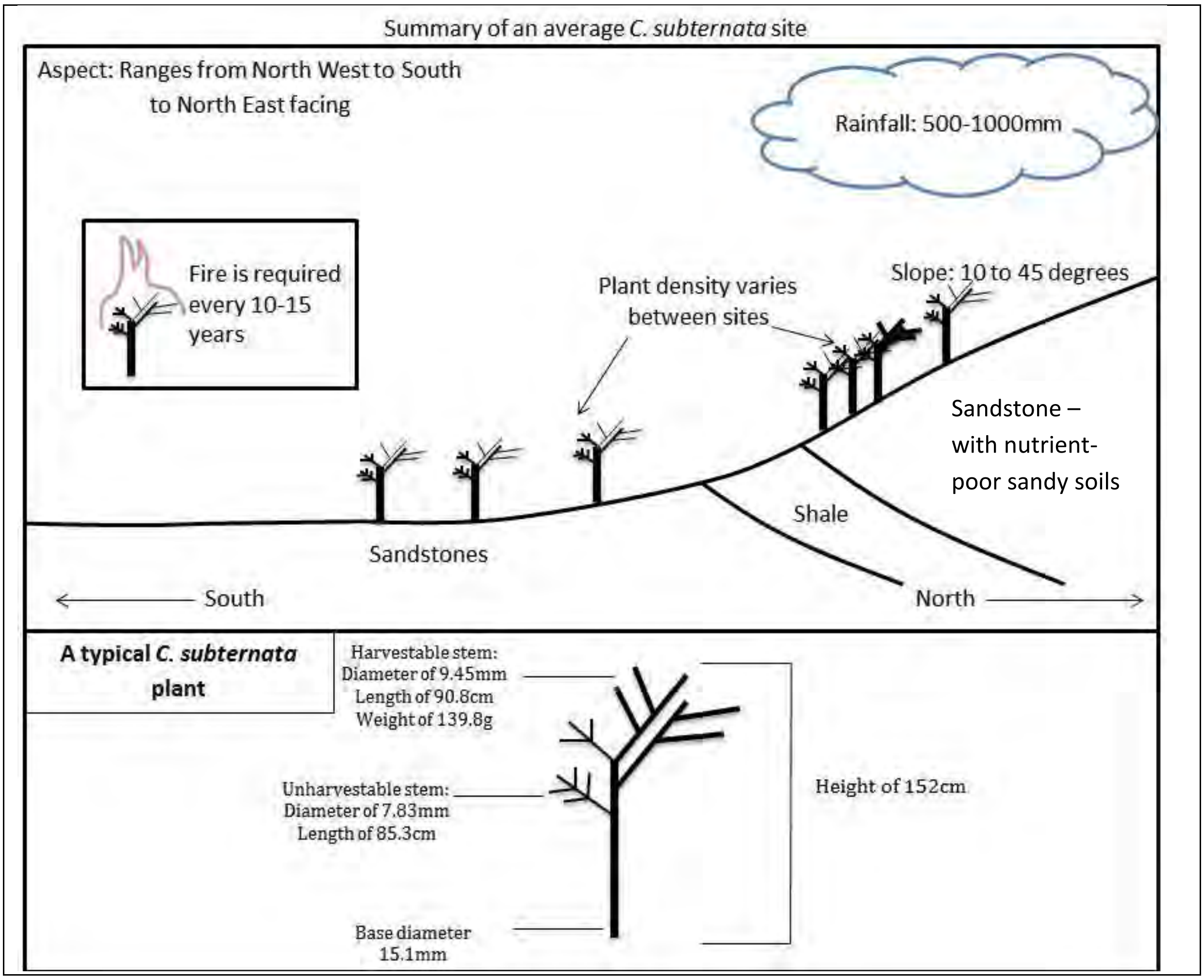


Figure 3-17 Summary of an average *C. subternata* field site

In terms of the harvesting process, the most important principles which must be maintained are as follows: each plant population must be looked at in its unique environment; in its environment the plant being harvested must also be considered individually; the harvesting process is not a one-size-fits-all practice; a maximum of two thirds of the plant may be harvested if the plant is in good condition; plants must not be harvested when they are in flower. While these principles outline the basic strategies which need to be followed when harvesting plants, the guidelines created in Chapter 5 expand on the best practices for harvesting.

The knowledge gathered from harvesters is essential in understanding the harvesting process. The knowledge gathered from literature acted as confirmation of the harvesters' knowledge. Field visits showed that plants which had previously been harvested at more than 2/3 of their original biomass had mostly died. According to harvesters, the maximum amount that can be removed from a plant is 2/3 of the biomass if the environmental conditions allowed this. Joubert *et al.* (2011) and Schutte (1995) suggest that *C. subternata* should be harvested differently from *C. intermedia* as survival occurs when the entire *C. intermedia* plant is harvested. Both North *et al.* (2017) and the harvesters agree that young plants should not be harvested because they do not give the same taste as older plants and if harvested early, the plants do not flower and seed. Additionally, the harvesters' knowledge agrees with Beyers (2016) in taking the environmental conditions into account before a harvest takes place. If the conditions are not suited to sustained growth, a harvest should not occur. It is important to note that harvesters do harvest during flowering periods, which has been shown by research to be detrimental to plant populations (North *et al.,* 2017).

While the variability of individual plants may lead to confusion about whether or not a plant should be harvested, criteria can be established which will eliminate this confusion. Using a standard list of variables, which can be compiled at each site, the site can be assessed to establish its potential to facilitate honeybush plants. Information such as previous harvest history, rainfall, health of the population and location can be used to create the best harvesting practices for each unique site. The data gathered and depicted in this chapter shows that even with a variety of growth conditions, the harvesters clearly distinguish which plants should be harvested and which should be left. The harvesting of these plants cannot be looked at as a one-size-fits-all approach but rather should be looked at individually to provide the best practices during harvesting.

The core of the sustainability of honeybush plants stems from individual harvester knowledge. The survival of each individual plant depends on the ability of the harvester to distinguish what should and should not be done in the unique circumstances which they are presented with daily. Harvesters can be educated to recognise characteristics which are suitable for harvesting in a unique environment while taking the condition of the surrounding environment into account. They must ensure, for example, that even if the plants look suitable for harvest, the current environmental conditions will support recovery in terms of regrowth, flowering and seedlings.

Chapter 4

CASE STUDY: RESOURCE ASSESSMENT AND HARVESTING RECOMMENDATIONS FOR C. SUBTERNATA ON MTO LAND

AIM

The aim of this chapter was to present an example of a *C. subternata* resource assessment on the MTO forestry land.

MOTIVATION

Given the concerns about the sustainability of harvesting, a first step in determining the best practice for harvesting in an area is to carry out a resource assessment. A basic method for determining the location, size and extent of the resource is described in the *Guidelines for Sustainable Harvesting of Wild Honeybush* (McGregor, 2017a). It involves gathering of expert and local knowledge about the resource, mapping the location of populations of honeybush, determining density through plant surveys, and estimating potential harvest yield through a representative harvest.

In order to determine the potential sustainability of the harvesting of *C. subternata* on MTO land, a resource assessment was undertaken. The assessment took place over a 10-day period in the flowering season. This chapter presents the findings of the resource assessment and serves as an example of how a resource assessment can be carried out to provide the basis for a sustainable harvesting approach. While it is specific to the plantation conditions under which *C. subternata* grows, the methods and approach are relevant to any context. This research will aid in decision-making with regard to the sustainable use of honeybush tea in the specific context of a commercial forested landscape. Not only is this assessment of economic benefit to MTO and the community members involved, it is essential in ensuring the persistence of the species for future generations and the overall biodiversity of the area.

INTRODUCTION

Forestry is an important industry in South Africa with forest products contributing 0,6% (R34.5 billion) of the 2017 GDP (South African Government, 2018). According to the Forestry profile (DAFF, 2016), the total commercial timber plantation area in the 2015 period was 1 224 456 hectares, 83% of which is privately owned, while 17% is state land. In 2000, the South African Government implemented a policy to reduce its ownership of forestry lands (De Beer, Ham, Längin & Theron, 2014). These so-called exit lands were to be made available for private ownership (to encourage BEE development) and restoration and rehabilitation in the interests of biodiversity and water conservation. Forestry is a valuable generator of foreign income making up 9% of the manufactured goods exported from South Africa (DAFF, 2016). In terms of employment, the sector directly employs 158 400 people, while an estimated 534 000 people depend on plantation forestry for their livelihoods (DAFF, 2016). MTO, a private multinational timber corporation, is a major lessor of extensive tracts of state forestry lands in the Eastern and Western Cape. It is one of the major land custodians with large parts of the *C. subternata* range falling within its boundaries.

This case study on the state of the resource on MTO land serves as the first attempt at a *C. subternata* resource assessment. While a set of principles for the sustainable use of *C. intermedia* established the basis for the knowledge required to do the same for *C. subternata,* these methods need to be revised for *C. subternata.* Honeybush tea is a uniquely South African product made from plants of the genus *Cyclopia,* which occur in the fynbos biome. The bulk (85%) of the annual tea crop comes from the harvesting of wild *Cyclopia* populations with the remaining 15% coming from cultivated stands of honeybush. There was thus an urgent need to understand the state of the wild resource in order to develop a suitable harvesting approach. Due to the increased demand for this naturally sweet flavoured tea in the overseas 'healthy' beverage market, the pressure on the wild resource has increased considerably over the past 15 years. The aim of this resource assessment and this chapter was to establish a resource assessment and harvesting approach for the utilisation of *C. subternata,* locally called Vleitee, on MTO lands.

There has been an increase in production from 150 tons in 2002 to an annual average of 350 tons in the last five years (McGregor, 2017a). Of the wild crop, 85% comes from bergtee

(*Cyclopia intermedia*), while wild *Cyclopia subternata*(vleitee) makes up about 10% of the crop; *Cyclopia sessiliflora, Cyclopia maculata* and *Cyclopia plicata* make up the remaining 5% (McGregor, 2017a). In an effort to protect the resource through better management, *C. subternata* and *C. intermedia* were declared protected species in the Eastern Cape by the Eastern Cape Department of Economic Development, Environmental Affairs and Tourism (McGregor, 2017a). In order to harvest the crop in the Eastern Cape, a permit with an annual tonnage quota is required from Eastern Cape Department of Economic Development, Environmental Affairs and Tourism (EC DEDEAT). In the Western Cape, permission to harvest is via the landowner and a permit from Cape Nature is required for transport to the processing plant.

The Western Cape Department of Environmental Affairs and Development Planning (WC DEADP) commissioned a project developing guidelines for sustainable harvesting of wild honeybush, specifically *C. intermedia,* which resulted in a set of best practice guidelines, which was made available in April 2017. The exercise was significant in raising awareness and concern about the sustainability of the industry. However, there are currently no formal *C. subternata* guidelines. Overharvesting of *C. subternata* has been reported in parts of the Langkloof, Tsitsikamma and Kouga mountain ranges (SANBI, 2017). As one of the major custodians of land within the *C. subternata* distribution, MTO has recognised the need to implement a sustainable harvesting plan for *C. subternata (vleitee)* on their lands.

Growing in the MTO plantations are many *C. subternata* populations, which have been harvested periodically over the past 20 years. With increasing demand for access to the resource, MTO requested that a resource assessment of their *C. subternata (vleitee)* populations be carried out. MTO recognises the need to conserve and protect the species, while still considering the needs of the local community and their livelihoods.

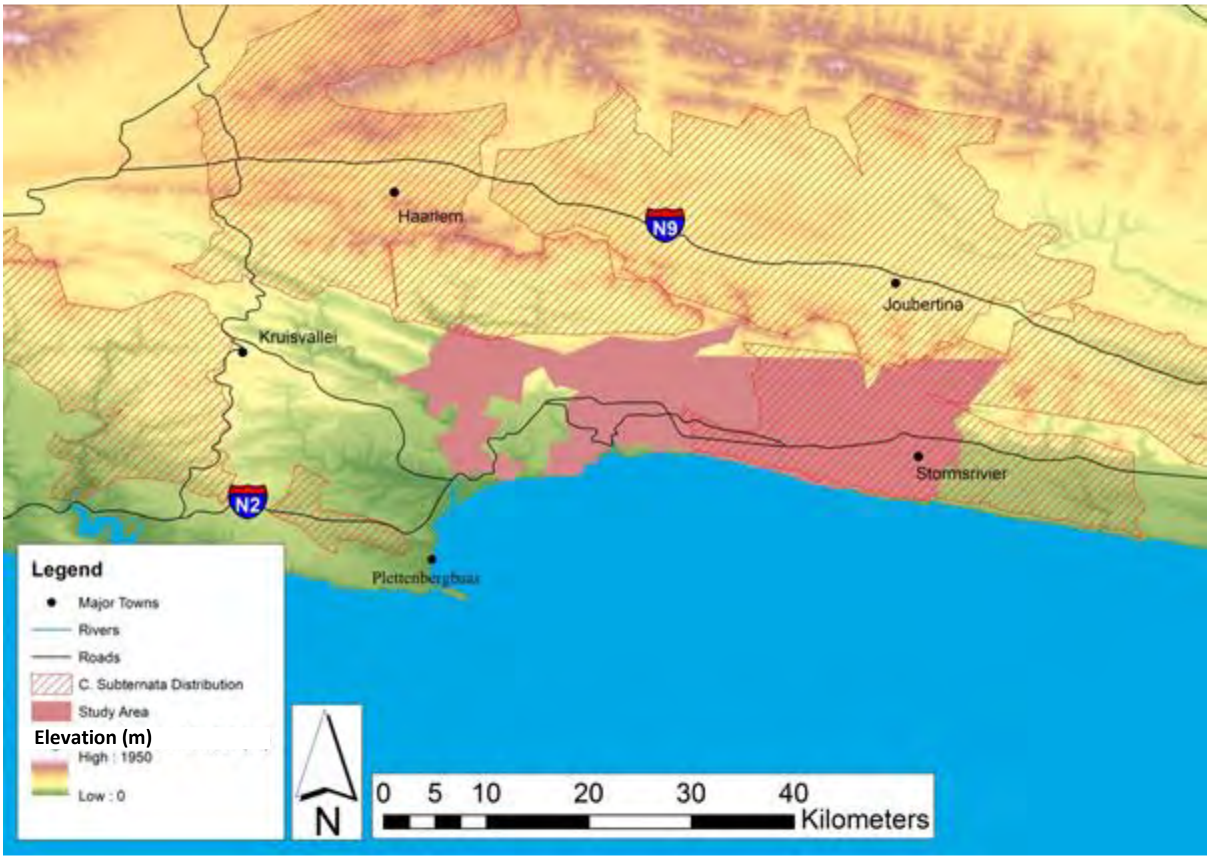


Figure 4-1 Outline of Lottering (MTO) plantation compared with the *C. subternata* distribution

Objectives

The objective of chapter 4 – to conduct a resource assessment of the *C. subternata* resource on the MTO lands to capture context specific information about the harvest history and the resource distribution in this area – was achieved by using the following steps in this chapter:

1. to gather knowledge and information about the resource through consultation with local experts (harvesters, MTO rangers, managers, scientists) with knowledge of the area and knowledge of the existing *C. subternata* populations;
2. to map the location of *C. subternata* populations in the Lottering and Witelsbos plantations;
3. to quantify the extent, distribution and density of selected and representative populations of *C. subternata;*
4. to carry out a harvest sample in order to quantify potential yield from the area.
5. to make recommendations regarding the potential for sustainable harvesting of the resource.

REVIEW OF LITERATURE

CORPORATE RESPONSIBILITY

At the core of its business model, forestry is an extractive industry which has an impact on the environment it uses. The extractive nature of the industry leads to the need for companies to be aware of and consider their environmental impacts and their social responsibility (Jenkins, 2005). Due to forestry's impact on the environment being very visible and dramatic, the need to avoid public criticism has grown in the last decade (Vidal & Kozak, 2008). The need for companies to match their corporate behaviour with stakeholder expectations has become a main driver for the adoption of corporate social responsibility (Dawkins, 2005).

The need for corporate responsibility to be defined and implemented within a company will ensure that businesses can be held accountable for their actions. Due to the fact that corporate responsibility is defined by the use of economic, social and environmental factors, this has led to many sustainable practices within the businesses in the past (Vidal & Kozak, 2008). However, corporate responsibility has neglected to include the social responsibility of business in the communities where they are based (Vidal & Kozak, 2008). The ever-changing definition of corporate responsibility shows that the needs of communities and the environment are constantly changing and adapting just as the definition is changing.

While it has been difficult to ensure responsible practices in the forestry industry, certification from third-party companies has increased the effectiveness of these practices (Bek *et al.,* 2013). Responsible practices ensures suitable forestry practices through the correct use of the forest resources, ensuring forest health, productive functions of the forest, the socio-economic benefits of the forest, and finally, implementing legal and institutional frameworks. With the increased use and surveying of *C. subternata* plants on the MTO lands, local communities can benefit from the increased job creation, selling of the cash crop and upskilling. There is a need to ensure that companies consider enriching the communities around them in order to satisfy the economic, social and environmental responsibilities.

Participatory action research

Action research can be defined as "research that is initiated to solve a problem involving the people affected by the problem" (Stringer, 2013). Reason and Rowan (1981) provides the following description: "Action research is concerned with doing research with and for people, rather than doing research on them." It is further described as being a (more) meaningful way of doing research. The process involves dealing with an identified actual event or problem in the field of interest, responding to the problem as it occurs in reality, implementing a solution and monitoring the outcome (Reason & Rowan, 1981).

The approach requires that participants recognise the need for change and are willing to play an active part in the research (Meyer, 2000). Participatory action research (PAR) acts as a means of reflecting and data collecting in order to create improvement with a selected problem (Baum, MacDougall & Smith, 2006). Action research is the process of creating knowledge through the use of practice problem-solving with the participants who are involved (Huang, 2010). This type of research allows for knowledge to be called into question and for it to be improved if information is lacking. While the research is taking place, it is crucial that the individuals involved (the participants) improve their knowledge and are able to implement this new knowledge to better their working environment, their results and the world around them. Participatory Action Research (PAR) aims to empower people through reflection on the knowledge which they have and to help them integrate this knowledge with input from researchers (Baum *et al.,* 2006).

In the context of this research, the MTO case study was well suited to and complemented the use of corporate responsibility. This case study allowed for the inclusion of local individuals who could benefit from the use of the crop, it also allowed for the inclusion of locals who had harvesting and industry knowledge and it could boost the local economy.

Focus Groups

In order to obtain information about harvesting, plant growth and likely distribution from harvesters, landowners and rangers on the MTO lands, focus groups were used. Wholey, Hatry and Newcomer (2010, p. 700) define a focus group as "a form of qualitative research where a small group of participants discuss a topic under the guidance of a trained moderator". An essential component in this type of research is that the participants of the focus group are knowledgeable about the honeybush industry. Importantly, the leader of the focus group must not go into the meeting with a preconceived idea of what he or she wants out of the meeting but must rather analyse what has been said and draw together multiple sources in order to establish different viewpoints on the question (Wholey *et al.,* 2010). Some important benefits of focus groups are as follows: fast means of data collection, in-depth opinion from multiple sources on the research, and finally, questions can be explored in a flexible manner.

McGregor (2017) used a workshop setting along with questionnaires and expert mapping in order to gain the base knowledge, which was used to establish the questionnaires for the focus group in this research. The work with these focus groups was accompanied by a set of questionnaires which were individually tailored to harvesters, farmers, landowners and processors in order to gain specific information.

Thematic analysis is an approach used to analyse qualitative data by identifying patterns or themes that are of importance or relevance to the topic of the research. The analysis should not only summarise the material collected, but interpret and analyse it (Maguire & Delahun, 2017). Clarke and Braun (2013) note that simply using the main interview questions as the themes is not a true analysis.

AGROFORESTRY

Agroforestry is identified as essential to the future of a South African forestry industry that can contribute to a national agenda of economic efficiency, environmental sustainability and social empowerment (Mayers, 2001). The benefits of agroforestry are broad and can be measured in economic, ecological and social terms. Some of the benefits described by authors are improvement of crop yields with low input costs (e.g. fertiliser), improvement of soil and reduced erosion, increased product diversity, water and biodiversity conservation (Ofori *et al.*, 2014; Parwada *et al.,* 2010; Mwase, Sefasi, Njoloma, Nyoka, Manduwa & Nyaika, 2015). In South Africa, Tsubo, Mukhala, Ogindo and Walker (2003) report on the highly successful practice of maize-bean-intercropping in the Free State where they found that intercropping was positive in terms of yield, growth and water use when compared with a monoculture of maize alone.

The mixing of cultivated plant crops through intercropping and agroforestry is seen as a way of reducing pressure on land and water resources while producing better yields (Hong, HeerinkJin, Berentsen, Zhang & van der Werf, 2017). Intercropping can also be seen as a way of dealing with some of the typical modern agricultural problems of pest and pathogen control and soil degradation (Van der Meer, 1989). The use of intercropping and agroforestry is a practice that is common among small-scale farmers in Africa who often operate on marginal land (Ofor *et al.,* 2014).

In a chapter titled 'Challenges ahead: growth, livelihoods and sustainability" [of the South African forestry industry], one of the recommendations by Mayer (2001) is as follows: "Intercropping in the first two years of forest growth should be supported by all forest companies." A successful agroforestry project is described in the Forest Policy Discussion Document (South African Government, 1995) where for many years, the forestry plantations of HL&H Mining Timber and Hans Merensky Holdings have existed side by side with rural communities. In recent years, farmers (mostly women) have successfully cultivated groundnuts and bambara nuts between rows of young bluegum trees.

A main goal of any intercropping system is to decrease the time between cropping in order to improve financial gain. These gains can offset forestry expenses and provide an income as the plantation blocks are rotated or in the event of a loss of trees (Garrett & Kurtz, 1983). This process can also aid in creating soils which have a variety of nutrients used and replenished due to different crop needs. Intercropping can provide an improved yield per hectare, and finally, create financial security (Garrett & Kurtz, 1983). In the forestry context, the space between trees must be considered and altered if the newly introduced crops will affect their root systems. While this may affect the quantity of trees which can be planted in an area, there will be an offset with increased yields and income from the other crops that are grown (Garrett & Kurtz, 1983).

In the *C. subternata* and MTO context, there is the potential for an intercropping system to be used to aid in the managing and maintenance of *C. subternata* in the plantation setting. It will be feasible and desirable to grow these crops to allow for an additional income in the industry. There are also large areas of forestry exit lands which need to be restored to their original state due to no longer being economically feasible for forestry (Van Wilgen, 2015).

These areas can be used as either the testing ground for pine and honeybush intercropping or to test if honeybush can be used to rehabilitate areas after being cleared of pine forests. This not only helps rehabilitate natural fynbos lands, it also creates an economic incentive to rehabilitating the land, which has been lacking in the past (Van Wilgen, 2015).

METHODS

This study used exploratory data gathering as a means of data capture to establish where there are *C. subternata* populations. This approach served two purposes. Firstly, it was used as a primary data source of the location of populations and sites which had previously been harvested. Secondly, the information was used to refine other map-based data sets that were created using environmental characteristics suiting the needs of *C. subternata* growth.

OBJECTIVE 1

Information was gathered via a questionnaire and individual interviews with attendees at a workshop at the Lottering plantation. This information allowed researchers to identify areas of interest throughout the plantation. Due to the forestry context, recording expert knowledge was essential in understanding where populations previously grew and were removed. Through these interviews, knowledge of *C. subternata* (vleitee) harvesting methods, past harvesting locations and issues of sustainability were recorded. Through group discussions, common ideas were consolidated and the information gathered was refined. See Appendix 6 for workshop attendance register.

OBJECTIVE 2

Mapping the populations in the plantations was done by using expert knowledge in order to locate *C. subternata* populations. Areas of interest mentioned in Kirkman's report *Honeybush tea (Cyclopia spp.) on MTO land in the Tsitsikamma* (Kirkman, 2003) were revisited in order to see whether these populations had survived. A visual inspection was done from a vehicle and random walking surveys throughout the plantation blocks, with input from an experienced harvester. Populations were identified and marked on a GPS with a description of perceived distribution. Areas of interest were noted and marked for survey.

Rangers from MTO aided in the navigation of the plantation and helped to identify areas which could be accessed. Rangers assisted the researchers in finding suitable routes, areas of interest and in gathering basic survey information. These rangers were also taught to identify the *C. subternata* plants and recognise areas where the plants could potentially grow. Both parties benefited from each other's knowledge and understanding of the veld in this unique context.

Objective 3

In order to assess the potential for harvest on the MTO lands, belt transect surveys were conducted in selected blocks of the plantation. These transects were used to estimate the density, potential yield, nature of the resource and the health of the resource (Table 1). Along with defined transects, survey walks were done to establish the extent of populations within plantation blocks. This allowed for the extrapolation of transect data to estimate populations for an entire block.

Based on the belt transect survey method described by Mueller-Dombois (1974), belt transects used in this survey consisted of a 10 by 100 m belt, which was positioned perpendicular to the road separating it from the adjacent block. All bushes were marked with a numbered tag and a GPS point. Each *C. subternata* plant was measured for height, harvestable and unharvestable branch length and diameter, stem colour, base diameter and number of stems. Because *C. subternata* in its natural form is like a small tree, with a trunk and many branches, these features were used to describe its physical make-up (see Figure 4-2). In areas where visual inspection from a vehicle did not reveal any *C. subternata* plants, a second method, namely survey walks, was used to ensure thoroughness.

Figure 4-2 Diagrammatic representation of the small tree-like structure of reseeder *C. subternata*

In the Witelsbos area where expert knowledge was lacking, four sites in natural vlei areas and forested land were selected randomly for survey walks. A random sampling grid was used to determine the starting point of the survey walks and the research team conducted walks with the purpose of identifying and locating *C. subternata* plants. In vlei areas, the outline of the vlei was also walked. The track was mapped and areas of interest highlighted.At each site, a set of environmental variables was recorded. These included slope, perceived sunlight exposure, aspect and land cover. This was done to establish a profile of each site to provide a better understanding of why areas might yield different quantities of *C. subternata*.

Objective 4

To establish the possible harvest yield of *C. subternata*, a sample harvest of 30 plants was carried out. Before the *C. subternata* was harvested in a predefined area, plant measurements of height, plant base diameter, stem colour and number of branches were taken.

Based on the advice from a harvester, the most suitable stems were cut from each plant and measured (stem length, weight and stem diameter). After the harvest, the area was revisited and bushes which were not harvested were noted, and unharvested branches measured for their length and diameter. This process allowed for a comparison of harvested and unharvested plants.

Objective 5

In order to establish recommendations for harvesting of *C. subternata,* the results from Objectives 1 to 4 were considered. By looking at other best practices for the harvesting of other resources (e.g. *Cyclopia intermedia* guidelines, wildflower harvesting and the rooibos industry), a set of best practice recommendations was drawn up.

Results

In the Lottering plantation, there were well-defined areas of *C. subternata* growth. These areas were identified by using expert mapping from harvesters and rangers who knew the lands well. By employing expert mapping, sites could be selected which showed areas of potential high, medium and low yield for harvesting. These sites could easily be identified by harvesters on maps as they knew exactly which forest blocks contained *C. subternata* plants and which did not. Therefore, the focus could be on sites where *C. subternata* was known to occur.

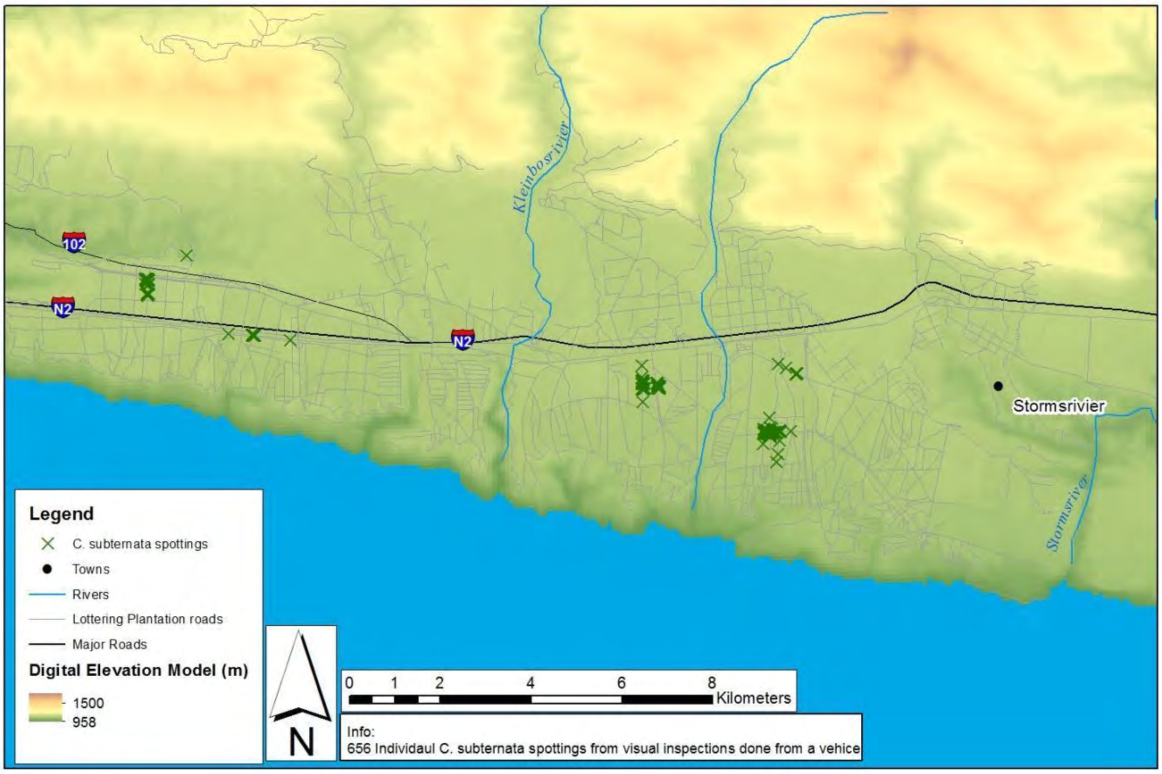


Figure 4-3 : Location of visual inspections done from a vehicle in order to establish possible study sites at the Lottering Plantation

On the Lottering plantation, surveys were conducted at the following sites:

Table 4-1 Surveys conducted in Lottering plantation

Block	No. of transects	Other surveys	Site description
C10	1	Harvest survey and full block survey	Old tree growth with few pine needles on the forest floor; not many ferns growing in this area; sedges present
C25a	3		Old tree growth; small dead ferns on the forest floor; appeared to be drier than C10
D56	1		Natural fynbos next to the N2 highway and not under plantation. Vegetation ranged from knee-high to overhead in height. There were clear signs of human activity with paths and rubbish around the plants
E5b	4		Small ferns growing at the base of old trees
R35a	1		Fern growth and pine needles on the forest floor, which created complete, deep ground cover
R37a	3		This site had moist soil. The area was also moderately sunny due to gaps from fallen trees
R50	2		Patchy vegetation, mainly ferns – higher than knee-high. There was moderate sunlight with dry soil
R49	1	Full block survey	Patchy vegetation, mainly ferns – higher than knee-high. Moderate sunlight and dry soil
Woodlands	1		Untouched fynbos area between two fire breaks, which had honeybush growing on the edges of the fire break. The surrounding vegetation was over head height and very dense
Visual survey	1		The visual inspection of the Lottering plantation revealed 656 individual plant sightings

RESULTS PER SITE AT THE LOTTERING PLANTATION

Table 4-2 Transect data for all the blocks surveyed in the Lottering Plantation and the number of plants found

Block	Transect 1	Transect 2	Transect 3	Full survey (every plant counted in this block)	Predicted number of plants per individual block area[4]
C10	188			528	741
C25a	23	43	17		711
D56	129			/	
E5b	10	5	4		86.13
R35a	12			/	60
R37a	22	6	5		45.8
R50	34	17			451.7
R49	33			175	470
Woodlands	29			/	

[4] The number of predicted plants in a block were calculated by using the transect data and multiplying this to match the area of the individual block.

Table 4-3 Harvest data for block C10 – cut plant material measurements

	Diameter (mm) Harvestable	Length (cm) Harvestable	Diameter (mm) Unharvestable	Length (cm) Unharvestable	Average weight (g)
1st Branch	11.9	146.9	7.7	107.85	161.82
2nd Branch	10.5	134.7	6.7	97.92	148.43
3rd Branch	10.4	139.5			83.83
4th Branch	10.5	113.3			111.33

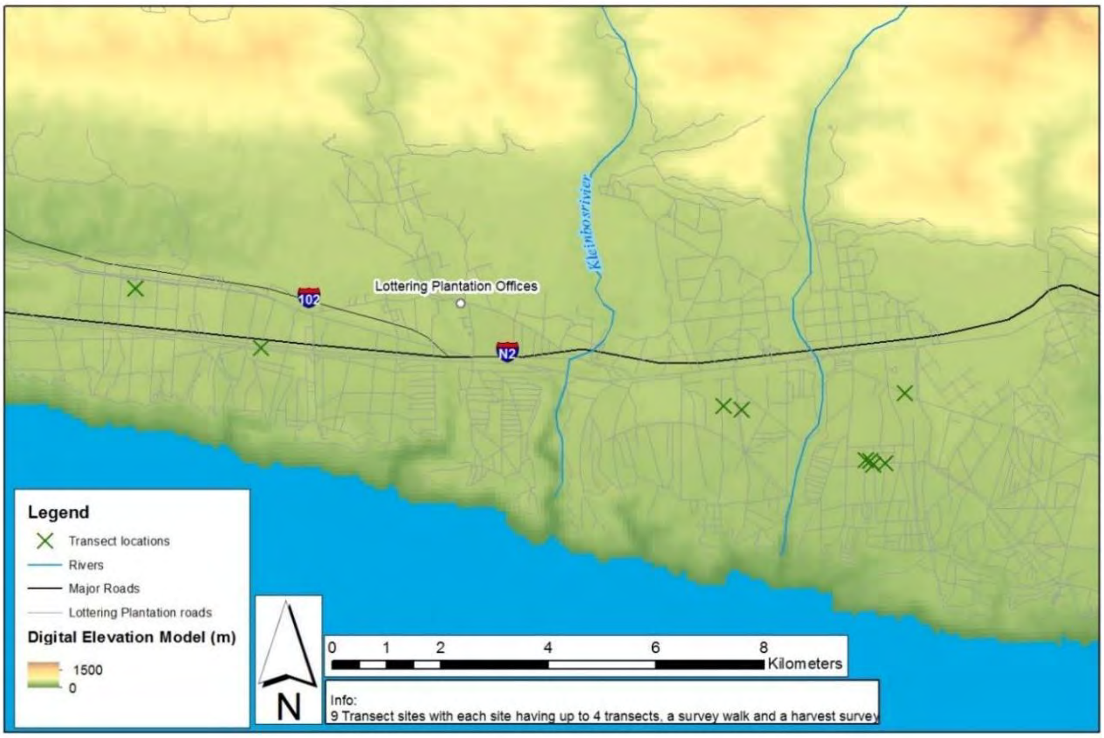


Figure 4-4 Location of population surveys in Lottering plantation

Table 4-4 shows the potential harvest yields for blocks surveyed in the Lottering plantation. These yields were based on a harvest of only 25% of the current standing population in each block. This number could be inflated due to the overestimation of plants occurring within each plantation block. However, a 25% harvest portion is a conservative one (and was based on the accompanying harvesters' advice) and could be increased to 50%, given the precaution of only taking two to four branches per plant. In order to have a sustainable harvest regimen, the criteria mentioned in Table 4-4 should be used and blocks should only be harvested every 24 months.

Table 4-4 Potential harvest yield based on cropping of 25% and 50% of the population

Block	Predicted total plants in block	Harvestable plants[5]	Potential harvest yield at 50% harvest (kilograms based on 4 branches per plant)	Potential harvest yield at 25% harvest (kilograms based on 2 branches per plant)
C10 (1)	741	185	93.48	57.39
C25a	711	177	89.43	54.9
D56 (4)	129	32	65.18	9.93
E5b (3)	86	21	10.61	6.51
R35a	60	15	7.58	4.65
R37a	46	12	6.06	3.7
R50	452	113	57.1	35.05
R49 (2)	470	118	59.62	36.6
Total (25% crop)		673	**389.1 kg**	**208.7 kg**
Total (50% crop)		1346	**778.2 kg**	**417.4 kg**

Figure 4-5 refers to the sampling method used at different locations within the study area. These methods were used to best represent the state of the population within each block and for the population as a whole.

(1) Site: Block C10

Figure 4-5 shows the areas around Block C10 where a harvest survey, transect (A), and a walking survey (B) were completed. Most of the plants were clumped in groups in the western area of the block. There were no *C. subternata* plants in the overgrown vlei area to

[5] The number of harvestable plants was averaged from actual harvested plants vs. unharvested plants in the harvest survey. Roughly 25% of plants were harvestable in this context based on the harvesters' choice.

the east of the block. The insert map shows the transect survey which took place in this block.

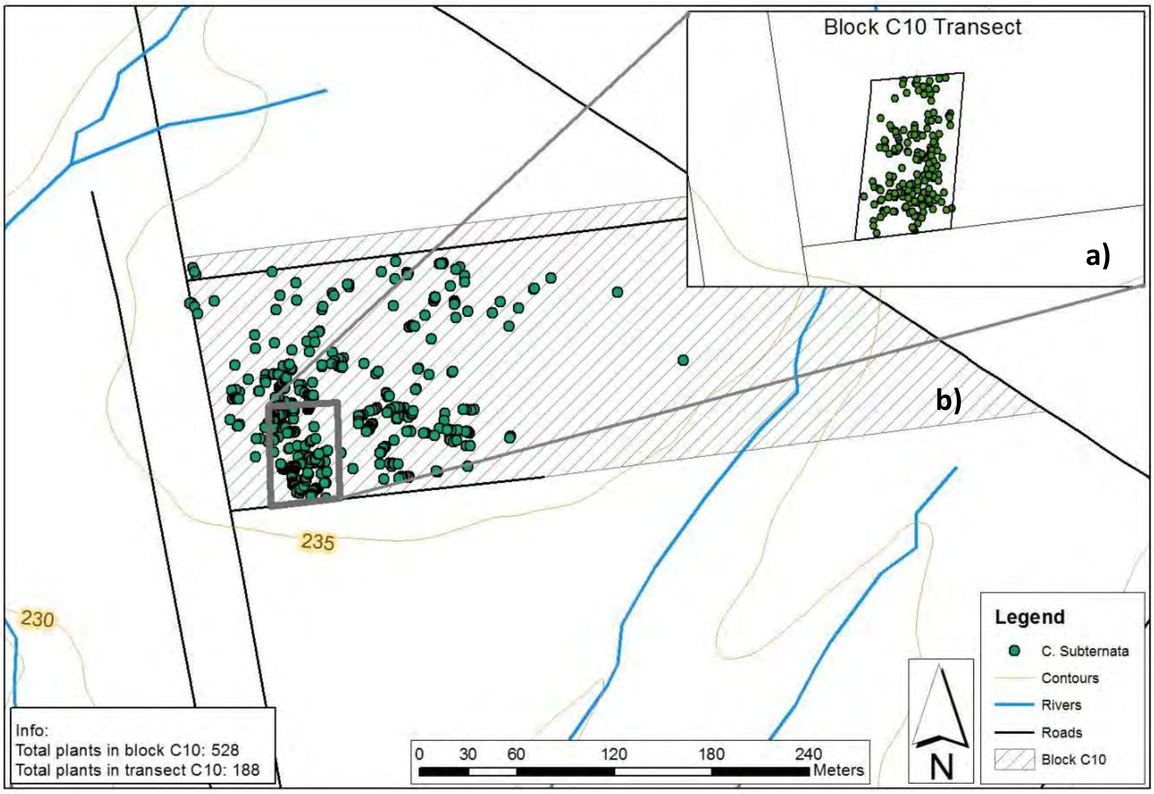


Figure 4-5 Block C10 with a) transect and b) survey walk

(2) SITE: BLOCK R49

Figure 4-6 illustrates the results of mapping the *C. subternata* population in Block R49. The transect (A) was laid out in the NE corner and the plants were located and measured. A grid walk (B) was done in order to cover the whole block area and each plant was located and mapped. There was no discernible pattern of growth.

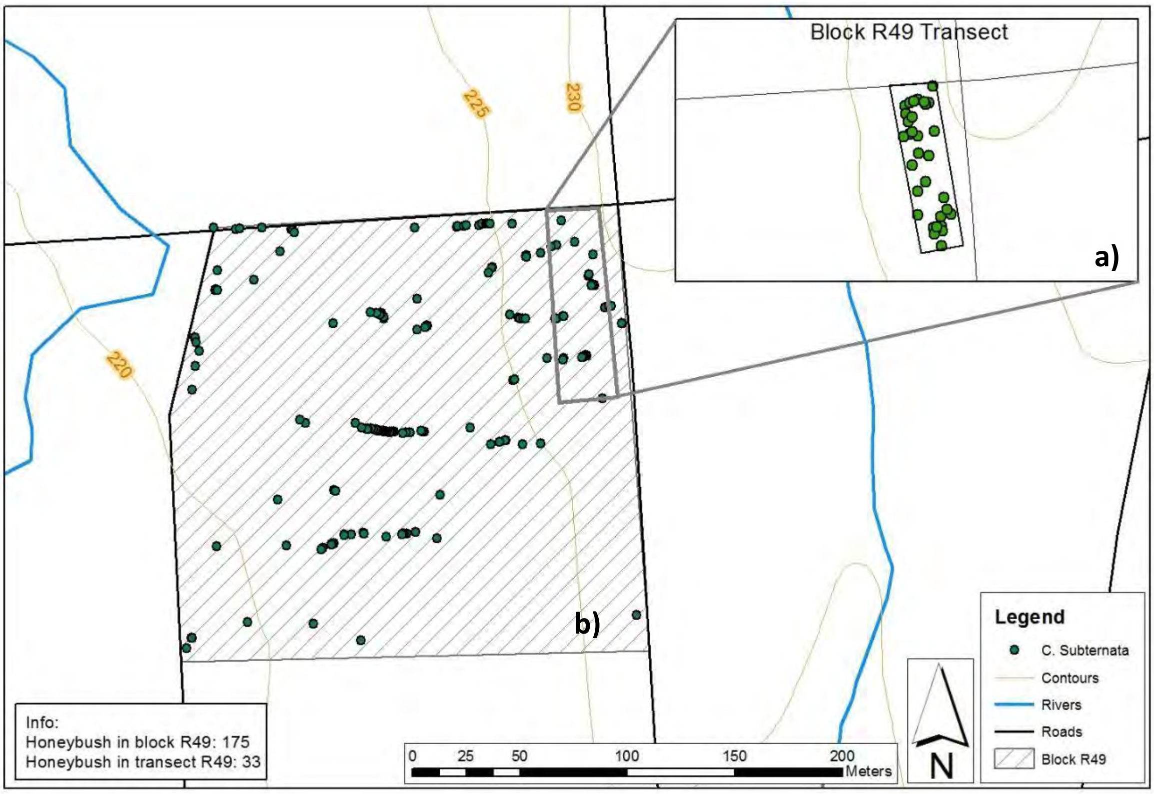


Figure 4-6 Block R49 with a) transect and b) survey walk

(3) SITE: BLOCK E5B

Figure 4-7 shows the layout of two different transect methods in Block E5b: first, a 50 by 20 metre transect (A) to show how *C. subternata* declines into the forested area; second, three 10 by 100 metre transects (B) from the road, which also show that the populations are most often located near the edges of the plantations. In the case of the 50 by 20 metre transect, there was only one plant within 100 metre of the road.

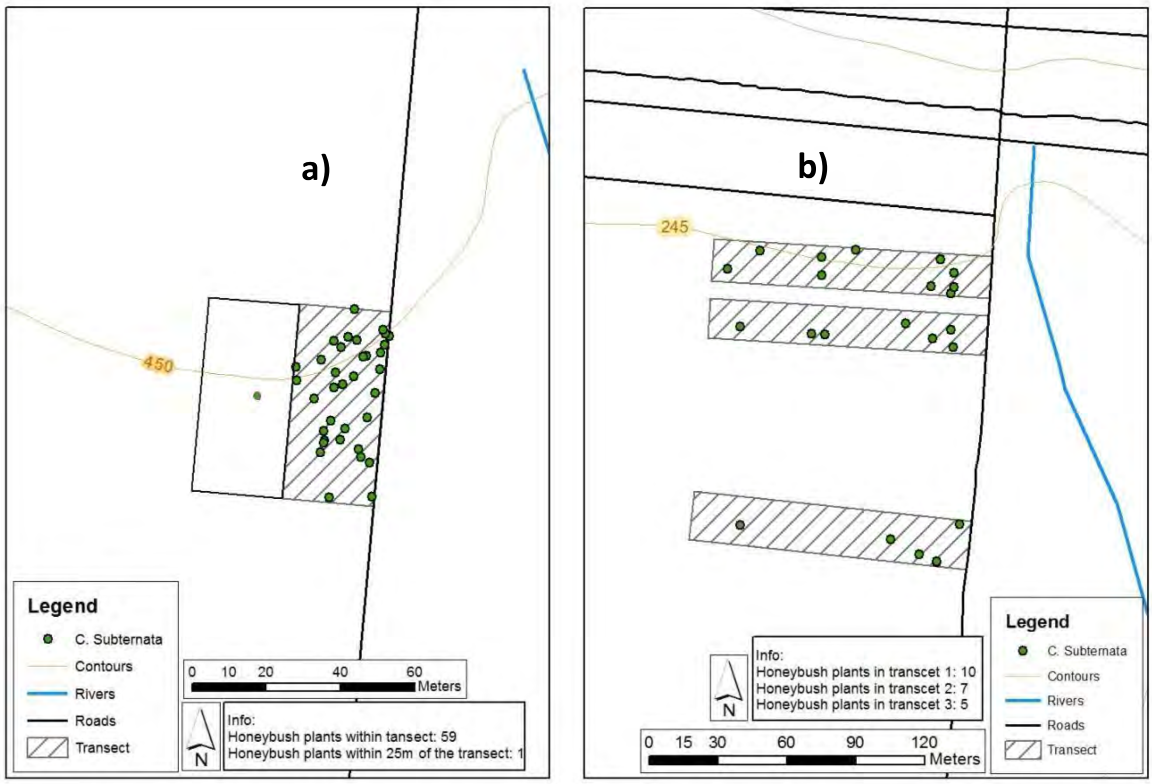


Figure 4-7 Block E5b with two different transect methods: a) 50 m by 20 m transect, and b) 10 m by 100 m transects

(4) SITE: BLOCK D56

Figure 4-8 shows a natural population of *C. subternata* occurring on the MTO property in an area that was not covered by trees. The transect was laid out parallel to the N2 highway running alongside the MTO plantation. Every plant was located in the transact and measured.

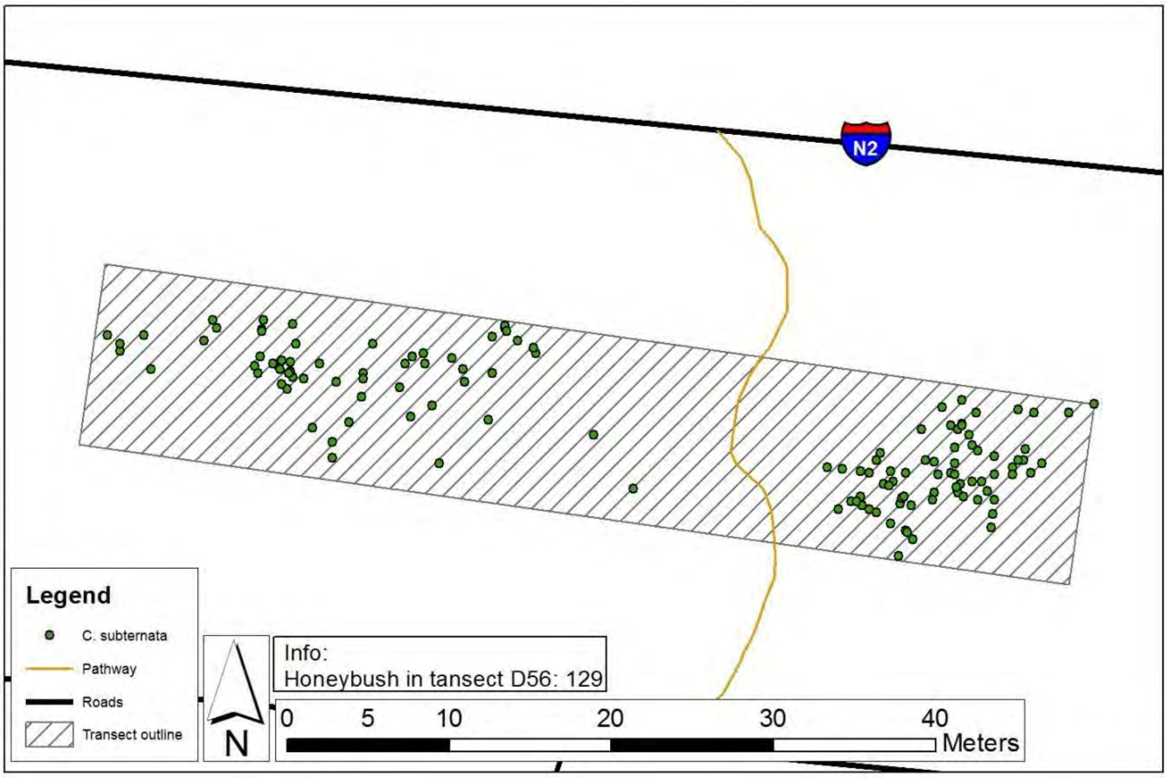


Figure 4-8 Block D56 – a natural population

Table 4-5 shows the comparison between a natural population (D56) and two forested *C. subternata* populations (C10: a high-density population and C25a: a low-density population). The population in D56 was classified as natural due to the lack of forestry practices taking place in this block. The area has been left to grow naturally without being impacted by shade cover from pine trees, herbicides or forestry activity, as seen in sites C10 and C25a. While the *C. subternata* did not grow as tall in the natural population as in the other two, the plants had a much thicker base diameter and branch diameters of harvestable branches. The taller plants were expected in the forested populations because these plants grew taller in order to reach sunlight. In the case of block D56, sun exposure was not a problem.

Table 4-5 Comparison of branch measurements in a natural population and non-natural populations

Transect	Branch diameter (mm)	Branch height (cm)	Base diameter (mm)
D56 (natural)	11.7	104.5	13.5
C10 (non-natural)	10.8	153.4	7.3
C25a (non-natural)	11.3	160.4	9.7

Results for the Witelsbos plantation

Eight randomly sampled transect walks were conducted in vlei areas and four in forested areas. The vlei regions all had vegetation more than head high, which was very dense. The forest areas had little or no vegetation on the forest floor. Pine needles covered the floor and there were the occasional small shrubs.

Along these transect walks, no *C. subternata* plants were sighted. In and around the vlei regions, in a buffer of 15 to 25 metre, there was also no *C. subternata*. These findings were also noted by Kirkman (2003) in the Witelsbos plantation. This could be due to the fact that this pioneer species had been outcompeted. Due to a lack of fires in these areas, other plants became dominant and *C. subternata* disappeared. In the event of a fire occurring, it can re-establish after a long absence.

Figure 4-9 shows the Witelsbos area, which required an adapted method in order to try and locate plants. Initial visits to the area did not reveal any *C. subternata* plants. Most of the area of the plantation was covered in a vehicle and the area was surveyed visually without any success (visual inspection was used successfully in the Lottering plantation in order to identify possible populations). In order to verify the vehicle survey results, walked surveys were also employed, as shown in Figure 4-9. Four vlei walks and four forest walks were completed. The four largest vleis were selected and no *C. subternata* plants were found in either the forested or vlei regions.

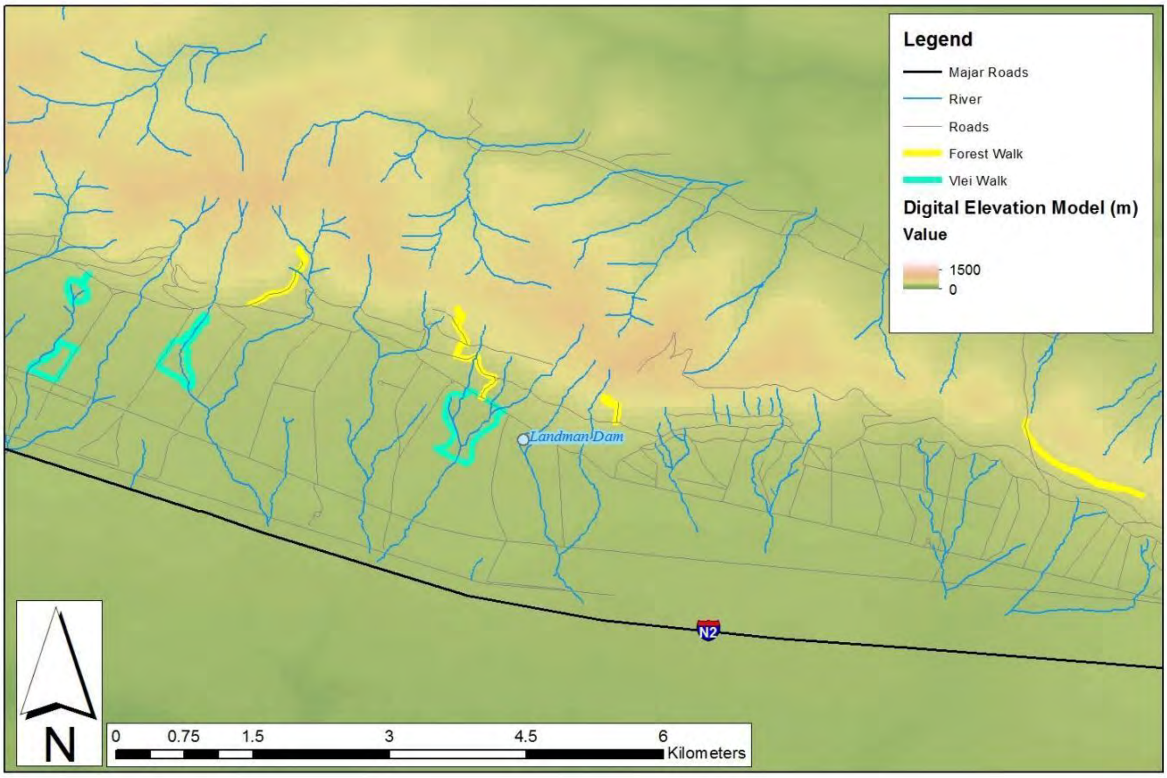


Figure 4-9 Witelsbos plantation and more specifically the walked surveys conducted at Clarkson

DISCUSSION

HONEYBUSH AND PINE INTERCROPPING

The results show that *C. subternata* does grow in certain areas in the plantation (Meyer, 2001). This is not a typical intercropping example because the plants are wild. However, a formal intercropping approach can be implemented. Allowing areas underneath the trees to be used for planting *C. subternata* can provide a supplemented income as well as job creation in the short term for the local community (Jenkins, 2005). The area underneath the trees is left unused for periods of up to 10 years and may be suitable for a cultivation stand for *C. subternata* in areas which show growth potential. Intercropping can be beneficial because it provides short-term cash income from regular harvests, improved soil and job creation (Garrett & Kurtz, 1983).

De Beer *et al.* (2014) highlight the need for an exit strategy to be used on old forestry lands. There is potential for the land to be restored by using the *C. subternata* crop as main driver for this process. Its function as a pioneer species (Vlok & Schutte, 2010), the benefits from economic use (Joubert *et al.,* 2011) and the transition of the exit lands (De Beer *et al.,* 2014) can be beneficial to the local areas.

Fire plays a crucial role in the lifecycle of the honeybush plants and is a common occurrence on the MTO land. The use of a fire-adapted crop in a fire-prone area will result in a highly productive intercropping system if managed correctly (Meyers, 2001; Garrett & Kurtz, 1983; Bond *et al.,* 1984). Using *C. subternata* plants will also provide a quick initial return on investment in areas which have recently burnt (Mayer, 2001). Where recent fires in the Tsitsikamma region have exposed land to erosion, honeybush plants can be planted in order to reduce soil erosion, create income and create jobs while the forests are replanted (Dawkins, 2005).

Conditions are ideal for planting honeybush plants due to the recent fire, which created ideal conditions for pioneer species (Vlok & Schutte, 2010) and because the area naturally supports fynbos growth. As stated by Van Wilgen (2015), there is potential to use forestry exit lands in a manner which can help rehabilitate the land. This can be done by using honeybush plants as cultivated crop within these lands, which will not only enable natural species to be reintroduced to the system but will also create an economic incentive for the rehabilitation of these lands. Finally, there are large areas of land which are not currently being used which can create areas of growth for the honeybush industry as a whole. These unused areas can be used to grow honeybush plants, which will increase the availability of jobs in the South African forestry industry and create economic growth within these areas (Dawkins, 2005).

Harvesting and Growth Guidelines

With sustainability in mind, there are some criteria which need to be met to ensure the future of the honeybush population on MTO lands. From conducting harvester interviews and doing harvest transects, it is evident that harvester experience is crucial (Kuhnert *et al.*, 2010). This is the first step in ensuring the sustainable use of the resource. A 'good' harvester is one who knows the importance of conservative cropping, implementing an 18-month return interval to ensure the future of the crop.

The blocks that were surveyed on the MTO lands show that on average in this physical setting, only one third of a population can be harvested in order to ensure sustainable growth for the plants. Populations such as block C10 only had 185 of 741 plants harvestable. Block R35a had 15 of 60 plants harvestable. Finally, R50 had 113 of 452 plants harvestable. This can be attributed to many plants either being seedlings or not having enough branches to crop the plant sustainably. Natural populations in the plantation have thicker base diameters and shorter heights than populations which occur in the forests themselves. This can be attributed to plants seeking sun in the forests and thus becoming very tall and skinny in their growth. Plants in the forests are on average 50 cm taller and have stems which are 6 mm thinner.

While the current non-typical intercropping system does not yield enough plant material to sustain the livelihood of the harvesters, a formal intercropping system may (Meyer, 2001). Due to the ideal situation of the forestry lands within the typical growth site for *C. subternata*, an intercropping system can be used. The typical distribution is fire prone, which has led to massive losses for MTO each year. These losses can be offset by the use of honeybush as a cash crop on the forestry lands.

In this specific context, the following guidelines for both harvesting and growing are appropriate:

Harvesting Guide

1) Plants with a single-stem trunk younger than three years old must not be harvested.
2) Multi-branch plants younger than three years can have the larger branches cropped:
    a. The number of branches to be cut varies according to the health of the plant, the size of the other branch, and the height of the plant;
    b. Cutting up to 50% of the side branches is acceptable if these branches and the plant are in good health;
    c. Branches are cut above regions of new growth to enable the plant to regenerate after harvest;
    d. One major limb must be left to support the plant.
3) Plants which are taller than 2,5 metre may be cropped because these have reached the limit for factory take-in.
4) Any plant smaller than hip height must not be harvested.
5) In every population, some plants must be left to bud, flower and set seed.

Growing Guide

1) Blocks younger than 10 years should not normally be harvested due to forestry activity taking precedence in that period.
2) Blocks older than 20 years should not be harvested due to the forestry activities which take precedence.
3) From initial establishment, a three-year period will enable plants to reach maturity, flower twice and ensure a suitable soil seed bank store.
4) After this initial three-year period, harvesting can take place every 24 months on each site.

Table 4-6 Harvesting timeline

Harvest 1 January 2017	Rest January 2018	Harvest 2 January 2019	Site 1
Harvest 1 January 2018	Rest January 2019	Harvest 2 January 2020	Site 2
Potential Harvest of 400 kg per harvest at each site			

HARVESTING ALTERNATIVES – SEED HARVESTING

Seed harvesting is an alternative to harvesting the crop itself. There is currently a large growing market for *Cyclopia* seeds. Along with the harvesting schedule proposed above, a seed harvesting schedule can be implemented. This will not only allow MTO to sell seeds to the cultivated sector, but also enable MTO to create a cultivated honeybush crop.

Seedpods of *C. subternata* (vleitee) in the Tsitsikamma should be ripe for collection in September to October, depending on the season. (Unusually warm dry weather can speed up the ripening process, while late rains may delay the flowering.) With any wild plant, conservative harvesting of seed is recommended, with at least 50% of the seed left on the plants to ensure that the soil seed bank is replenished. Jones (2004) advises as follows: "…seedpods must be completely hard and brownish/black when harvested, with no fleshiness or green colouration. Harvested pods should be left in the sun for two to three days in thin layers on a suitable surface (e.g. canvas or plastic sheeting) or container (e.g. a cardboard box). Cover the seeds with shade cloth to prevent seeds popping out of the container."

CONCLUSION

This formal *C. subternata* resource survey demonstrated an approach to a resource assessment on a property. This kind of information will be useful to the landowner in making management decisions and will provide input for the permitting applications to the Eastern Cape DEDEA. It was demonstrated that the methods used (focus groups, expert knowledge, harvest site survey and site surveys) are suitable for any honeybush site survey. The use of participatory action research enabled a two-way knowledge share to occur between the researchers and the harvesters, which will not only aid in understanding sustainable harvesting but will also help to create criteria for sustainable practices.

The results of the resource assessment show that to ensure the future of honeybush on the MTO lands, a conservative harvest regime needs to be followed to allow the crop to recover and set seed in between harvests. The amount of *C. subternata* available for harvesting based on this resource assessment is not substantial. The results in Table 4-4 suggest a maximum of about 800 kg and a low-yield harvest of about 200 kg every 24 months. The low yield is largely a consequence of the plant growing in the plantation setting where it is unable to reach normal dimensions with multiple branches. Due to the unique nature of the plant's growth, each site must be individually assessed for its harvesting potential by experienced harvesters in order to ensure the sustainable use of the crop.

Although the yield is low, at a factory price of R8.00 per kilogram, this will be worth the effort for a single, small harvest team. In order to get a better measure of actual yields, a harvest monitoring session should be undertaken in which actual harvesting is compared with the potential yields calculated in this assessment. The use of a formal intercropping system may improve yields.

To ensure successful conservation, expert knowledge, participatory research and scientific surveys must be used together. While MTO must meet their corporate responsibility by engaging with the surrounding community, the current low yielding and wildly scattered populations will be difficult to manage. Allowing the local community to use the crop as part of MTO's corporate responsibility will not only empower the community but been environmental and social responsibility needs (Dawkins, 2005)

The low yields can be increased by using a formal intercropping system, which will benefit the community in the area through job creation. It is important to emphasise that the benefits of a conservative harvesting approach by experienced harvesters will be crucial to create a successful harvesting system. It will also ensure that honeybush is not lost from the area.

Action and participatory research were used to great effect in conducting this research. The research enabled a two-way knowledge share to occur between researchers and harvesters. Additionally, this knowledge was passed on to rangers at MTO, who now has the ability to identify and help conserve the plant in its physical setting.

Limitations of the study

Future studies need to consider the best time to survey plantation blocks. Honeybush plants need to be in flower to be easily identified and spotted. While the potential number of *C. subternata* plants per plantation block can be estimated, the true value remains unknown because not all seedlings and small plants will be discovered. In order to best understand the population in the entire Lottering and Witelsbos plantations, more expert knowledge is required over a longer time period (Stringer, 2013; Reason & Rowan, 1981). This includes having more experienced harvesters map the area and show the research team the previously harvested regions. Ranger knowledge of honeybush identification was initially low; in order to facilitate future research and identification of areas of interest, this knowledge must be expanded.

Chapter 5

DISCUSSION AND CONCEPTUAL MODEL FOR HARVESTING

AIM

The aim of this chapter was to establish a best harvesting practice guideline for the use of *C. subternata*.

INTRODUCTION

This chapter concludes the research by bringing together what has been covered in Chapters 2, 3 and 4 in the applied context of developing best practice guidelines for harvesting *C. subternata.* While the aim of this research was to develop an understanding of the nature and state of the wild resource and set up guidelines for best harvest practices, many other questions were also answered through the research. Increasing the understanding of the species, its environmental setting and the role it plays in the livelihoods of those involved in the industry will result in a sustainable approach to harvesting and the future of the industry.

While this research aided in understanding the species as a whole, the impact of honeybush on the livelihoods of individuals in the industry and the biodiversity within the fynbos biome has yet to be fully determined. The concerns that Joubert *et al.* (2011) raised about overharvesting and harvesting practices which are unsustainable were partly resolved through this research. The harvesting guides and practices proposed here were developed from a better understanding of population distributions (Chapter 2), the state of the known populations (Chapter 3), recordings of harvesting, and existing knowledge of plant ecology (Chapters 3 and 4) and other areas of relevant knowledge to ensure sustainability. The integration of this knowledge can contribute to the sustainable use of the resource, and therefore, improved market supply and better security of livelihoods for all those involved.

The call for drawing up of guidelines was recognised formally by the honeybush community at several meetings: Joubertina, February 2013 – Sustainable management honeybush workshop by Living Lands; Uniondale, February 2014 – Honeybush tea workshop organised by Eden municipality; Storms River, July 2015 – Storms River Workshop on honeybush management issues. These meetings resulted in a call for development of guidelines for sustainable harvesting of wild honeybush by the Western Cape DEADP in November 2016, which was supported by the South African Honeybush Tea Association (SAHTA) and the Honeybush Community of Practice (HCOP). This research is part of the response to that call to provide information on and develop guidelines for the *C. subternata* resource.

OBJECTIVES

The following objectives were explored in this chapter:

1) to review existing guideline-type documents and fynbos and honeybush ecology.
2) to establish harvesting guidelines.

REVIEW OF LITERATURE AND RESULTS

GUIDELINE TYPE DOCUMENTS

The starting point for developing guidelines comes from Schippmann (1997), who gives a broad outline of what should be covered in a management plan for Medicinal and Aromatic plants utilisation: biological studies (growth and regeneration rates, pollination system, seed dispersal, potential for confusion with similar species, etc.); assessment of harvest impact on viability of individuals; assessment of annual sustained yield; review of local knowledge and harvest practices.

Other useful information on resource utilisation in fynbos is provided in the booklet by Jones (2004). It covers the use of several fynbos species including honeybush. It also provides recommendations for seed collection and harvesting cycles. Other areas which should be considered are pointed out by Williams and Kepe (2008), who note that there is insufficient research on socio-economic aspects of harvesting, and that a management approach should consider four crucial issues: appropriate legislation, tenure, impacts of cultivation and a transdisciplinary approach towards adaptive management.

While cultivation has led to reduced pressure on wild populations of plants such as rooibos, buchu and the wildflower industry, there is limited scientific evidence of the longer-term effects of harvesting on the plants. Industries such as buchu and wildflowers rely on 50% and 25% wild production respectively (Louw, 2006; Bek *et al.,* 2013). While these industries use wild production, there is still little known about the effect that the prolonged harvesting of plants in the wild will have.

Rooibos wild harvesting

In the context of wild harvesting of rooibos, pressure to overharvest can be attributed to not only the need for local communities to use the products but also the demand which has been created by the overseas market for the use of the plants, which creates an economic incentive for local communities. A study by Louw (2006) used harvest height and seasonality to determine the effect of harvesting on rooibos plants. Harvesting severity (in terms of height) was tested at 60% of the above-ground biomass harvested and 70% of the above-ground biomass harvested. The plants which were harvested at 60% showed average regrowth and had the ability to reproduce once they had regrown, while the plants harvested at 70% showed 30% less regrowth and only half of the plants were capable of reproduction.

Louw's (2006) study also looked at seasonality of harvest to ensure sustainability. He concluded that plants harvested in January (summer) had the slowest rate of regrowth but the highest increase in biomass. Plants harvested in April (autumn) had an average rate of regrowth but also resulted in the highest death of adult plants in the study. Finally, a July (winter) harvest resulted in the fastest rate of regrowth but the least gain in biomass. The winter harvest led to the least plants flowering after a 12-month period.

Louw's (2006) study shows that conservative harvesting practices in the summer months when the plants are not in a flowering period will result in the greatest regeneration of biomass while still allowing the plants to reach a reproductive state within a 12-month period. Louw (2006) also notes that harvesters should be paid per unit (kg) weight of the final product, not in terms of the weight of the wet harvested material. Louw (2006) believes that this will result in better harvesting practices because stems which are not suitable for processing will be rejected and thus payment to harvesters will be reduced. This can be an effective means of combating unsuitable practices.

Malgas and Oettle (2007) produced a wild harvesting guide based on their research. Briefly, their recommendations are a formal record of the practices of traditional rooibos harvesters, which include considerations such as the following: harvest can happen every second year depending on rainfall; the best time to harvest is in summer and autumn; 50 to 70% of a plant can be cropped; plants should be cut 2.5 cm above the last cut and stems should be less than 2 mm in diameter. Some of these practices relate to the ecology of the plant, some relate to optimal processing results. The guide is available in English and Afrikaans.

Wildflower harvesting

A study by Privett *et al*. (2014) tested the effects of harvesting on wild flowers on the Agulhas Plain. The study looked at both resprouters and reseeders and the effect that the harvesting of differing proportions of plant material will have on the plant. Plants which were harvested at 100% over a five-year period were found to have 100% mortality and did not produce the same quantity of harvested material as plants which were harvested more regularly at a reduced percentage of harvest. The study suggests that best practice harvesting should aim to crop 25% and 50% of the individual plant. Not only is this a conservative harvest quantity, it also aids in setting seed in the seed bank, as noted by Mustart and Cowling (1992).

Privett *et al.* (2014) showed that while high harvesting rates (75-100%) do produce a higher yield in the short term, the added mortality rates which are experienced do not create a sustainable harvesting regimen. The lower percentage of harvest (25-50%) leads to increased ecological sustainability (due to survival of the plants and growth of the seed banks) and better economic gain due to increased productivity in the long term.

The guideline product for this industry is the *Field guide for wild flower harvesting* (Van Deventer, Bek & Ashwell, 2015). This guide is based on inputs from various studies and surveys on fynbos ecology and the impact of cropping of fynbos flowers for the cut-flower market. It includes information on what flowers can be picked (related to scarcity and conservation status), sustainable harvest quantities, methods of picking for least damage and fynbos plant identification. It also includes an easy-to-use pocket guide version for harvesters to use in the veld based mainly on pictures and summary information of all the species. The guide is provided in English, Afrikaans and Xhosa. This guide formed part of the knowledge which established the best practices for the harvesting of honeybush plants presented in this research.

BUCHU

De Ponte Machado (2003) investigated sustainable harvesting of the fynbos plant *Agathosma betulina* (buchu), which is sourced from the wild and used in the production of essential oils. The aim of the research was to provide stakeholders with scientific evidence of the impact of different buchu harvesting practices and to suggest guidelines for the conservation of wild buchu populations in order to guarantee a sustainable and profitable industry. Traditional knowledge and ecological knowledge showed that an interval of three to four years between harvests or fires ensures sustainable use of the plant and best oil yield. Stakeholders further recommended an interval of three years between harvests to allow for optimal conditions for flowering and seeding. By combining the traditional knowledge of the harvesters gathered through other research (Agricultural Research Council mainly) with the scientific results of trials, De Ponte Machado (2003) derived a set of guidelines.

In terms of the socio-economic impact of wild harvesting of a fynbos species (i.e. buchu), Williams and Kepe (2008) put forward the following recommendations: there is a need for new legislation or a review of the current legislation to guide the industry; there is a need for improved monitoring; there is a need for opportunities for stakeholders to interact. They also note that improved knowledge of the social aspects of the trade is needed for long-term sustainable management and use of the resource.

CYCLOPIA INTERMEDIA

McGregor (2017a) created a detailed technical document, which includes a formal record of harvesting knowledge based on interviews, workshops and field visits with representatives of all stakeholder groups in the honeybush community including landowners, farmers, researchers, government officials, harvesters and processors. Field surveys of the harvest, pre- and post-harvest as well as wild population characteristics, were used to gather data to support the delineation of best practice guidelines. Historic yield data from seven farms was also analysed in an attempt to test the anecdotal evidence of declining yields (the records did not show any discernible change). Recommendations were made in terms of tools to use, best time for harvest, height of cut, selection of mature stems on mature plants, recommended harvest interval based on a 50% cutting plan (two-year return interval) or an 80% cutting plan (four-year return interval) and general care of the fynbos veld (McGregor, 2017c). The recommendations took into account the best available scientific evidence as well as information supplied by harvesters, processors and landowners.

A year later, McGregor (2018) used the information from the technical document in a summarised version and presented this in a field guide format, published, at the request of stakeholders, in Afrikaans and English as the *Wild honeybush harvesting field guide*. In addition to describing best practices for harvesting, a set of 'tools' for harvesters and farmers were included in the booklet such as a honeybush resource mapping method for landowners and a harvest record form for a harvester. Of use to resource managers is the yield map showing potential harvest yields from sites across the *C. intermedia* range. A section on policy and legislation relevant to honeybush harvest and sales is included. A *Cyclopia* spp. plant identification guide is also included in the booklet.

From the above guideline-type documents (Bek *et al.,* 2013; De Ponte Machado, 2003; Jones, 2004; Louw, 2006; Malgas & Oettle, 2007; McGregor, 2017a; McGregor, 2017c; McGregor, 2018; Privett *et al.*, 2014; Van Deventer *et al.*, 2015; Williams & Kepe, 2008), the following common points can be summarised as features of a typical guideline document:

- Provide a background of species ecology.
- Provide a map of the distribution range of the plant.
- Understand the industry context such as the market, prices, demand and the value chain.
- Account for policy and legislation within the industry.
- Collect information on the resource stakeholders (harvesters, landowners and processors). This should include the best practices for harvesting based on harvesters' knowledge.
- Include the best available scientific evidence for best practices for harvesting.
- Consider the socio-economic context, including the well-being of the harvesters, landowners and the processors.

The key points to understanding *C. subternata* ecology, as a background to practising sustainable harvesting (Cowling *et al.,* 1996; Du Toit *et al.,* 1998; Joubert *et al.,* 2011; Jones, 2004; McGregor, 2017c; Vlok & Schutte, 2010); are as follows:

- flowering;
- resprouting and seeding;
- phenology;
- fire.

The key points to understanding the honeybush industry as a whole, which were discussed in Chapters 2, 3 and 4, are as follows:

- the physical environment for growth (highs, lows and variability in growth);
- harvesters' knowledge and the measurements of harvestable plants (suitable stem size, colour, tools, number of branches harvested and harvesting interval);
- insights and useful comments from stakeholders, not only in the harvesting process but also the location and sustainable practices for the plants.

METHODS

OBJECTIVE 1:

Objective 1 was achieved through the following process:

A review of selected guideline-type documents and a summary of relevant developing guidelines were used. The guidelines created for *C. intermedia* (McGregor, 2017c) were used as the basis of this objective in conjunction with the knowledge gained from this research.

A review and summary of what is known about fynbos and *cyclopia* ecology as a background to understanding what is considered "best practices" were conducted. Of particular relevance were harvesting and growth guides from other fynbos industries: rooibos, the wildflower industry and buchu. These industries are directly comparable with the honeybush industry due to similar concerns about harvesting methods, intervals, fire regimens, growth conditions, and the fact that these plants all occur in the Cape Floristic Region.

Objective 2:

This involved extracting all the relevant information from Chapters 2, 3 and 4 on harvesting practices employed by harvesters, namely interval harvest, harvesting percentages, consideration of flowering, seed bank replenishment and general ecological knowledge.

The information was gathered through workshops, interviews and questionnaires and presented in Chapters 3 and 4. These findings were combined with other expert knowledge on harvesting methods and mapping of the resource (Chapter 2) as a reference for sustainable management and to create a set of best practices for harvesting. Based on the above mentioned key points and the information gathered throughout the previous chapters the following guideline document was compiled:

GUIDELINES FOR THE HARVESTING OF *C. SUBTERNATA* (VLEITEE)

C. subternata (vleitee) is widely distributed along the Tsitsikamma, Outeniqua and Langeberg mountain ranges at elevations from 160 to 1000 m, where rainfall is high. It is found in dense patches along drainage lines, in kloofs and around freshwater seeps where conditions are cool and moist. The species has a predicted range of 4 541.9 km^2.

Figure 5-1 Diagram of a typical *C. subternata* plant

The plant is identified when it is in flower by its bright yellow sweet-smelling flowers. It normally has a single main stem with smaller side branches. The leaves are small, leathery and green with a grey-blue colour on the backside (illustrated in Figure 5-1).

C. subternata (vleitee) ecology and the role of fire

C. subternata (vleitee) is a pioneer plant. It establishes soon after a fire and grows quickly in tall, dense stands of plants. The plants have a single thick stem or trunk with several side branches. *C. subternata* (vleitee) is described as a reseeder: the adult plants produce many flowers (Figure 5-2), and therefore, many seeds to ensure that there are plenty of seeds stored in the soil, which germinate when conditions are right. When a fire passes through, the adult plants are killed. The heat of the fire cracks the hard seed coats of the buried seeds, which then germinate provided there is enough rainfall. The seedlings that survive then grow into young plants. Because *C. subternata* (vleitee) relies totally on seeds for replacement after fire, enough plants must remain unharvested so that they can flower and make plenty of seed. In the wild, plants flower from around July to September and they produce flowers in the first year of growth.

Figure 5-2 *C. subternata* vleitee) in abundant flower, showing typical small tree form (Van der Walt, 2018)

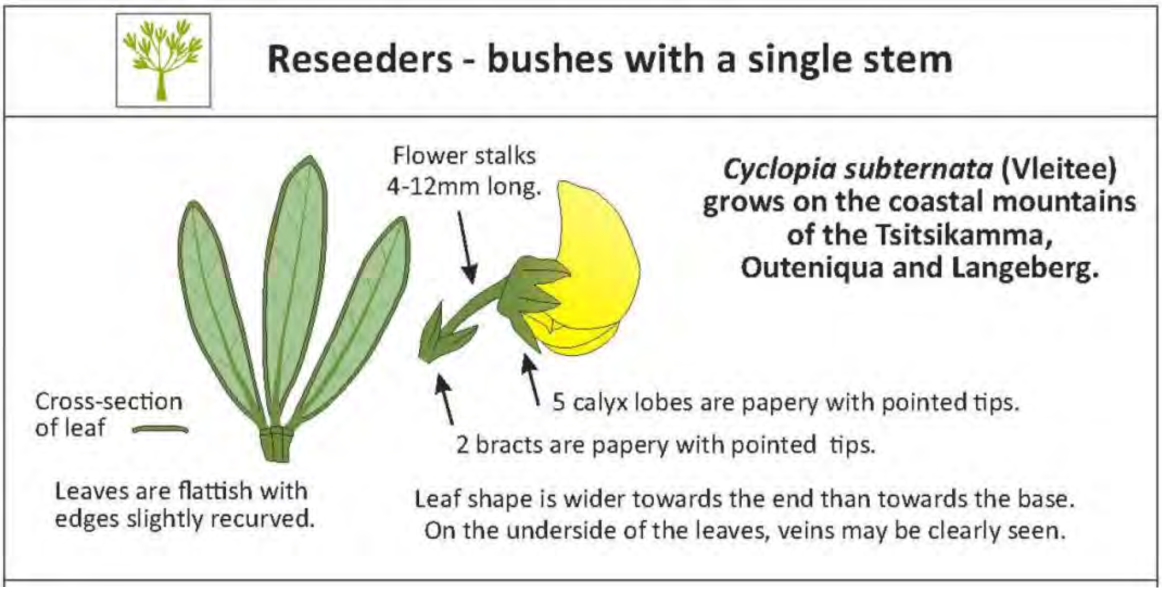


Figure 5-3 Characteristic features of *C. subternata* (vleitee) leaves and flowers (adapted from Schutte, 1995)

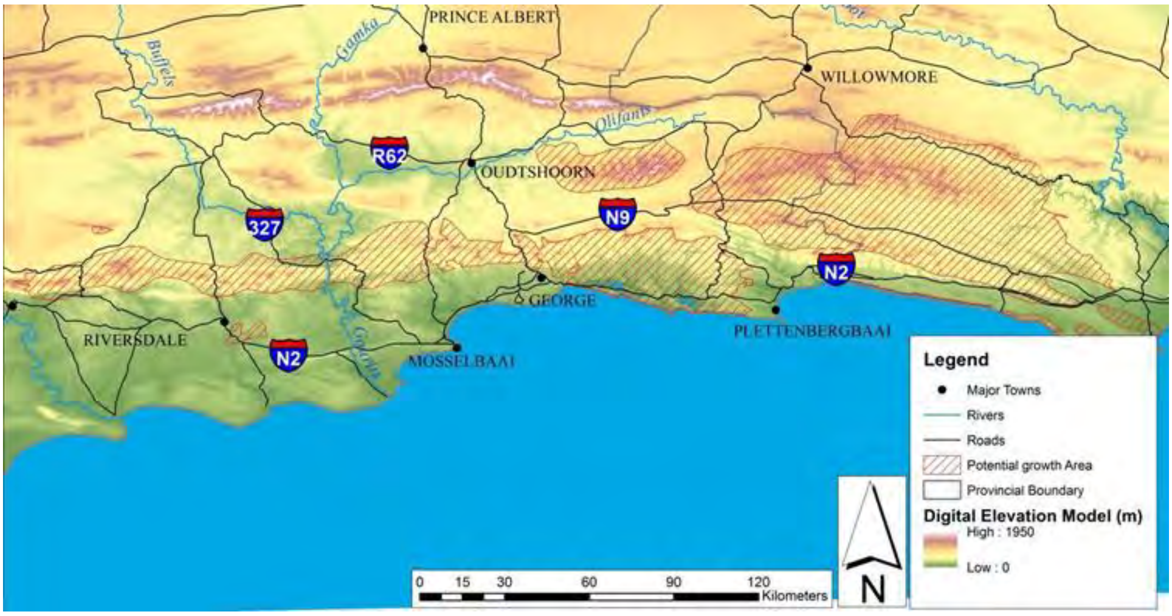


Figure 5-4 Distribution of *C. subternata* (vleitee) in its endemic range on the boarder of the Western and Eastern Cape.

A sustainable harvesting approach for C. subternata (vleitee)

C. subternata (vleitee) is a high-yielding honeybush plant, which may grow in very dense stands of many thousands of plants. Harvested *C. subternata* (vleitee) plants look like small trees with a single stem or trunk bearing long leafy branches, which produce many flowers (Figure 5-2) and seeds (Figure 5-5).

A sustainable harvesting approach should include a management plan with maps of the *C. subternata* (vleitee) patches on a farm showing approximate area and densities. Harvest areas should be managed according to a two-year cycle of harvesting such that a site is harvested one year and then rested for 18 to 24 months.

Best Practice in the field for C. subternata (vleitee) *harvesting*

Figure 5-5 Ripe *C. subternata* (vleitee) seed pods (McGregor, 2017)

Harvesting of *C. subternata* (vleitee) should be seen as “pruning” because great care must be taken to select and cut only some of the branches on a plant to avoid killing the plant.

Cropping the plants

Taller plants with many branches may be pruned:

- The number of branches which may be cut varies according to the health of the plant, the size of the other branches and the height of the plant.
- Pruning up to 50% of the branches on a plant is acceptable if the stems and leaves are in good health, thus leaving 50% of the plant uncut.
- Upper branches should be cut above regions of new growth to allow regeneration after harvest.
- The main trunk of the plant must be left intact.

Flowers and seeds

In every population, some plants must be left uncut so that they can form buds, flowers and set seed.

When NOT to harvest

Small young plants less than two years old (post-fire) and those with long single stems without branches should not be harvested. Preferably, they should not be harvested when in flower.

Environmental conditions

At each site, the landowner or harvesters will have local knowledge of environmental conditions. They are the best people to judge the state of the environment in terms of recent weather, drought, fire and will need to adapt their harvesting plan according to that wisdom.

Harvest tools

The best harvesting tool is secateurs, which should be kept sharp and clean for best cutting.

Experienced harvesters who know which plants to select and which branches to cut are key to the sustainable harvesting of *C. subternata* (vleitee). It is important that they mentor and teach new harvesters best practice harvesting.

Threats

There are many areas where *C. subternata* (vleitee) is harvested illegally. The occurrence of *C. subternata* (vleitee) plants in the low-lying areas of the Tsitsikamma and Outeniqua means that they are more accessible than bergtee plants, which grow in the mountains. Also, the many service roads in lower regions make *C. subternata* (vleitee) vulnerable to illegal harvesting. It is particularly vulnerable to untrained or inexperienced harvesters who may kill plants through poor selection of plants and incorrect pruning methods.

Respect for the veld

The following precautions must be taken at all honeybush harvest sites:

- All litter should be removed and carried home including water bottles, bundling twine, cigarette wrappers, food wrappers.
- If a cooking fire is made, it should be set in a safe site, preferably a rocky site out of the wind, and must be put out completely after use.
- Honeybush seedlings should not be stood on, and damage to other plant species should also be avoided.
- Wire slides should be removed between seasons so that animals are not snared.
- Access roads should be adequately constructed to prevent erosion and visual disturbance.

HARVESTING DECISION TREE

This diagram can be used to help plan whether it is the right time to harvest.

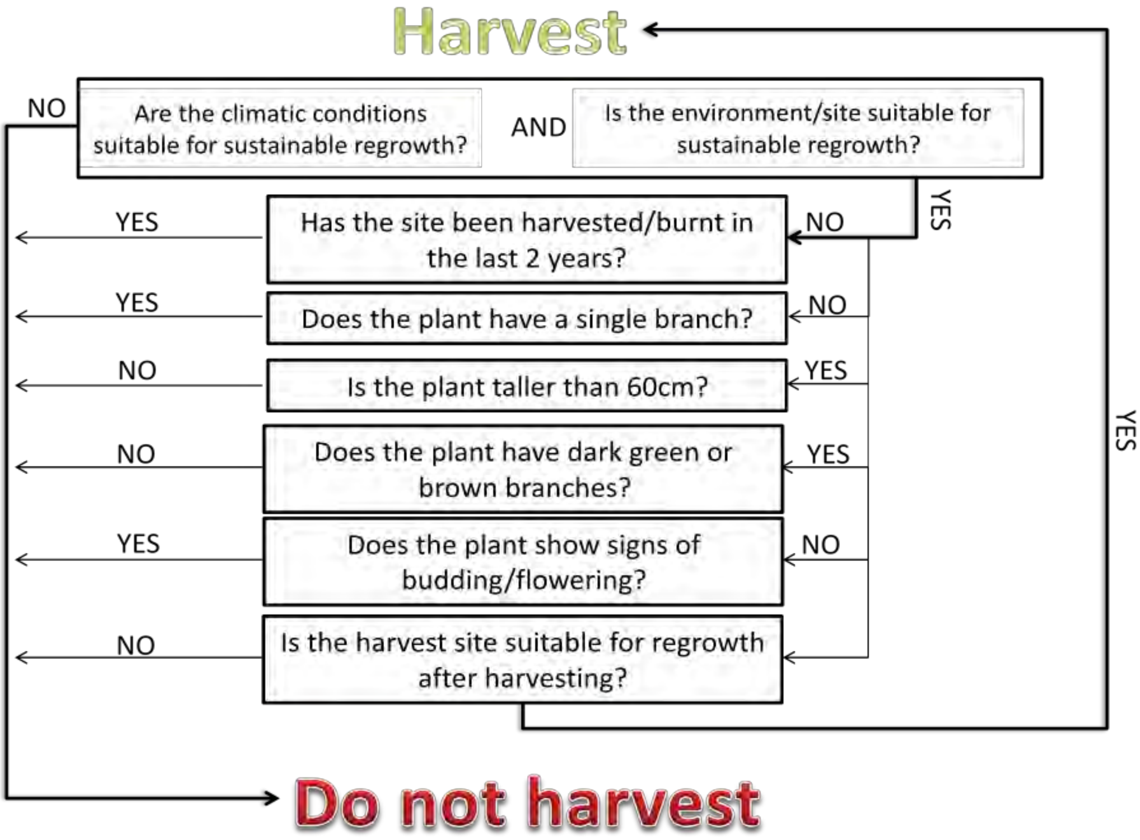


Figure 5-6 Harvesting decision tree

REGULATIONS

Before anyone can handle honeybush plant material, they must first apply for the necessary permits and licences to ensure that they have the documents required to comply with the law. In the Eastern Cape, the basic permit required is for harvest (from EC DEDEAT). In the Western Cape, a permit for transport of honeybush materials is required (CapeNature).

Table 5-1 Regulatory authorities for the harvesting of honeybush

Authority	Contact person	Physical address	Postal address
EC DEDEAT	Gerrie Ferreira Tel: 042 292 0339 gerrie.ferreira@dedea.gov.za	Seekoei River Nature Reserve, Swan Road, 6332, Aston Bay	P.O. Box 1733, 6330 Jeffrey's Bay
WC Cape Nature	Danelle Kleinhans Tel: 021 483 0121 dkleinhans@capenature.co.za	PGWC Shared Services Centre, cor Bosduif & Volstruis Streets, 7764 Bridgetown	Private Bag x29, 7766 Gatesville

CONCLUSION

While the honeybush industry is set to expand in the near future, the need to implement structures for the continued use of the plants is essential to ensure supply to the market. In theory, the economic incentive to do this is high but the potential for biodiversity loss if these plants are not managed well is great (Ticktin, 2004). The use of harvesting practices which will enable the plants to not only regrow after a harvest event, but thrive, is essential. Ensuring that harvesters implement a best practice harvesting process (see Figure 5-6) and develop understanding of the environment in which these plants grow will be the key to ensuring the long-term survival of the wild honeybush harvesting industry (Joubert *et al.,* 2017; McGregor, 2017a).

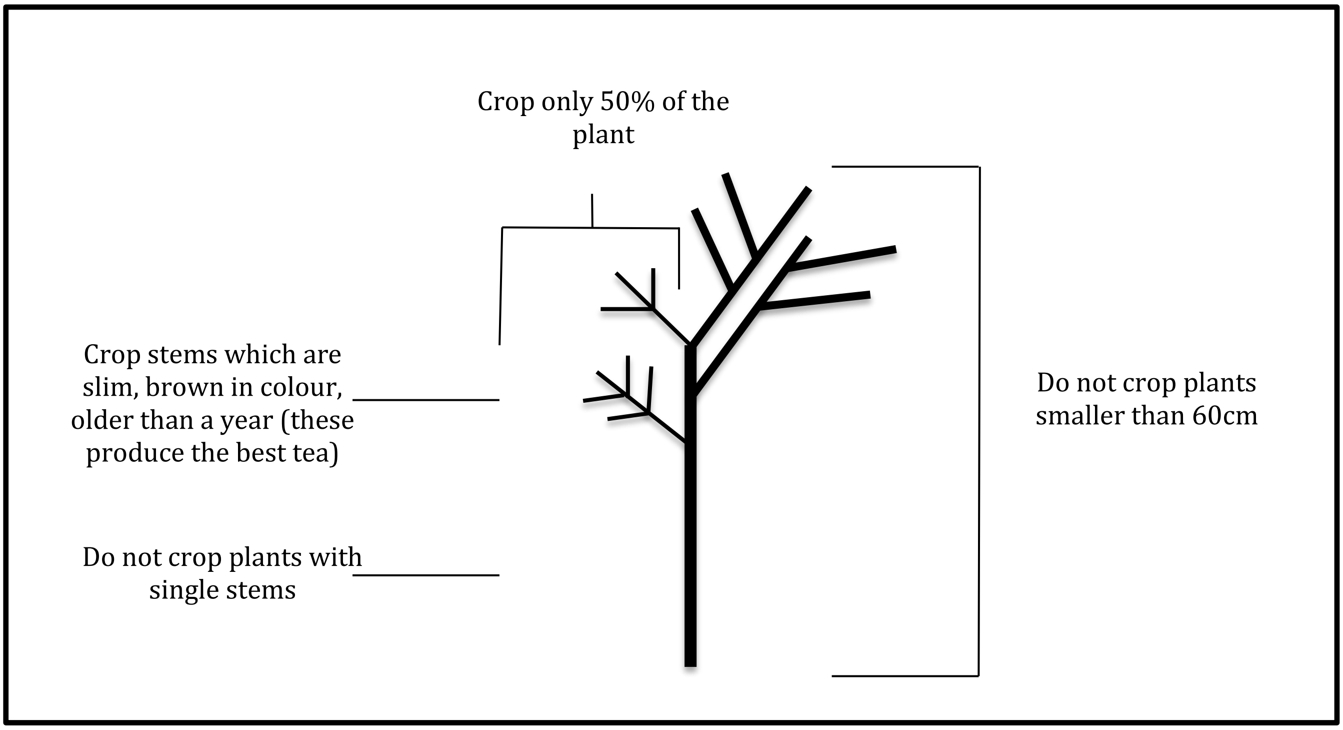


Figure 5-7 Diagram of the harvesting guideline summary

This research achieved all the goals set out at the beginning of the dissertation. A map-based inventory of the *C. subternata* resource was created and this inventory is the most comprehensive map created to date for the species. The mapping exercise was reinforced by field mapping of sites, which showed the distribution extent of the population across the population range of *C. subternata.* The case study conducted on the MTO lands was carried out as a trial resource survey of honeybush plants in the Lottering and Witelsbos plantation sites and the researcher engaged with harvesters to ensure that proper harvesting practices are followed in the future. Lastly, a set of best practices for harvesting or harvesting guidelines was established through combining local ecological knowledge, field survey data and the best available scientific knowledge to create a system which would result in the honeybush market remaining sustainable while providing a formal record of harvester knowledge for future generations.

In this research, mixed methods were used successfully to fully understand the problem at hand, as advocated by Hawthorne (2017). These methods included interviews with harvesters, expert mapping, measuring harvested plant material and reviewing guideline-type documents. By using a variety of research methods, both quantitative and qualitative data could be collected. This was essential because it resulted in a holistic understanding of the research problem, as advised by Creswell (2014). Beaulieu *et al.* (2018) highlight the need to include community partners and to do research which is meaningful to the community. This need was fulfilled in the engaged research, which answered questions relevant to the honeybush community about sustainability and best practices for harvesting.

Figure 5-8 Harvester carrying a load of honeybush tea to the collection point (McGregor, 2017)

The potential for wild harvesting to continue supporting the livelihoods of many local communities is high and will continue to grow as the market does. The honeybush industry must ensure that appropriate management tools, such as these guidelines, are in place to ensure that the desire for short-term economic gains does not overcome the potential for a sustainable wild *C. subternata* industry.

RESEARCH LIMITATION

Limitations which hindered this study were as follows:

Soil methodology was limited due to the limited laboratory facilities which were available to the researcher. Additionally, the low number of sites was not suitable for rigorous statistical analysis. Sites were few due to accessibility, limited time to visit sites and landowners which were not open to researchers on their property.

The GIS data, which was used, was limited in its resolution, was coarse and thus lacked detail. The knowledge of plant locations was limited and could not increase the resolution of the available data. There is a lack of broader botanical knowledge of the *Cyclopia spp.* such as pollination biology and long-term harvesting impact monitoring, which still needs to be explored.

Although harvesters may have practised suitable harvesting techniques while being observed, there may be changes in behaviour when researchers are not present. Additionally, without the implementation of policies in both the Eastern and Western Cape, there will be no standardisation or enforcement of sustainable harvesting techniques on the ground. Lastly, there is a knowledge implementation gap, which needs to be bridged in order for these guidelines to be successful in a real-world setting. This dearth of knowledge is being resolved by Living Lands and their ongoing research into the application of these guidelines (Sephton, 2020).

Figure 5-9 Typical honeybush site with juvenile honeybush plants marked with purple flags (McGregor, 2017)

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APPENDIX:

1) MTO QUESTIONNAIRE

DEVELOPMENT OF THE UNDERSTANDING OF THE WILD HONEYBUSH RESOURCE ON THE MTO LANDS

PARTICIPANT WORKSHEET

The purpose of this worksheet is to record the depth of knowledge from individuals who are a part of the honeybush harvesting process on the MTO lands. Group discussions will be held on topics covered in this worksheet in order to gain even further insight into the harvesting process. This information will be treated confidentially and will be presented anonymously in a report.

<table>
<tr><td colspan="12">**1) Background Information**
a) Have you harvested on MTO lands before?
b) When last did you harvest on the MTO lands?</td></tr>
<tr><td colspan="12">c) How far do you travel to get to the MTO lands?</td></tr>
<tr><td colspan="12">d) Do you harvest honeybush anywhere else except on MTO lands?
If yes, where?</td></tr>
<tr><td colspan="12">e) Where/when/from whom did you learn to harvest honeybush?
f) Which species do you/have you harvested?</td></tr>
<tr><td colspan="3">C. Intermedia</td><td colspan="3">*C. subternata*</td><td colspan="3">C. Maculata</td><td colspan="3">C. Plicata</td></tr>
<tr><td colspan="12">g) How long have you been harvesting (number of years)?</td></tr>
<tr><td colspan="4">h) What is your harvest interval? *(Make a cross in the chosen box.)*</td><td colspan="2">Every year</td><td colspan="2">Every 18 months</td><td colspan="2">Every 3 years</td><td colspan="2">Every 4 years</td></tr>
<tr><td colspan="12">i) Are you a full-time harvester?
If no, what other work do you do?</td></tr>
<tr><td colspan="12">**2) Your Team**
To describe the make-up of your team, please complete the boxes below:</td></tr>
<tr><td colspan="4">How many team members?</td><td colspan="4">How many males?
How many females?</td><td colspan="4">Age of oldest member?
Age of youngest member?</td></tr>
<tr><td colspan="12">a) What is your role in the team? *(Make a cross in the chosen box, or specify.)*</td></tr>
<tr><td colspan="3">Harvester</td><td colspan="3">Team Leader</td><td colspan="3">Transporter</td><td colspan="3">Other. Specify:</td></tr>
<tr><td colspan="12">b) How are you paid? (*Make a cross in the chosen box.)*</td></tr>
<tr><td colspan="6">Weight of harvest</td><td colspan="6">Per day</td></tr>
<tr><td colspan="12">**3) Harvesting Process**
Complete the questions below to help describe a typical harvest day from leaving home in</td></tr>
</table>

the morning to the end of the day when you offload your harvest. a) On average, how many hours per day do you harvest for?
b) On average, how many kg's do you harvest in a day?
4) Plant and Harvesting Knowledge of '*C. subternata* (vleitee)' *In terms of the harvesting of honeybush, complete each question below to your best knowledge and why you say so.* a) What is the best harvestable plant age? Why?
b) What should the height of the plant be to harvest it? Why?
c) What should the colour of the stems be to harvest? Why?
d) What should the diameter of the stems be to harvest? Why?
e) Do you harvest when the plant is in flower?
f) Do you cut the whole plant or only a part and why?
g) Does the growth of the plant get affected by the trees around it?
h) When last did the MTO lands burn?
i) How often do you think '*C. subternata* (vleitee)' should be burnt?
j) How long after a fire do you harvest the plant?
k) What cutting method do you use? *(Make a cross in the chosen box below.)*

Secateurs	Sickle	Why this tool?

l) Are there any other factors that need to be considered when harvesting the plant? Please list them.
5) Experiences as a Harvester a) What are the things you like most about being a harvester?
b) What are some of the problems you face being a harvester?
c) Based on your experiences what are some of the threats and issues you see in the wild harvesting honeybush industry?
d) Do you think that a permitting system for harvesting wild honeybush is a good thing? Yes/No? Why?
6) Linking Experiences to Guidelines a) Based on what you have seen in the industry and what is happening to the plant, what do you think needs to be included in guidelines for harvesting wild honeybush?
b) Do you support having guidelines and a monitoring system in place to ensure the sustainability of honeybush? *(Make a cross in the chosen box below.)*

Yes	No

If you have any additional information you would like to share, please do so…

2) FIELD DATA CAPTURE SHEET (STANDARD MEASURABLE VARIABLES):

Table 5-2 Data capture sheet

Date:	Transect Number:	GPS Start Point	Vegetation Type	GPS Used
GPS Point	Harvested (Stem Diameter mm)	Harvested Stem Length cm)	Harvested (weight g)	Base Diameter (mm)
	1 2 3 4	1 2 3 4		
	Unharvested (Stem Diameter mm)	Unharvested (Stem length cm)		
	1 2 3 4	1 2 3 4		
Comments				

3) BioClim data set used in MAXENT modelling of C. subternata

Table 5-3 BioClim data set used in Maxent modelling

BIO1 = Annual Mean Temperature
BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))
BIO3 = Isothermality (BIO2/BIO7) (* 100)
BIO4 = Temperature Seasonality (standard deviation *100)
BIO5 = Max Temperature of Warmest Month
BIO6 = Min Temperature of Coldest Month
BIO7 = Temperature Annual Range (BIO5-BIO6)
BIO8 = Mean Temperature of Wettest Quarter
BIO9 = Mean Temperature of Driest Quarter
BIO10 = Mean Temperature of Warmest Quarter
BIO11 = Mean Temperature of Coldest Quarter
BIO12 = Annual Precipitation
BIO13 = Precipitation of Wettest Month
BIO14 = Precipitation of Driest Month
BIO15 = Precipitation Seasonality (Coefficient of Variation)
BIO16 = Precipitation of Wettest Quarter
BIO17 = Precipitation of Driest Quarter
BIO18 = Precipitation of Warmest Quarter
BIO19 = Precipitation of Coldest Quarter

4) Farmers and harvesters mapping sheet (along with a site-specific map):

Tasks for Farmers: Mapping the honeybush lands on a farm

Fill in this form to accompany your map. We will capture this information digitally in a Geographic Information System and send you the spatial data (kml files for use in Google Earth) and a table of hectare values for all the honeybush patches on your farm. We will also supply you with a new map in .pdf.

Your name	
Farm name	
Approx ha.	
Approx. ha honeybush	

In order to make your honeybush map, you need to create a legend for the map so that we can understand what you have drawn. Use different colour pens/pencils and patterns to indicate different features. Record what you used in this table.

Feature	Symbol used
Farm boundary	
Honeybush-specific infrastructure, e.g.: loading place, wire slide, etc.	
Patches of honeybush (if you want to note an area of high, medium or low yield, mark the area with an H and M or an L, also note species)	
Problem areas, e.g.: aliens or regular poaching.	

5) *EXPERTS USED TO CREATE SPATIAL DATA SET OF C. SUBTERNATA*

Table 5-4 Names of individuals associated with gathering spatial data for *C. subternata*

Title	Name
Botanists	Mr Nick Galuszynski
	Mr Jan Vlok
Farmers	Mr Sidney Scheepers
	Mr Justin Bramford
	Mr Gerard Botha
Harvesters Manager	Mr Pieter van Rensburg
Extension officer	Mr Sam van der Merwe
Harvesters	Edward Bornado
	William Geogo
	Ilse Kemineth

	Seun Godfree

6) *WORKSHOP ATTENDANCE REGISTER*

Table 5-5 MTO workshop attendance register

	Name	Role	Affiliation
1	Peteon Philander	Harvester	
2	Edward Bornado	Harvester	
3	William Geogo	Harvester	
4	Godfrey Visagie	Plantation Manager	MTO
5	Gamede Lungsi	Harvester	
6	Otto Goliath	Harvester	
7	Gillian McGregor	Researcher	Rhodes University
8	Graham Goliath	Ward Councillor	Clarkson
9	Theo Didiza	Ranger	MTO
10	Curtis Alexander	Ranger	MTO
11	Johannes Champion	Ranger	MTO
12	Greg Wilmens	Eco Tourism	MTO
13	Karen Kirkman	Environmental Consultant	MTO
14	Wouter van der Walt	Researcher	Rhodes University
15	Tom Vos	Research assistant	Rhodes University
16	Gareth Snyman	Research assistant	Rhodes University