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RESOURCE ASSESSMENT FOR ALOE FEROX IN SOUTH AFRICA

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Acknowledgement of the Project Team

Dr Moscow Marumo - Department of Environmental Affairs
Mrs Preshanthie Naicker-Manick - Department of Environmental Affairs
Mrs Lacticia Tshitwamulomoni - Department of Environmental Affairs
Siyanda Samahlubi Consultant (PTY) Ltd - Consultant

FOREWORD

South Africa is the third most megadiverse country in the world, containing nearly 10 % of all known species of birds, fish and plants registered in the world, and 6 % of the mammal and reptile species. The country's biodiversity presents prospects such as the socio-economic benefits for the communities they occur in and because of its importance in the commercial sector as the biodiversity economy, it ultimately contributes to the Gross Domestic Production (GDP) of the Country. The biodiversity economy of South Africa encompasses the business and economic activities that either directly depend on biodiversity for their core business or that contribute to conservation of biodiversity through their activities. It identifies three main sub-sectors which include the wildlife, ecotourism and bioprospecting sub-sectors. The sustainable growth of the biodiversity economy lies in the fact that activities (economic or socio-economic) undertaken within the respective industries of the biodiversity economy needs to conform to the National Environmental Management Biodiversity Act 2004 (Act no. 10 of 2004) (NEMBA). This Act provides for the management and conservation of South African biodiversity; the protection of species and ecosystems that warrant national protection; the sustainable use of indigenous biological resources; and the fair and equitable sharing of benefits arising from bioprospecting involving indigenous biological resources. The Act is supported by other secondary legislation that regulates the utilization of indigenous biological resources which includes the Regulations on: The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES); Threatened or Protected Species (TOPS) and Bioprospecting, Access and Benefit Sharing regulations (BABS).

To ensure the sustainable use of our biodiversity, the Department of Environmental Affairs decided to embark on a study of the most utilised plant species listed in the CITES and TOPS regulations in order to better understand its distribution and its abundance so as safe guard against its over-exploitation and local extinction. To this end, the Department has completed a study on *Aloe ferox* commonly known as Cape Aloe, Bitter Aloe, Red Aloe or Tap Aloe, which is a shallow rooted, succulent plant species that is characterised by its tree-like shape and orange-red to bright scarlet inflorescence and listed in Appendix II of CITES regulations. The aims of the study were to understand and map the current distribution and abundance of *Aloe ferox* in the country; determine its percentage of occurrence in conservation areas; the frequency and quantity of harvesting of the resource; the extent of cultivation and the contribution of cultivated material to the market and lastly to evaluate the sustainability of current utilization and provide recommendations on sustainable off-take quotas for areas of occurrence.

The Report on the study (Resource Assessment for *Aloe ferox* in South Africa) indicates that the plant is distributed throughout the Western Cape, Eastern Cape, Free State and KwaZulu-Natal Provinces and is one of the most frequently used indigenous biological resource in the bioprospecting industry in the country. It further possesses economic benefits for communities where they occur and is likewise utilised commercially in the pharmaceutical and cosmetic industries. *Aloe ferox* products derived include crystals, powders, granules, gels, juices or solids. The bulk of the harvested aloe leaves are exported with very little secondary or tertiary processing in the country. The study showed that the predicted range and observed distribution of the species is extensive. Current harvesting levels do not seem to have impacted negatively on the presence of *Aloe ferox* within its predicted range. However, localised damage to harvested plants and low flowering occurrences in harvested areas were observed. Similarly, areas within the range demonstrate clusters of significant abundance of the species (≥10 plants/km). However there were also large expanses of land in the range which contained no or limited presence of *Aloe ferox*. The key recommendations made in the report are that:

- Current harvesting levels do not seem to have impacted significantly on the presence of *Aloe ferox* within its predicted range. The plants are abundant in certain areas of this range.
- To protect the growth point, the top 16 leaves (top 4 rosettes) of a plant should not be harvested.
- Plants smaller than 70 centimetres or sexually immature plants should not be harvested.
- The leaves collected from a plant (at any one time) should be limited to the SANS recommendation of 8-12 leaves.
- Plants harvesting cycles should be no shorter than 12 months to allow plants to recover and for leaves to reach harvestable lengths (>30cm).
- SANS 369: 2008 recommends that only leaves 30 cm in length collected from plants should be implemented – this will also improve yields from leaves.
- Time of harvesting needs to be a consideration as the harvesting of plants during their flowering season or close to flowering season may negatively impact the re-establishment of populations.

The Department hopes that this study will serve as a guideline for the sustainable utilisation of the *Aloe ferox* through ensuring that it is not over-utilised or over-exploited so as to guard against local extinction, and that this species continues to yield sustainable economic benefits for poor communities where it continues to occur.

Director-General

Department of Environmental Affairs

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I. EXECUTIVE SUMMARY

Aloe ferox is a shallow rooted, long-lived succulent plant species that is characterised by its tree-like shape. The species is indigenous to South Africa, found in the Free State, KwaZulu-Natal, Eastern Cape and Western Cape Provinces of the country. The *Aloe ferox* plant is characterised by a single stem which is clothed in a persistent skirt of dry leaves and can reach heights greater than 2 metres. On the main stem of *Aloe ferox* are rosettes of succulent leaves which form the basis for a thriving *Aloe ferox* industry in South Africa.

Aloe ferox is the most commercially utilized indigenous plant in South Africa, with bitters and aloe gels extracted from the leaves of the plants and utilized in cosmetics, hygiene products and as complimentary medicines. The *Aloe ferox* industry provides significant socio-economic benefits to South African, including benefits to poor individuals who derive an income from harvesting of the plants. The industry also supports a range of businesses in the country, producing *Aloe ferox* products for the local and international market. Large volumes of the species have also been exported since the 1980s.

With the ongoing exploitation of wild populations of *Aloe ferox*, knowledge of the distribution and abundance is vital for the sustainable management of these populations. Department of Environmental Affairs has thus commissioned this study to undertake a resource assessment for *Aloe ferox* in South Africa, with the purpose to:

- Understand and map the current distribution of *Aloe ferox* in the country;
- Determine and map the relative abundance of *Aloe ferox* in the area of occurrence;
- Determine the percentage of occurrence of *Aloe ferox* in conservation areas;
- Determine the frequency and quantity of harvesting of the resource;
- Determine the extent of cultivation and the contribution of cultivated material to the market offering;
- Discuss the sustainability of current utilization; and the local and range-wide significant of current utilization levels on the integrity of plant population; and
- Provide recommendations on sustainable off-take quotas for areas of occurrence.

The resource assessment of *Aloe ferox* adopted a two-fold approach to data collection to address the objectives of the study, firstly, stakeholder interviews with individuals involved in the commercial industry, as well as with individuals involved in the in-field harvesting of plants and secondly, field assessment of *Aloe ferox* sites to determine a suite of parameters such as plant height, leaf content, presence of flowers, number of flower racemes and colour of flowers. The fieldwork was chiefly conducted during or immediately post flowering season.

The distribution of *Aloe ferox* is extensive, covering 4 provinces of the country. The presence of the species was verified for three of the provinces, during this study. Due to the extent of distribution it is impossible to estimate the relative abundance of the species (i.e. plants per metre). These plants are found in clusters at various sites across its range Site selection for the field assessment was thus purposefully, focussed on selecting site where plant data could be collect (i.e. site focussed on those were plants were present).

The study shows that the predicted range and observed distribution of the species is extensive. Current harvesting levels do not seem to have impacted significantly on the presence of *Aloe ferox* within its predicted range. However, localised damage to harvested plants and low flowering occurrences in harvested areas were observed in the study.

Similarly, areas within the range demonstrate 'clusters' of significant abundance of the species, in some cases much greater than the 10 plants/km ^{2} estimated by Parker and Bernard, (2008). However, there were also large expanses of land in the range which contained no or limited presence of *Aloe ferox.*

Based on the fieldwork conducted in this study and from literature the following recommendations are made related to sustainable harvesting of the species:

- To protect the growth point, the top 16 leaves (top 4 rosettes) of a plant should not be harvested.
- Plants smaller than 70 centimetres or sexually immature plants should not be harvested.
- The leaves collected from a plant (at any one time) should be limited to the SANS recommendation of 8-12 leaves.
- Plants harvesting cycles should be no shorter than 12 months to allow plants to recover and for leaves to reach harvestable lengths (>30cm).

- SANS 369: 2008 recommends that only leaves 30 cm in length collected from plants should be implemented – this will also improve yields from leaves.
- Time of harvesting needs to be considered as the harvesting of plants during their flowering season or close to flowering season may negatively impact the reestablishment of populations. Department of Environmental Affairs should consider instituting long-term study sites monitoring of harvested sites to determine whether harvested plants continue to flower or not on an annual basis.

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- Mr Vena — Harvester in Eastern Cape
- Ms Ngqina — Harvester in Eastern Cape
- Mr S Ngqina — Harvester in Eastern Cape
- Harvesters/Tappers — Vetvlei Farm (Little Karoo)
- Harvesters/Tappers — De Tuine Farm (Little Karoo)

1. INTRODUCTION

Aloe ferox is the most commercially utilized indigenous plant in South Africa. Bitters and aloe gels are extracted from the leaves of the plants and utilized largely in cosmetic and hygiene products (Newton and Vaughan, 1996). The medicinal potential of *Aloe ferox* is also widely recognised, with the gel industry associated with the plant having gained momentum since 1994 (O'Brien *et al.,* 2011). Significant socio-economic benefits also accrue from the South African *Aloe ferox* industry, including benefits to poor individuals who derive an income from aloe harvesting and the socio-economic benefits from large pharmaceutical and cosmetic industries. Large volumes of the species have been exported since the 1980s, including consignments of reportedly wild-collected plants, which have raised concerns at the time about the persistence of *Aloe ferox* in the wild (Merlin, 2009).

According to Anon., 2006a *Aloe ferox* is a species which grows in the semi-arid plains and on the rocky mountain slopes of South Africa. This same literature indicates that the current population size *of Aloe ferox* is unclear however indicating that:

- In 1989, the wild population of *Aloe ferox* was estimated to be distributed over an area of more than 10 000 km^2 (Donaldson, 1989).
- Its southern range is from the Swellendam district in the Western Cape Province, a province that the population of *Aloe ferox* is not believed to have declined in the last ten years and is still very common and therefore specifically not listed as a protected species (Pers.comm., D. Hignett)
- It covers the Eastern Cape Province, where it is reported to be a very common species that is not threatened.
- The northern range is into southern KwaZulu-Natal where the species is considered to have very large population's sizes and not threatened.
- Although not endemic in South Africa, *Aloe ferox* is found in the Eastern Cape, Free State, and KwaZulu Natal – from Swellendam in the south to southern KZN in the north and inland to Lesotho and the southern Free State (Rainmondo et al., 2012).
- *Aloe ferox* occurs in a wide variety of habitats ranging from easily accessible valleys to inaccessible mountain ridges, which ensures the survival of the species in the wild even if agricultural development has decreased its range on arable lands (Newton and Vaughan, 1996).
- *Aloe ferox* is common throughout its range in South Africa (Grace, 2011)

Since most of the material used in commercial *Aloe ferox* products is wild-harvested and the utilization of the species has increased significantly in recent years, there are concerns that increasing demands will threaten the sustainability of the resource (Grace, 2011). However, as Shackleton and Gambiza (2007) indicate, *there is very little ecological information on the species and thus no estimates of abundance over different climatic zones and habitats, growth rates or sustainable harvests.*

With the ongoing exploitation of wild populations of *Aloe ferox*, knowledge of the distribution and abundance is vital for the sustainable management and conservation of these populations (Cousins, 2013). However, the implementation of a sustainable harvesting regime for wild populations of *Aloe ferox* is somewhat hampered by the un-reconciled abundance and distribution of the species and the limited ecological information on estimates of abundance over different climatic zones and habitats.

1.1. Background

Due to these gaps in current knowledge of *Aloe ferox* and the growing demand on the resource, the Department of Environmental Affairs has indicated a need to determine the current distribution and abundance, including conservation areas, of this species. Taking these concerns into consideration, Department of Environmental Affairs has commissioned this study to undertake a resource assessment for *Aloe ferox* in South Africa, with the purpose to:

- Understand and map the current distribution of *Aloe ferox* in the country;
- Determine and map the relative abundance of *Aloe ferox* in the area of occurrence;
- Determine the percentage of occurrence of *Aloe ferox* in conservation areas;
- Determine the frequency and quantity of harvesting of the resource;
- Determine the extent of cultivation and the contribution of cultivated material to the market offering;
- Discuss the sustainability of current utilization; and the local and range-wide significant of current utilization levels on the integrity of plant population; and
- Provide recommendations on sustainable off-take quotas for areas of occurrence.

The resource assessment of *Aloe ferox* adopted a two-fold approach to data collection to address the objectives of the study.

- Firstly, stakeholder interviews were conducted with individuals involved in the industry, as well as individuals involved in the harvesting of plants in the field. Interviews took the form of semi-structured interviews, based on a suite of questions shown in Appendix 1.
- Secondly, field assessment of *Aloe ferox* sites was conducted to determine a suite of parameters (see Appendix 2). Site selection was important to the study, as sites within the range of *Aloe ferox* were selected based on the presence of the plants i.e. sites which did not include *Aloe ferox* were not selected. Both harvested and un-harvested sites were selected in the range.

It is important to note that since the *Aloe ferox* range is enormous, stretching across four provinces of the country, it is impossible to estimate the relative abundance of the species. Sites thus represent those areas where the species is present, and would demonstrate areas where the species is relatively abundant. Plants are found in clusters of abundance at various sites across the range of the species.

1.2. Content and Structure

The report includes the following sections:

- Section 1: introduction and background
- Section 2: an overview of the botanical aspects of the *Aloe ferox* species
- Section 3: historical aspects of the species
- Section 4: distribution of the species in South Africa
- Section 5: relative abundance estimates of the species
- Section 6: wild harvesting practices and activities in South Africa
- Section 7: cultivation activities of the species in the country
- Section 8: traditional use and knowledge of the species
- Section 9: commercial activities related to the species
- Section 10: conservation status of *Aloe ferox*
- Section 11: recommendations of sustainability and sustainable harvesting of the species

1.3. Important Ecological Definitions

The study of the distribution of a plant or animal species is known as **biogeography**. The approach followed in this study is therefore a biogeographical study with a later focus on sustainable utilisation of natural resources. Central to the study are the ecological definitions of distribution, habitat and abundance, which are defined below:

Distribution refers to the manner that a particular biological taxon is spatially arranged. The distribution of a species is often represented by a species range map.

Habitat refers to the ecological or environmental area that is inhabited by a particular species. It is the natural environment in which an organism lives, or the physical environment that surrounds a species population.

Abundance is an ecological concept referring to the relative representation of a species in a particular ecosystem. It is usually measured as the number of individuals found per sample. How species abundances are distributed within an ecosystem is referred to as relative species abundance.

2. BOTANICAL SPECIES DESCRIPTION

2.1. Taxonomy and Nomenclature

Aloes are succulent plants originating in southern and eastern Africa and Madagascar (Knapp, 2006). The genus name *Aloe* is derived from the Arabic word alloeh, which translates to 'a shiny bitter substance' in reference to the exudate (Dagne *et al.,* 2000). It is estimated that there are over 500 species of Aloe that are distributed throughout Africa (Grace *et al.,* 2013).

Aloes are well represented in southern Africa and especially South Africa, where they form an important component of the local taxonomy, ethnomedicinal economy and horticultural flora (Smith *et al.,* 2000). 'Ferox', meaning ferocious, in the botanical name of *Aloe ferox*, was given to the species due to the thorny sharp reddish spines of the leaves (Chen *et al*., 2012).

Aloe ferox species is part of the family Xanthorrhoeaceae (formerly Asphodelaceae), a diverse family of plants with few characteristics uniting the subfamilies. Characteristics, which do unite the subfamilies of Xanthorrhoeaceae, are the presence of anthraquinones (a yellow highly crystalline solid) in the plants and the presence of flowers typically borne on leafless stalks that arise from a basal rosette of leaves.

Aloe ferox was previously known as *Aloe candelabrum* (Aubrey, 2001), which has sometimes been considered a geographical variant of *Aloe ferox* (Viljoen, 2008), and was more recently considered to be a conspecific[1] (Carter *et al.,* 2011). The species was reported to form various natural hybrids with other Aloe species (Jeppe, 1969). According to Lange (1999) and Glen and Hardy (2000), several common names exist and these are included in the Table 1 below.

[1] Being the same biological species as another.

Table 1: Scientific classification of *Aloe ferox*

Attribute	Taxonomy
Kingdom	Plantae
Clade	Angiosperms
Clade	Monocots
Class	Equisetopsida
Subclass	Magnoliidae
Superorder	Lilianae
Order	Asparagales
Family	Xanthorrhoeaceae
Sub-family	Asphodeloideae
Genus	Aloe
Binomial name	*Aloe ferox* (Mill.)
Synonyms	*Aloe candelabrum, Aloe ferox erythrocarpa, Aloe ferox galpinii, Aloe ferox hanburyi, Aloe ferox incurva, Aloe ferox subferox, Aloe galpinii, Aloe muricata, Aloe perfoliata, Aloe perfoliata epsilon, Aloe perfoliata ferox, Aloe perfoliata gamma, Aloe perfoliata zeta, Aloe pseudoferox, Aloe socotorina, Aloe subferox, Aloe supralaevis*
Common names	*Aloe capensis (Latin; (l), Aloe lucida, Aloe(l) Bitter Aloe (English;(e), Cultivated Aloe (e), Lucid Aloes (e), Tap Aloe (e), Uganda Aloes (e), Aloes du Cap (French; (f), Aalwyn (a), Bergaalwee (Afrikaans (a), Bergaalwyn (a), Bitteraalwyn (a), Kanniedood (a), Kraalalwee (a), Kraalalwyn (a), Mak-aalwyn (a), Makalwee (a), Opregte Aalwyn (a), Regte Aalwee (a), Regte Aalwyn (a), Swellendam-aalwyn (a), Swellendamsaalwee (a), Tapaalwyn (a), Tap-aalwyn (a), Tapalwee (a), Tapalwyn (a), Umhlaba (Zulu (z), Ikhala (Xhosa (x), Umhlaba (x), Hlaba (seSothoi (ss), Lekhala La Quthing (ss)*

2.2. Biological Characteristics

Aloe ferox is a shallow rooted, long-lived succulent plant species that is characterised by its tree-like shape (Figure 1). Literature indicates that plants reach a height of 2-3 metres, although field surveys demonstrated plants of greater height (Knapp, 2006; van Wyk and Smith, 1996). The plants rarely branch from above the base, with the stems characteristically clothed in a persistent skirt of dry leaves that insulate the stem in the case of bush fires (van Wyk and Smith, 1996). Individual specimens have an estimated life span of 150 years (Newton and Vaughan, 1996).

(a)  (b) 

Figure 1: (a) *Aloe ferox* in the Eastern Cape, and (b) in KwaZulu Natal (pictures taken from this assignment)

At the apex of the main stem of *Aloe ferox* is a rosette of succulent leaves. The leaves have sharp spines along their margins (Figure 2). O' Brien *et al*. (2011) sampled 24 *Aloe ferox* plants from eight populations in South Africa, showing that the mean leaf weight from these plants was 0.65 kg, the mean leaf length nearly 485 mm, the mean leaf width almost 108 mm and the mean leaf thickness just over 16 mm. There was however, large variability in the in leaf characteristics (O'Brien *et al*., 2011).

Figure 2: Serrated edge of the *Aloe ferox* leaf (picture from this assignment)

Aloe ferox produces a single candelabrum-like inflorescence with dense erect spikes of flowers from May –August (Sept – November in colder northern parts of the distribution) (Botha, 1992 in Newton and Vaughan, 1996) (Figure 3). *Aloe ferox* usually produces orange-red to bright scarlet flowers, but some populations are known to produce much paler flowers ranging from lemon yellow to almost pure white (Cloete and Plumstead, 2000).

Figure 3: Flowers of the *Aloe ferox* plant (picture from this assignment)

3. HISTORY OF ALOE FEROX ABUNDANCE AND DISTRIBUTION IN SOUTH AFRICA

3.1. Historical documentation of *Aloe ferox*

The medicinal properties of *Aloe ferox* have been utilised since ancient times. Rock paintings of *Aloe ferox* have been found in a cave on the farm Pieterberg, Genadeberg, near the Orange River, east of Zastron.

According to Reynolds (1969), in his account of *The Aloes of South Africa, Aloe ferox* was first described and figured by Commelin in his *Praeludia botanica*, published in 1703.

This was followed by the records of Dr Andrew Sparrman, who arrived at the Cape in 1772. Sparrmen made a variety of trips in the vicinity of the Cape, collecting plants and documenting his observations of these trips (Reynolds, 1969). In these documents Sparrman records '*the River Goree has its name from the Aloe plant commonly called at the Cape the Goree-bosch…it grew in the greatest abundance in the tract of the country laying around about Muscle-bay, Gauritz and Duyvenhoeks rives'*. Sparrman also gives an account of the preparation of the drug from the sap drained from aloe leaves. Reynolds attributes this Goree-bosch aloe to be *Aloe ferox.*

The travels of Carl Peter Thunberg, the Swedish naturalist and pupil of Linnaeus, are well known. Thunberg arrived at the Cape in 1772 (Reynolds, 1969). During his visit to the Cape, Thunberg travelled extensively, documenting and collecting species of plants around the Cape. Thunberg observes in his travels to "Zoetmelks Rivier" east of Swellendam that *the aloe-tree (Aloe perfoliata) from the leaves of which the gum aloe distils, grew in greater abundance than I ever observed it to do in any other place"* (Reynolds, 1996). Reynolds (1969) attributes this observation to *Aloe ferox.* Thunberg, in his travels to the Sunday's River, north of Port Elizabeth, in 1773 also refers to *Aloe ferox* as *the whole of this tract produced aloe trees in abundance, which in some places entirely covered the hills and the sides of mountains, where they appeared at a distance like a numerous army. The trees are of the height of a man, with their stems quite bare below, and a crown at the top of broad thick fleshy leaves* (Reynolds, 1969). Thunberg is perhaps the first to record the use of *Aloe ferox* leaves in the production of 'gumma aloe'.

Francis Masson, who was sent to the Cape in 1772 to collect seeds and plants for the Royal Gardens of Kew, indicated in his documents of his travels to the Riversdale District that *the hills are quite*

*smooth and easy of ascent. On the declivities of these low hills grow the aloe Socotorina in large clumps, which when old have stems about five or six feet high, with only a few thick leaves on their tops, that at a distance appear like bans of Hottentots. The peasants make great quantities of the gum aloes from the sap of the leaves, which, they sell at the Cape from two to six pence per pound (*in Reynolds, 1969). Reynolds (1969) suggest that the indication by Masson that the leaves of the plant being limited to the top of the plant shows that the plants have been harvested for the juice. Reynolds also attributes the species which Masson is referring to as *Aloe ferox*, as the species was plentiful in Riversdale at the publishing of his book.

William John Burchell, an English botanist who travelled to South Africa in 1810, collected over 40 000 specimens of plants and made 500 sketches during his travels in the country. One of Burchells sketches is of the Graserburg District in 1811, clearly showing *Aloe ferox* observed by Burchell (in Reynolds, 1969). Similarly, Rev. C.I. Latrobe a missionary to the Cape indicated the hills surrounding the *Bueffelsjagd's Revier* were covered with a profusion of large Aloes – which Reynolds (1969) attributes to *Aloe ferox.* Latrobe in the same year also indicated that in the Mossel Bay area *aloes grow in great abundance on the surrounding hills. Formerly the extract of Aloes used in medicines fetched a price sufficiently high to make it a lucrative trade; but at present since this article has become more common, and the price has fallen, it appears to be not worth the farmer's while to attend to it* (in Reynolds, 1969). There are a number of accounts, by travellers to the Cape, of sighting of *Aloe ferox* in various areas of the Cape Province.

Marloth, in his account of Common Flora Names in 1917 indicates *Aloe* ferox having the common name Alwijn, bitter-aloe, and mentioned the preparation of a 'drug' from the *Aloe ferox*, principally in the Herbertsdale and Mosselbay districts. Marloth is also attributed with providing the first account of the chemical properties of the plant. The properties, uses, doses etc. of *Aloe ferox* are given in the British Pharmaceutical Codex.

Peppe (1847; 1850; 1857) gives a list of indigenous Cape Plants used as remedies in this country, indicates the following for *Aloe ferox – the cape aloes are procured from several species of this extensive genus, so particular to South Africa. The Aloe ferox, Lam., a native of Swellendam, is generally acknowledged to yield the best extract.*

Reynolds (1969) provides an account of the production of "Cape Aloes" from the leaves of *Aloe ferox*, indication that *a skin is spread over hollow on the ground and the leaves are stacked in circular fashion*

with the cut basal end inwards, the spines of the leaves preventing them from slipping. The aloetic juice collected in the skin is transferred to a large tin or pot, and boiled, and after evaporation is complete, it is transferred to a suitable receptacle to cool. When dry and hard it is ready for sale.

3.2. Historical literature on *Aloe ferox* distribution

Literature indicates that *Aloe ferox* is a terrestrial based endemic species to South Africa and Lesotho (Knapp, 2006). This species was found in various biomes such as Albany Thicket, Fynbos, Grassland, Indian Ocean Coastal Belt (Raimondo, 2013), more specifically in the Cape Floristic Region and Succulent Karoo.

Literature shows the species has a wide distribution extending from the Western Cape Province (Swellendam district), through the Eastern Cape Province (including the former 'homelands' Transkei and Ciskei), southern Lesotho into KwaZulu-Natal (Vaughan & Newton, 1996), particularly between the midlands and the coast in the Umkomaas and Umlaas river catchment areas (Figure 4). In a report produced for the CITES Secretariat from the South African CITES Management Authority (PC16 Doc. 10.3), *Aloe ferox* was reported to be "one of the most widely distributed aloe species occurring from the Swellendam area in Western Cape through the dry parts of the western and Eastern Cape Province"; to be very common in the Eastern Cape; to occur in the dry valleys of Southern-Natal in KwaZulu-Natal (where it is not threatened and populations are "very large"); and to be restricted to the Zastron district along the Lesotho border in Free State (where it is locally abundant) (UNEP-WCMC, 2012). The species is estimated to extend across an area of 10 000km^2 (Donaldson , 1989).

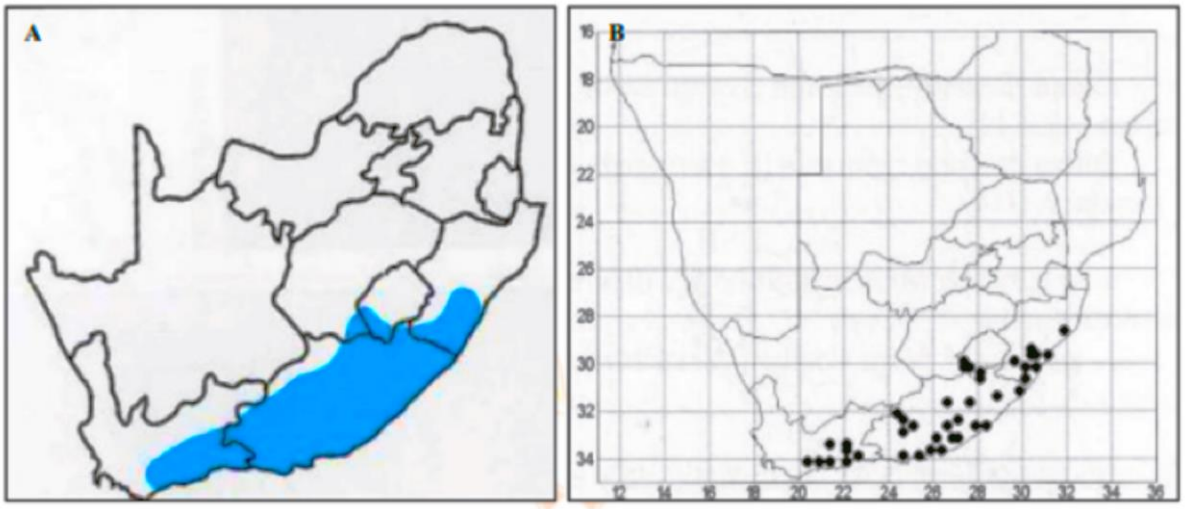


Figure 4: a) Geographical distribution map showing the general distribution of *Aloe ferox* (taken from Van Wyk and Smith (2008); b) a more detailed map from Glen and Hardy (2000).

Distribution map for *Aloe ferox* is also given by Coates Palgrave (2005) (Figure 5), showing similar distribution to those given by Glen and Hardy (2000) and Van Wyk and Smith (2008) (Figure 4).

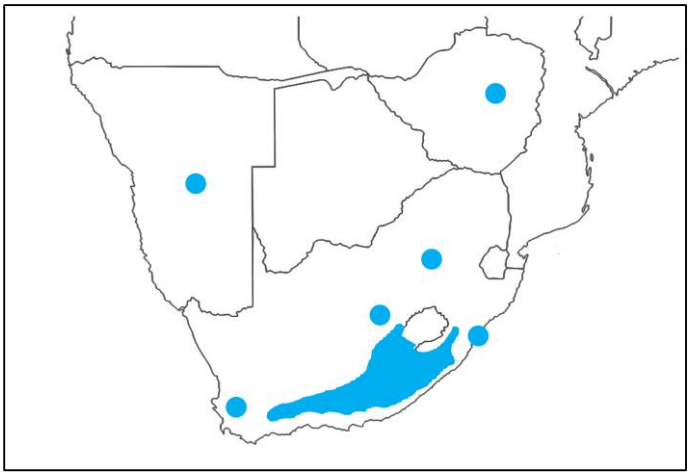


Figure 5: Geographical distribution of *Aloe ferox* (taken from Coates Palgrave (2005)

The literature and respondents indicate that the species in KZN may be *Aloe marlothii*, which is likely to have similar properties to *Aloe ferox.* Observation of some of the plants during this study indicated the presence of other Aloe species in KZN, as well as *Aloe ferox.* These observations support the above that the species were likely to be *Aloe marlothii,* although this was based purely on characteristics of the flowers of the plants.

3.3. Literature on relative abundance

There seems to be some contradictions in the literature related to population abundance of *Aloe ferox*.

Recent literatures show the species as abundant, occurring as large stands in suitable habitats. *Aloe ferox* is believed to have a weed-like ecology and acts as a pioneer species in disturbed vegetation. Land degradation in many areas is suspected to have led to an increase in the population of *Aloe ferox* over the past 30 years, hence the literature shows the population of the species as increasing (Raimondo, 2013). In contrast, some literature shows the *Aloe ferox* population trend as decreasing (Victor and Scott-Shaw, 2006), and Donaldson (2003) stated that it might have declined by up to 30 per cent.

Donaldson (2003) estimated the total population size to be over 100 000 individuals, noting that some populations were isolated, but not severely fragmented. Parker and Bernard, (2008) indicate that South Africa has become synonymous with large stands of *Aloe ferox,* reaching densities of >10 plants/km ^{2}.

Aloe ferox is believed to have a wide distribution over many habitat types where many populations are inaccessible. These populations serve as a gene reservoir against potential species extinction in production areas (Newton and Vaughan, 1996; Golding, 2002).

As a result to the uncertainty as to the abundance of the species, monitoring of the species is limited. Newton and Vaughan (1996) noted a lack of population monitoring, due to the perception that the plant was considered common and not threatened (UNEP-WCMC, 2012).

4. DISTRIBUTION OF ALOE FEROX

Population ecologists endeavour to understand the numerical impact of the interactions between species and their environment by studying population size, distribution and size structure, and how and why these change or stay constant over time (Silvertown, 1987; Rockwood, 2006). Long-term population monitoring data provide a substantial depth of knowledge about plant population dynamics and their implications for conservation and management. Recent studies on the impact of climate change on plant populations demonstrate the importance of longer-term climatic and demographic processes in shaping the patterns currently observed in plant populations (e.g. Foden *et al.,* 2007; Jack, 2012).

Hence, characterisation and interpretation of population size structure, and population size and density over space (biogeography) provides useful data that are readily available for management (Botha *et al.,* 2002) and for planning long-term monitoring.

4.1. Geographical Attributes

Aloe ferox is one of the dominant species in the 'succulent bushland' vegetation in South Africa. It grows in a wide range of climatic conditions, but is abundant on arid, rocky hillsides up to 1000m altitude, where mean temperature ranges from 27-31 ^{0}C and annual rainfall is 50-300 mm (Anjarwalla *et al.,* 2013).

Recent studies reveal that the plant can be grown on a variety of soils, including sandy, loamy sands, and silty loams that are moderately fertile and well drained. Waterlogged, saline and alkaline soils are unsuitable for aloe cultivation (DAFF, 2013). The adventitious root systems that grow only a few centimetres below the soil surface allow aloes to benefit from relatively low amounts of precipitation (Smith and Van Wyk, 2009; Jack, 2012). Waterlogging should be avoided, with *Aloe ferox* thriving in well-drained, rich soils. It withstands light frost, although the flowers may be damaged.

In addition, the species shows a remarkable adaptability in terms of rainfall and flourishes in the extremely dry areas of the Karoo but also in relatively wet parts of the eastern part of the distribution.

4.2. Method for determining the current distribution of *Aloe ferox*

The distribution of *Aloe ferox* was determined using a MAXENT habitat suitability model. The following layers of environmental variables were used, obtained from the South African Atlas of Climatology and Agrohydrology produced by Schulze (2007):

1. **Altitude(m) and relative relief**, which is described as "an index of the variability of the topography of an area, irrespective of whether that area is at a high or low altitude". (Schulze, R.E. and Horan, M.J.C. 2007. Altitude and Relative Relief. In: Schulze, R.E. (Ed). 2007).
2. **Acocks (1988) "Veld types"**, where a veld type is defined as "A unit of vegetation whose range of variation is small enough to permit the whole of it to have the same farming potentialities". A veld type is based on a major indicator species within it, it is a manageable unit at local, regional and national scale, and it is based on the separation of natural variation of vegetation types from variations induced by human influences. Acocks described 70 veld types across South Africa, Lesotho and Swaziland. (Schulze, 2007; Acocks, 1988.)
3. **Mean annual precipitation (mm)**, after Lynch (2004), (Schulze and Lynch, 2007 in Schulze, 2007; Lynch, S.D. 2004)
4. **Köppen Climate Zones,** the Köppen (1931) climate classification system which is based on rainfall magnitudes, rainfall seasonality and rainfall concentration, as well as durations above or below threshold temperatures on a monthly basis, was used by Schulze et al. (2007) to determine climate zones. They identified 12 classes over South Africa. (Schulze et al.,2007 in Schulze 2007; Köppen, W. 1931)
5. **Terrain morphology,** after Kruger (1983). Kruger (1983) divided the terrain morphology according to relief into six broad classes; in addition Schulze and Kruger (2007) subdivided five of those broad classes, and obtained a total of 30 subdivisions which describe the terrains morphological attributes (slope form, relief, drainage density, stream frequency, and percentage area with a slope of < 5 %). (Schulzeand Kruger in Schulze, 2007; Kruger, 1983)
6. **Mean annual temperature, (**Schulze and Maharaj in Schulze, 2007)
7. **Mean number of heavy frost occurrences per annum**, Schulze and Maharaj (2007) designated a minimum temperature of ≤ 0 degrees Celsius in a 50 year daily maximum and minimum temperatures time series as a "heavy frost day". They then obtained the mean number of heavy frost occurrences per year during those 50 years (Schulze and Maharaj in Schulze, 2007)

Presence records of *Aloe ferox* were obtained through the Biodiversity Information Management Directorate of the South African National Biodiversity Institute (SANBI); records that were not considered as natural occurrences were not included in the analyses. In addition, field work was carried out in a few sites to verify presence of the species across the range. Utilising all these variables, a map was generated to predict the probability of *Aloe ferox* in a particular area. In figure 6, the red patches indicates a high probability of suitable conditions for the species, green indicates conditions typical of those where the species is found, and lighter shades of blue indicate low predicted probability of suitable conditions. It can also be interpreted as an estimation of the probability of presence of the species conditioned on the environmental variables included in the model (Phillips and Dudik 2008)

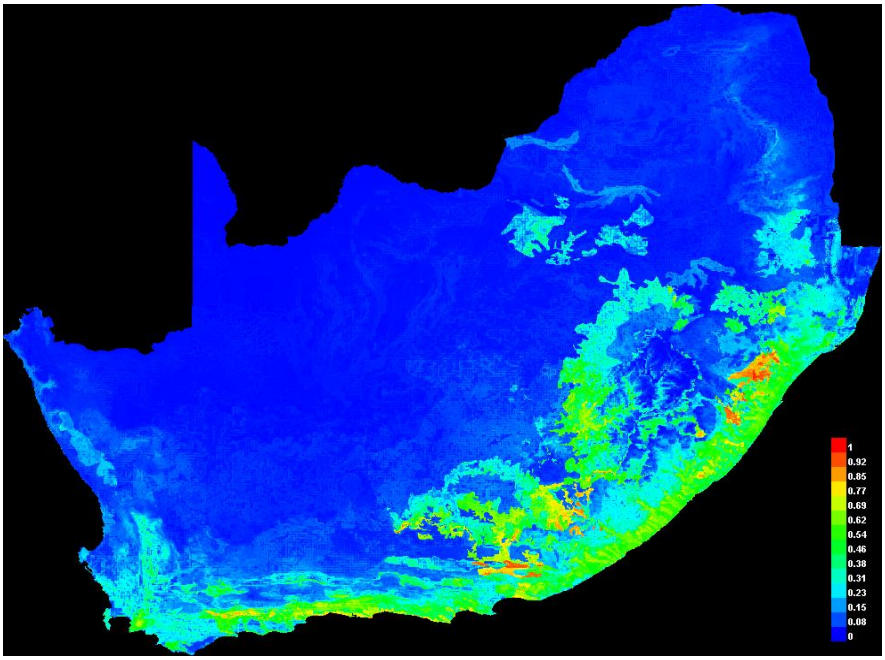


Figure 6: Map showing the predicted probability of the presence of *Aloe ferox* in an area of South Africa.

The cross-validated receiver operating curve (ROC curve) is shown below, as well as the mean area under the curve (AUC) and one standard deviation for the 47 replicates (Figure 7). The mean AUC value is 0.844 and the standard deviation is 0.162, this index provides a value of overall accuracy of the model (Fielding and Bell 1997). The AUC values range between 0.5 to 1.0, an AUC value greater than 0.7 is considered a good fit, while values of 0.9 and over are considered a very good fit (Baldwin 2009; Phillips and Dudik 2008). Figure

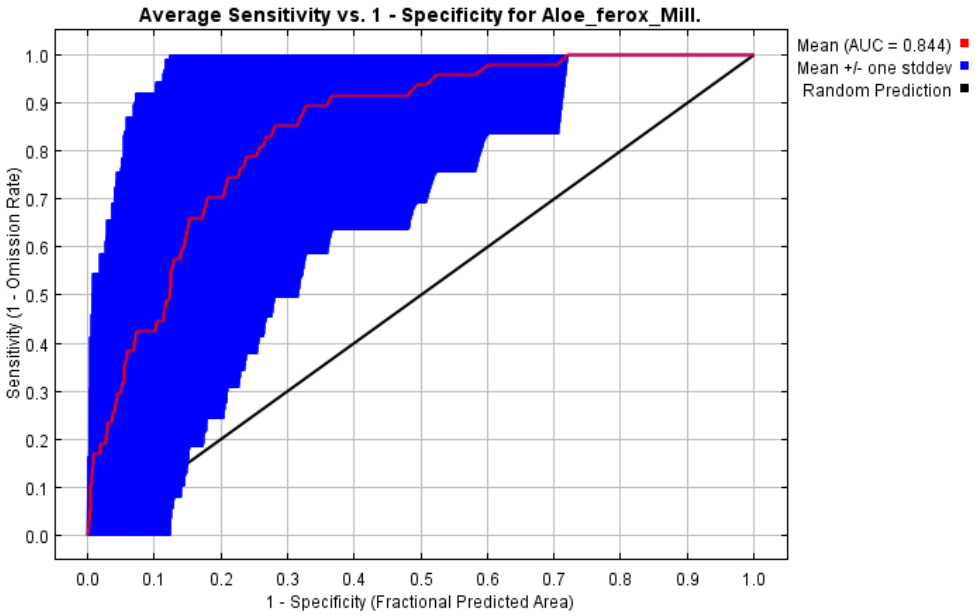


Figure 7: *Aloe ferox* cross-validated receiver operating curve (ROC curve and the mean area under the curve (AUC)

4.3. Current distribution map of *Aloe ferox*

Figure 8 shows the predicted area of *Aloe ferox* in the country. The model estimates that an area of 59126.35 km^2 has a medium to high probability (0.4-1.0) of providing a suitable habitat for the occurrence of *Aloe ferox*. However, a high probably (0.7 to 1.0) of suitability for *Aloe ferox* only covers in areas of 8214.73 km^2. This amounts to only 0, 05 % of South Africa's land area having a medium to high probability of providing a suitable habitat for *Aloe ferox* and an even smaller 0, and 01 % of South Africa's land area providing a highly suitable habitat for *Aloe ferox.*

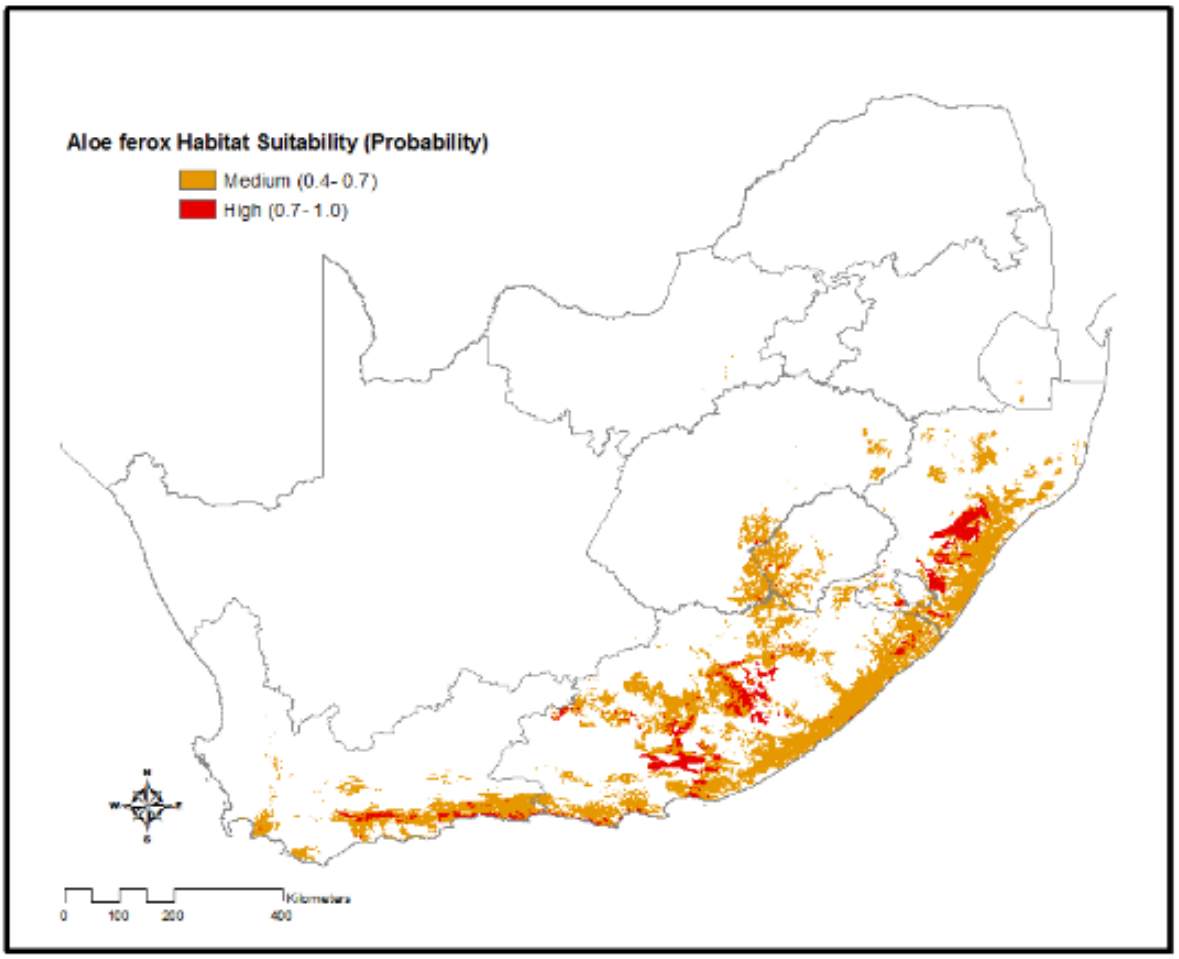


Figure 8: Map of area which displays habitat suitability for *Aloe ferox* - representing the current predicted distribution of *Aloe ferox* in the country.

5. RELATIVE ABUNDANCE OF ALOE FEROX

5.1. Method of estimating abundance

Due to the wide distribution of the *Aloe ferox* species it is impossible to determine abundance of species across the range. However, plant characteristics were determined through a series of sample sites in the Western Cape, Eastern Cape and KwaZulu-Natal. At sample sites, characteristics such as GPS coordinates, plant height, number of intact leaves on the plant, whether the plant was or had flowered, number of rosettes on the plant, whether the plant had been harvested and whether the plant was damage, were collected.

Data were compiled in excel before being analysed using different statistical packages. All data were subjected to Shapiro Wilk's W test to assess normality before testing for variance using ANOVA. When the data were normally distributed, as a posthoc treatment to separate out the means, the Tukey's Honestly Significant Difference (HSD) test was applied. Arcsine transformation for all percentage data were used before ANOVA. In some instances, the Whiskers plot was used as it represents the error of the mean and one-way ANOVA was used to compare means. Factorial analyses were conducted with quantitative data. In all instances, different letters associated with figures and tables represent statistical differences. All tests were conducted at the 95 % confidence level. Statistica version software programme (Statsoft Inc. 2007) was mainly used to infer statistical differences. The PCA-X model with pareto scaling was used as an unsupervised multivariate cluster technique. Inter-relationships of populations from different areas were revealed through PCA groupings using. The PLS-DA was conducted also to infer population relationships amongst the different sites but groupings were similar to those revealed by the PCA. These were conducted using SIMCA.

These data were utilised to provide some of the abundance details below.

5.2. Current estimation of abundance of *Aloe ferox*

One of the easiest observations of the abundance of *Aloe ferox* is that it displays areas of very high abundance (Figure 9a) and areas in close proximity to this with little to no abundance (Figure 9b). The distribution of the species demonstrates this throughout the range (Figure 10).

(a)  (b) 

Figure 9: (a) Area demonstrating high abundance of *Aloe ferox* plants and (b) the same point but in another direction showing relative absence of the species (pictures from this assignment)

It could also be observed that areas of the range still show high abundance of *Aloe ferox*, although these areas are limited to clumps of plants (Figure 10).

(a)  (b) 

(c)  (d) 

Figure 10: *Aloe ferox* at sites in the Eastern Cape (a & b) and KwaZulu-Natal (c & d) (picture from this assignment).

In the wild, *Aloe ferox* seeds typically germinated within three weeks of dispersal, with their viability considerably reduced a year after dispersal (Cousins and Witkowski, 2012). Shackleton and Gambiza (2007) indicated that the growth of the species varies but that the mean height growth, ranged between 1.7 cm per plant per year to 4 and 4.6 cm at various sites under investigation. The mean height increment across all sites and plants was 2.8 ± 0.2 cm. Plant height had a strong effect on annual

increment (r= 0.77; pb0.001) with small plants (6 cm) more than doubling their height in the 12 month period, whereas plants taller than 2 m grew by approximately 1 % over the year. In the same study, the mean number of leaves per plant increased by two per plant per year. Using the above data, Shackleton and Gambiza (2007) estimate that a 1 m plant is approximately 36 years old and the tallest plant in our sample (2.65 m) is approximately 95 years old. The mean plant height at each of the sites in this study are shown in Figure 11, showing that mean height of plants, estimated as the distance from the ground to the highest leaf point on the plant (plants greater than 2 metres, which could not be measure were listed as >2m), shows no significant difference between harvested and un-harvested sites.

(a)

Province	Harvesting Occurring	Site	Mean Plant Height(mm)
EC	Yes	Site 1	770.432 a
EC	Yes	Site 2	1102.533 b
KZN	No	Site 3	735.477 a
WC	No	Site 4	1702.500 c
WC	No	Site 5	1093.571 b
WC	No	Site 6	851.818 ab

(b)

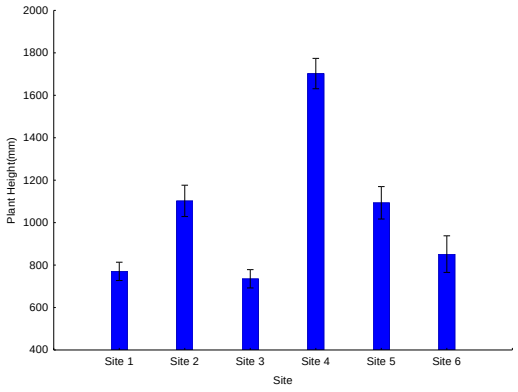


Figure 11: (a) Mean plant height at each site in this study and (b) Bar Graph depicting mean height. The Whiskers represent the error of the mean.

A healthy *Aloe ferox* site should demonstrate a range of plant heights (although it should be noted that age and height are not exclusively linked). In an estimation of plant height at 6 sites in the Eastern Cape and Western Cape of South Africa, various height distributions were found (Figure 12). There is large variation in terms of height regarding different populations of Aloes examined in this study. Aloes are expected to grow to 2-3 m tall and some of the populations had plants which were much shorter. The differences in population height may be linked to the environmental conditions as these plants are distributed in many parts of the country with significantly different geoclimactic conditions. The

population with the tallest number of individuals was found in the Oudsthoorn site where most individuals were 800 to 900 mm tall. Height distribution for most of the populations does not follow statistical normality. Outliers were close to 1700 mm. For all other sites, variation in terms of plant height was highly significant (p=0.00000).

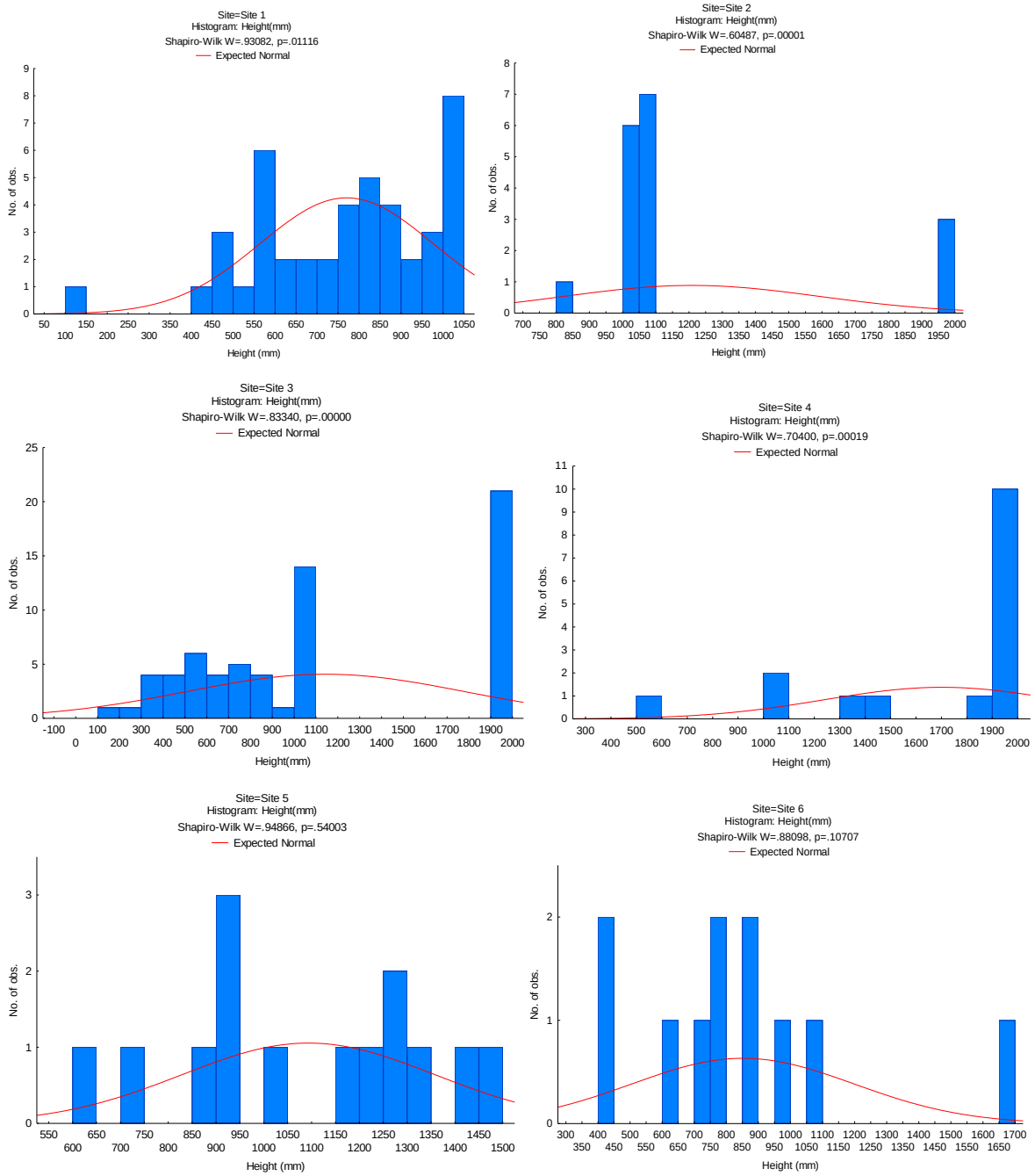


Figure 12: Plant height distribution within the six sites included in this study

Similarly, a healthy population of *Aloe ferox* should show flowering of reproductively mature plants during the flower season. Shackleton and Gambiza (2007) showed that plants flowering increased progressively with plant height. In their study, the smallest plant with flowers was 9.3 cm tall but sexual maturity seems closer to 0.5m. This differs from the 1 m suggested by Newton and Vaughan (1996).

One of the interesting outcomes of this study was that almost none of the plants at the *Aloe ferox* harvesting sites were flowering at the time of the assessment, which was during the flower season of the plants (Figure 13). However, it is unclear whether this is due to the effects of harvesting or whether other attributes such as temperature, rainfall, temperature etc. could have been the limiting factor. This study also showed that the smallest flowering plant was 43 cm. However, the medium height of flowering plants is 1, 46 meters, with flowering shown by a number of the smaller plants (<1m). It should be noted that some harvested plants which had reached a height where they could no longer be harvested, did flower.

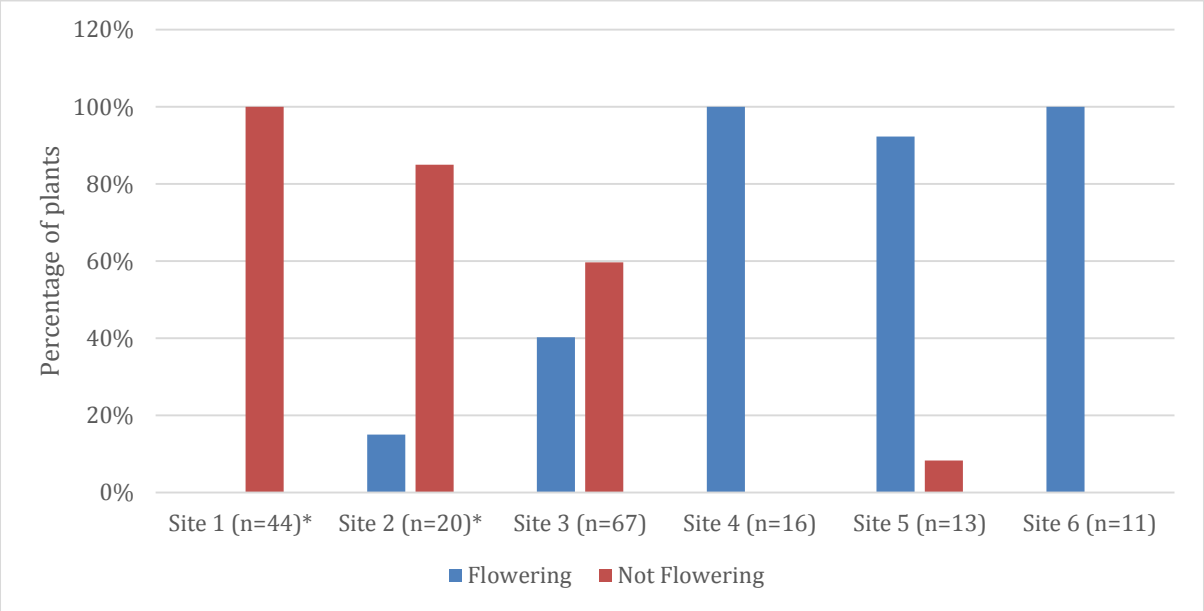


Figure 13: Percentage of plants flowering at each of the sample sites included in this study. Asterisks denote sites where harvesting is occurring.

Aloe populations strongly cluster according to regions with all the Eastern Cape populations grouping together based on harvesting. Interestingly, some of the KwaZulu-Natal plants are closely related in terms of their morphological characters and they appear on the same vector as those from the Eastern Cape (Figure 14). There is a clear separation of populations from the Western Cape from the other

populations and clustering is largely due to their ability to flower and the number of leaves associated with these plants. Although a distinct cluster of the Western Cape population is not resolved in the Principal component analysis (PCA), they are different in terms of the characters measured in this study. Plants in the Western Cape are distinguishable from the other populations as flowering and the number of leaves isolates them into one vector. However, there is no distinct variable which groups them closer to each other within that vector (Figure 14).

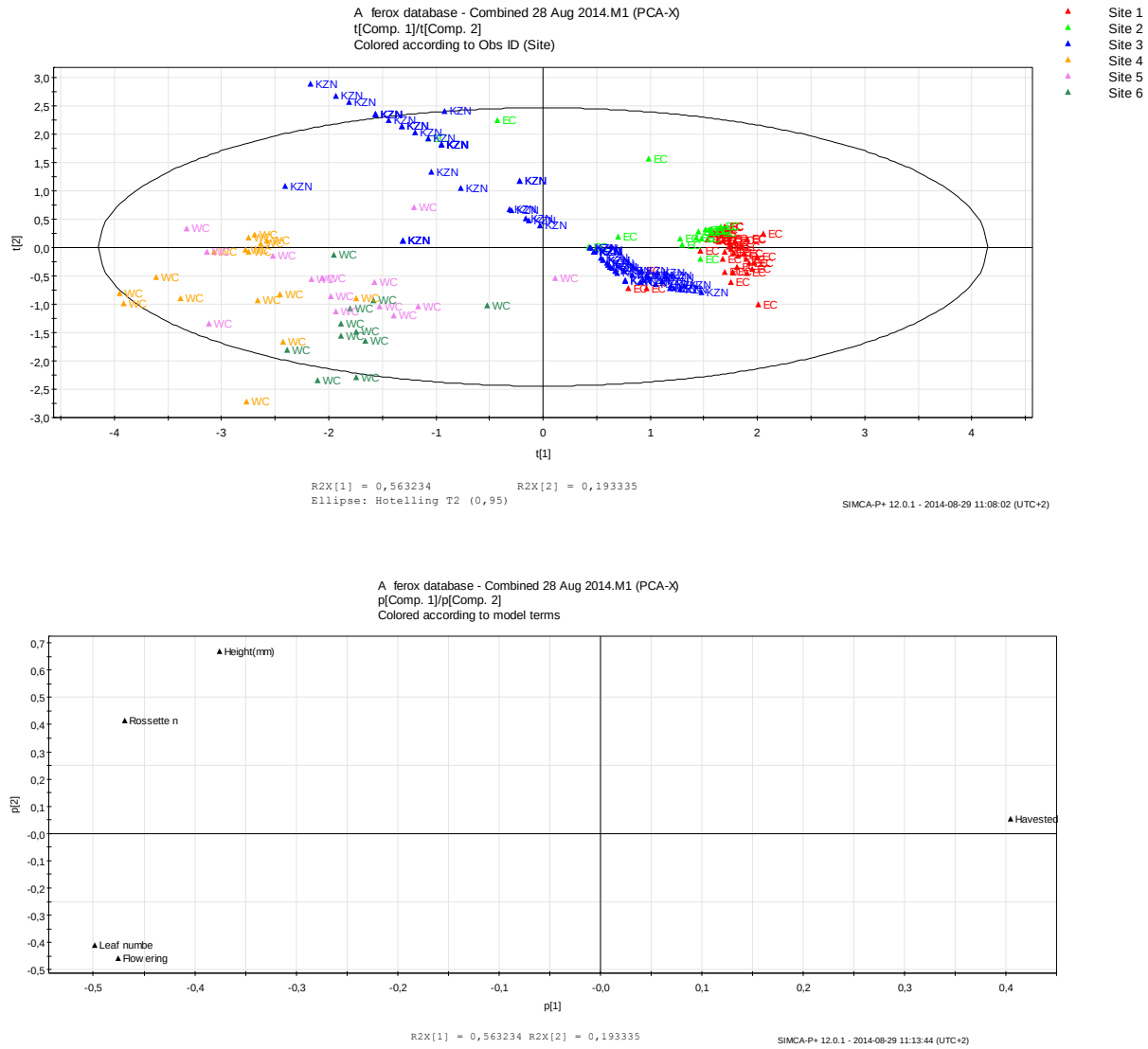


Figure 14: Principal component analysis (PCA) of the various *Aloe ferox* sites.

6. WILD HARVESTING OF ALOE FEROX

Aloe ferox was first exported to Europe in 1761 and today is considered South Africa's main wild-harvested commercially traded species (Grace et al., 2009; Knapp, 2006; Merlin, 2009). It is estimated that 95 % of *Aloe ferox* is wild harvested, with the remainder cultivated.

South Africa currently has no restrictions on the export of *Aloe ferox,* other than those associated with the Convention on International Trade of Endangered Species (CITES). Exports take many forms, of which the main categories according to CITES, are extract, derivatives, plants (dried or live leaves, timber, stems and live plant) and powder (Figure 15). Approximately, an average of 440 tonnes of *Aloe ferox* is either exported directly from South Africa or has its origin in South Africa between 1994 -2012. Of interest is that, of these exports, at least 11 % of exports are those from other countries – with the origin of the *Aloe ferox* being South Africa. This indicates that the *Aloe ferox* market is not limited to exports directly from South Africa but also includes re-exports of *Aloe ferox* from a number of other countries (although the origin of the resource is South Africa).

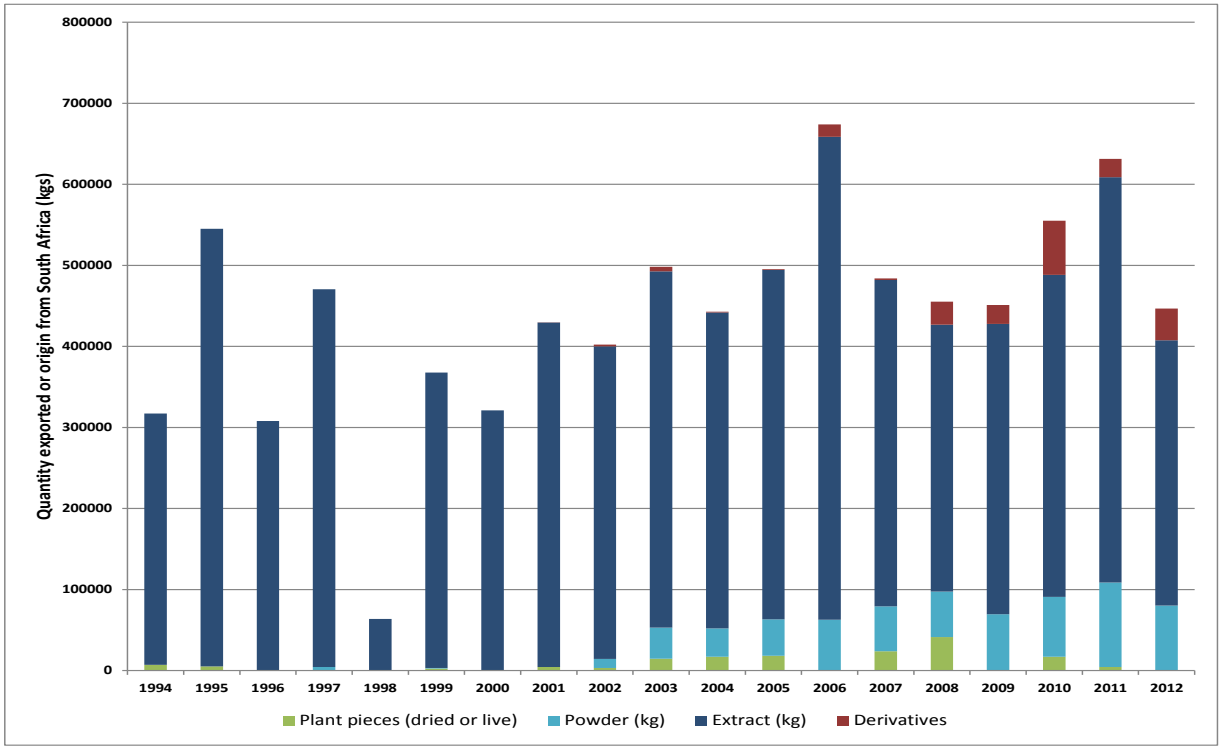


Figure 15: Quantity (kg) of *Aloe ferox* directly exported from South Africa or which originated from South Africa and was exported by another country (data source: CITES)

In the late-90s it was estimated that the industry yields some 400 tonnes of dried leaf exudate per annum from the leaves of around 10 million plants (Newton and Vaughan, 1996), with the worth to small-scale rural harvesters in the region of R12–15 million per year (Shackleton and Gambiza, 2007). The species is used to produce bitters, which had an estimated export value of approximately $1.2 million in 1996 (Dickson, 2008). Apart from its medicinal applications, owing to the gels richness in minerals, amino acids, vitamins, and trace elements, it is extensively used in the cosmetic industry (Drewes *et al.,* 2006).

Despite thousands of commercial products across the globe produced from wild species, typically much harvesting of wild plant resources for commercial purposes is done with little or no knowledge of the sustainable harvesting levels of the resource in question (Peters, 1999; Ticktin, 2004 and Emanuel *et al*., 2005). Indeed, the lack of a basic understanding of the ecology of the harvested species, and the absence of production and yield data is one of the greatest challenges to the development of viable and sustainable enterprises (Neumann and Hirsch, 2000, Cunningham, 2001; Shaanker *et al.,* 2004).

According to the literature the *Aloe ferox* leaf exudate, crystal and gel from the two main harvesting areas of South Africa, namely the Eastern and Western Cape, are distinguished by their aloin content. The Western Cape aloe bitters, known as the Mossel Bay Aloe, is characterised by a high aloin content (18-25 %), while the Eastern Cape aloe bitters, called Port Elizabeth or Cape aloe, is characterised by low aloin content (10-18 %) (Merlin, 2009).

Interestingly the *Aloe ferox* sector is very aware of the distinction in aloin content of the two sources of *Aloe ferox,* indicating that there is high value of collecting, purchase and sale of ‘Cape Aloe’ or ‘Mossel Bay Aloe’. This is mainly due to the Mossel Bay being in demand due to the higher aloin content of the leaf exudate. Sales of *Aloe ferox* gel are driven by the German market which demands aloin content of 18 % or more. Harvest seasons play a critical role in the quantity of extractable aloin (Zapata *et al*., 2013) together with growth stages.

Indications are that *Aloe ferox* south of the Steytlerville/Willowmore area of the province have this higher aloin content. It must be emphasised that the mode of action of extracts of Aloe is not fully elucidated and in fact is poorly understood.

Current studies have included the polysaccharide metabolomics of Aloe genus as they are useful diagnostic tools in differentiating between species (Grace *et al*., 2013) and this may be particularly useful when plants are not in flower. The use of phylogenetic approaches is also important in distinguishing species from each other and these approaches may become essential for the natural products sector in the future. In some of the areas, related species are distributed in close proximity to each other and harvesters may therefore not be able to discriminate species based on leaf morphology alone, especially when plants are not in their flowering season. The use of other diagnostic features then becomes essential.

6.1. Location of *Aloe ferox* harvesting

With the growing interest in the commercial use of *Aloe ferox* it is important that harvesting programmes are based on an adequate understanding of the ecology and productivity of the species, which will underpin estimates of possible sustainable yields (Shackleton and Gambiza, 2007).

Literature indicates that significant harvesting occurs in the Western Cape, throughout communal areas of the Eastern Cape as well as in some areas of the former Transkei region. Merlin (2009) also indicated that the harvest regime in the Eastern and Western Cape significantly differ, in that the Western Cape plants are harvested on private lands, while the Eastern Cape plants are harvested on the communal lands (Figure 16).

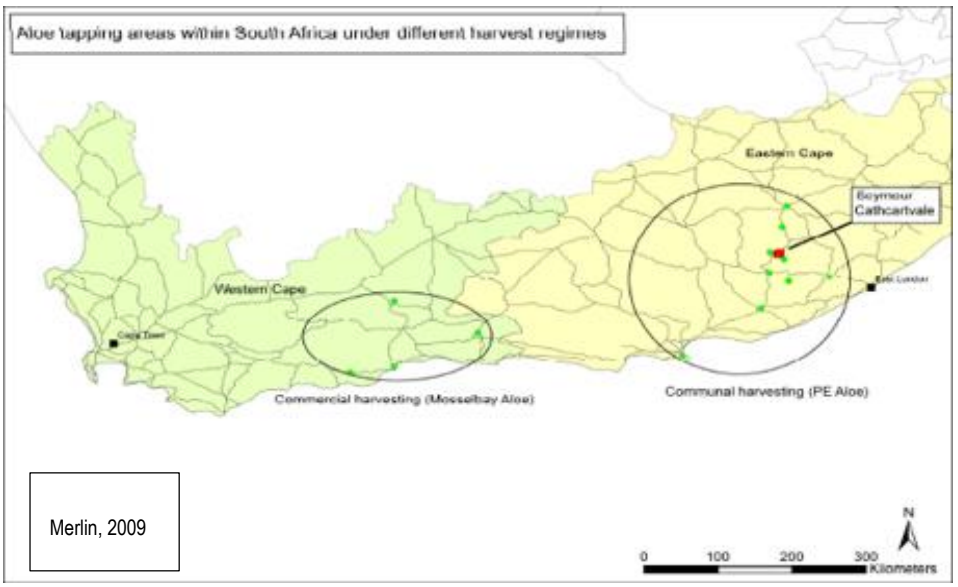


Figure 16: Harvesting regimes in South Africa

The current study correlated with data found in the literature, confirming that *Aloe ferox* harvesting occurs over a large area of the Eastern and Western Cape (Table 2). There has been some anecdotal evidence of harvesting occurring near Eshowe in KwaZulu-Natal and in North West but this is likely to be a different species as these harvesting points fall outside of the recorded range of the species.

Table 2: Areas highlighted as harvesting areas by interviewees included in this study.

Province	Harvesting Locations	Province	Harvesting Locations
Eastern Cape	Alicedale Bighra Bolotwa Breakfast Vlei Cofimvaba Cookhouse Crossroads Fort Beaufort Area Graaf Reinet Idutywa/Mbashe Ingobo Jansenville Kirkwood Klipplaat Mvezo Ndlambe Peddie Qunu Seymour Somerset Area Steytlerville	**Western Cape**	Albertinia Mosselbay Riversdale Herbertsdale Uniondale

Participants in this study also concurred with the literature on the land tenure issues related to wild harvesting of *Aloe ferox.* Wild harvesting of *Aloe ferox* in the Eastern Cape occurs largely on communal land, with an agreement from the Chief.

The institutional structure of this harvesting structure takes many forms, two of which is shown below. Figure 17 shows the model where the resource on the communal land is seen as a common resource and thus is in the trusteeship of the chief. The benefit sharing agreement is signed with the chief, who selects supervisors to manage the harvesters of the resource in an area. The exporter however, pays the harvesters directly. In this model the exporter will either purchase the aloe gel and 'cook' the product themselves to reduce water content to 6 % before exporting. Alternatively, the harvesters will 'cook' the exudate in-field and sell 20-25 litre containers of the aloe solid to the exporter.

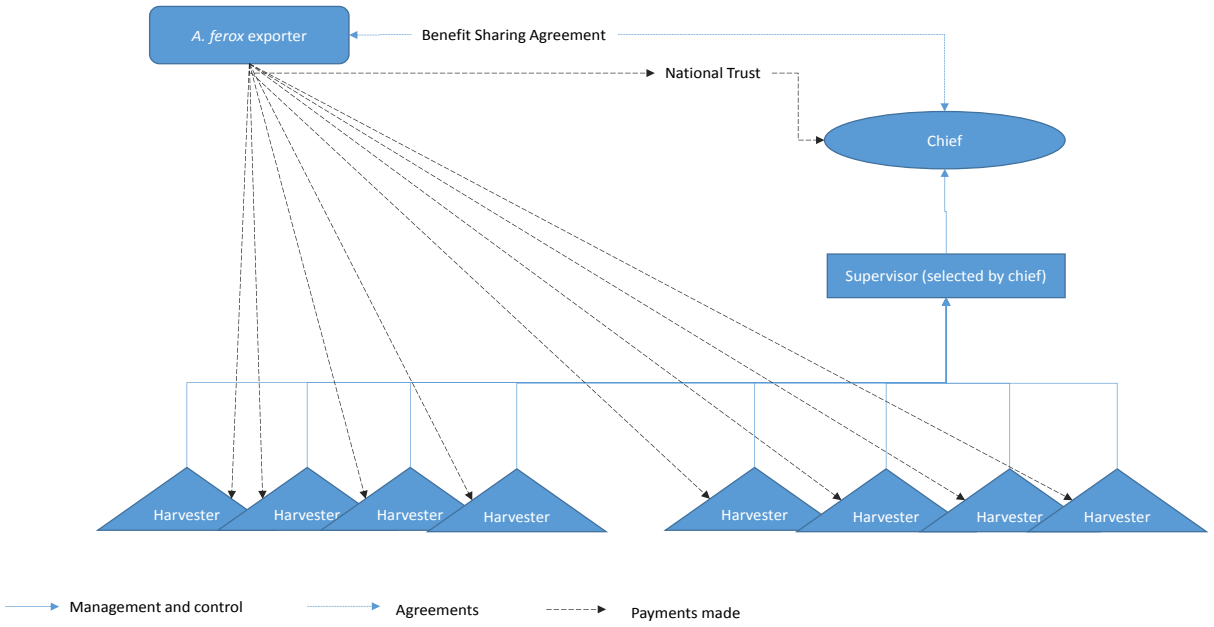


Figure 17: Institutional structure of agreements, payments and participants in the communal harvesting model where the BSA (Benefit sharing agreement) is signed with the Chief

A second institutional model is already being applied where the harvesters form a co-operative for the management and control of the products (Figure 18). Benefit sharing agreements may be with the co-operative or the chief and payment to harvesters may take various forms. In this model the cooperative would generally 'cook' the exudate and sell the aloe solid to the exporter.

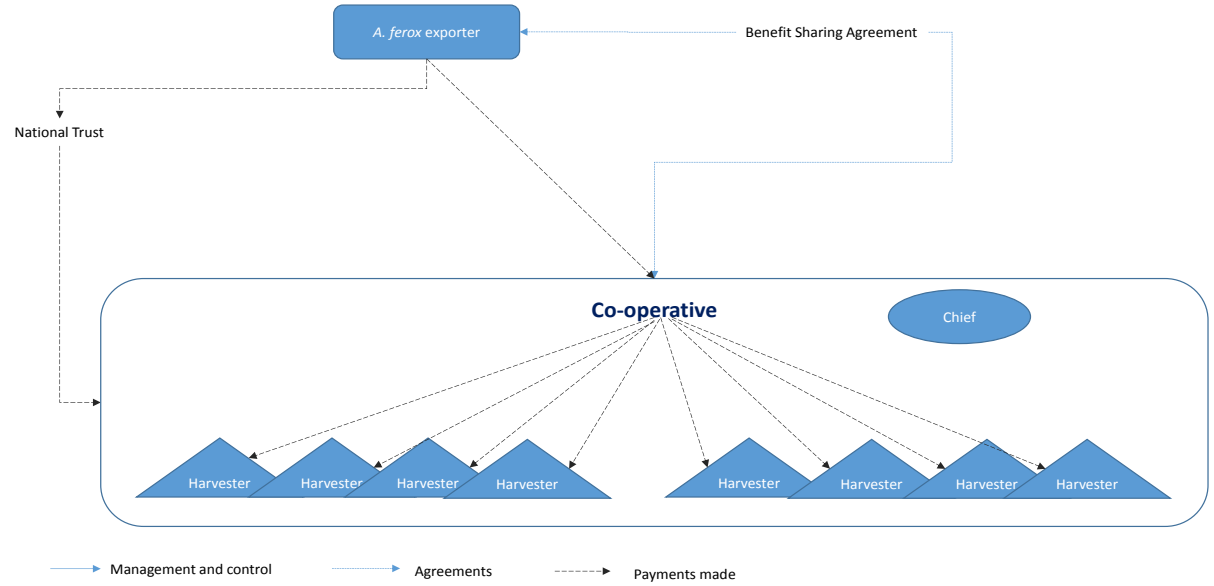


Figure 18: Institutional structure of agreements, payments and participants in the communal harvesting model where the BSA is signed with a cooperative

In the Western Cape, the institutional model is slightly different. The wild harvesting of *Aloe ferox,* generally providing the Mossel Bay derivative, is mostly done on privately owned land and harvesters (mostly men aged between 20 and 35 years) are independent self-employed individuals. At times, these individuals spend a minimum period of 2-3 weeks to a maximum period of one year on a privately owned farmland, depending on the target they have and the size of the farm. Tappers will generally give the landowner one third of any weekly income made from selling the leaf exudate.

6.2. Method of wild harvesting of *Aloe ferox*

According to the literature, the common method of harvesting *Aloe ferox* is manual leaf cutting (Figure 19a). Only 1 0 to 15 of the lower leaves of an adult *Aloe ferox* plant are harvested once a year. The leaves are cut with a sickle as close to the stem (3-4 cm) as possible (DAFF, 2013) (Figure 19b).

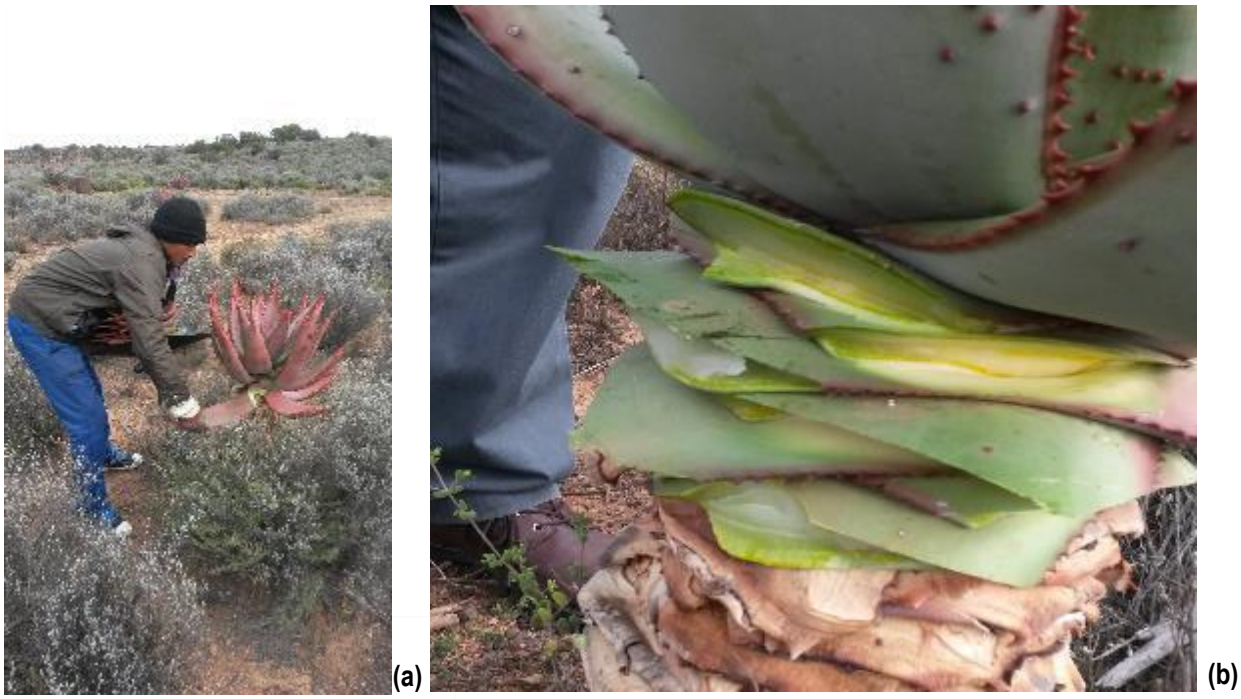


Figure 19: (a) Manual wild harvesting of *Aloe ferox* and (b) leaves cut close to the steam (pictures form this assignment)

Processing: Literature indicates three means of processing the *Aloe ferox* (Viljoen, 2008; Grace et al., 2009; Merlin, 2009; Grace, 2011; Cousins and Witkowski, 2012). Firstly, the 'draining' of the aloe exudates from the cut leaves is done by placing the cut leaves in a 'stack' around a plastic-lined hollow in the ground, with the cut end towards the centre of the circle. This allows the main extract from the tapping, the pale yellow 'bitter aloe' sap, to drain out of the leaf for collection and processing (Merlin,

2009). Draining takes between 4-5 hours. Literature also indicates more exudate in the wet season, as compared to the dry months (Merlin, 2009). This aloe leaf exudate is also called bitters, sap, juice or latex. Processing of the bitter aloe sap, according to the literature, includes the boiling of the sap to reduce the moisture content to less than 6 %, to product what is often referred to as aloe drug-, bitter-, crystalline- or powdered aloes, aloe lump or –brick (Grace, 2011).

Secondly, the literature indicates that the exudate may be extracted by squeezing the leaves or by warm or cold water retting (soak in water) (Adams, 2014).

Finally the gel, a recent entry into the *Aloe ferox* industry, can be derived from the mesophyll layer of the leaves of the plant (Grace *et al*., 2009). The processed derivatives of the leaf mesophyll, which often require advanced extraction technology to pulp the leaves to remove the gel (Newton and Vaughan, 1996), can be found as products sold as aloe gel fillet, concentrated- and crude gel, decolourised- and/or pasteurised gel, freeze- or spray-dried powdered gel.

This study found similar extraction and processing practices in the wild harvesting of *Aloe ferox* in the communal areas of the Eastern Cape and on land in the Western Cape. Tappers make use of a sickle (hand-held agricultural tool) for cutting the leaves, which are then 'tapped' through the stacking and draining process described in the above (Figure 19). Overall, only 1 % per leaf gets processed and the rest of the leaf is discarded, sometimes providing fodder for animals.

According to harvesters in the Eastern and Western Cape, it is possible to collect leaves from 60 to 100 plants a day depending on the weather and the willingness of the harvester to collect material. Cut leaves are collected in a rubber sheet hung around the tappers' neck or in a plastic bucket, and carried to the stack for processing (Figure 20a). The stack is built to approximately hip-height, which can include between 150 – 500 leaves (Figure 20 (b) and (c)). Exudate is drained from the leaves into the plastic hallow at the centre of the stack (Figure 20(d)). Harvesters are able to build more than one stack a day, with each stack producing approximately five litres of sap (weather permitting). Draining, according to the harvesters, can take between 2 to 3 hours in good weather conditions however, respondents indicated that they leave the stack for at least 24 hours.

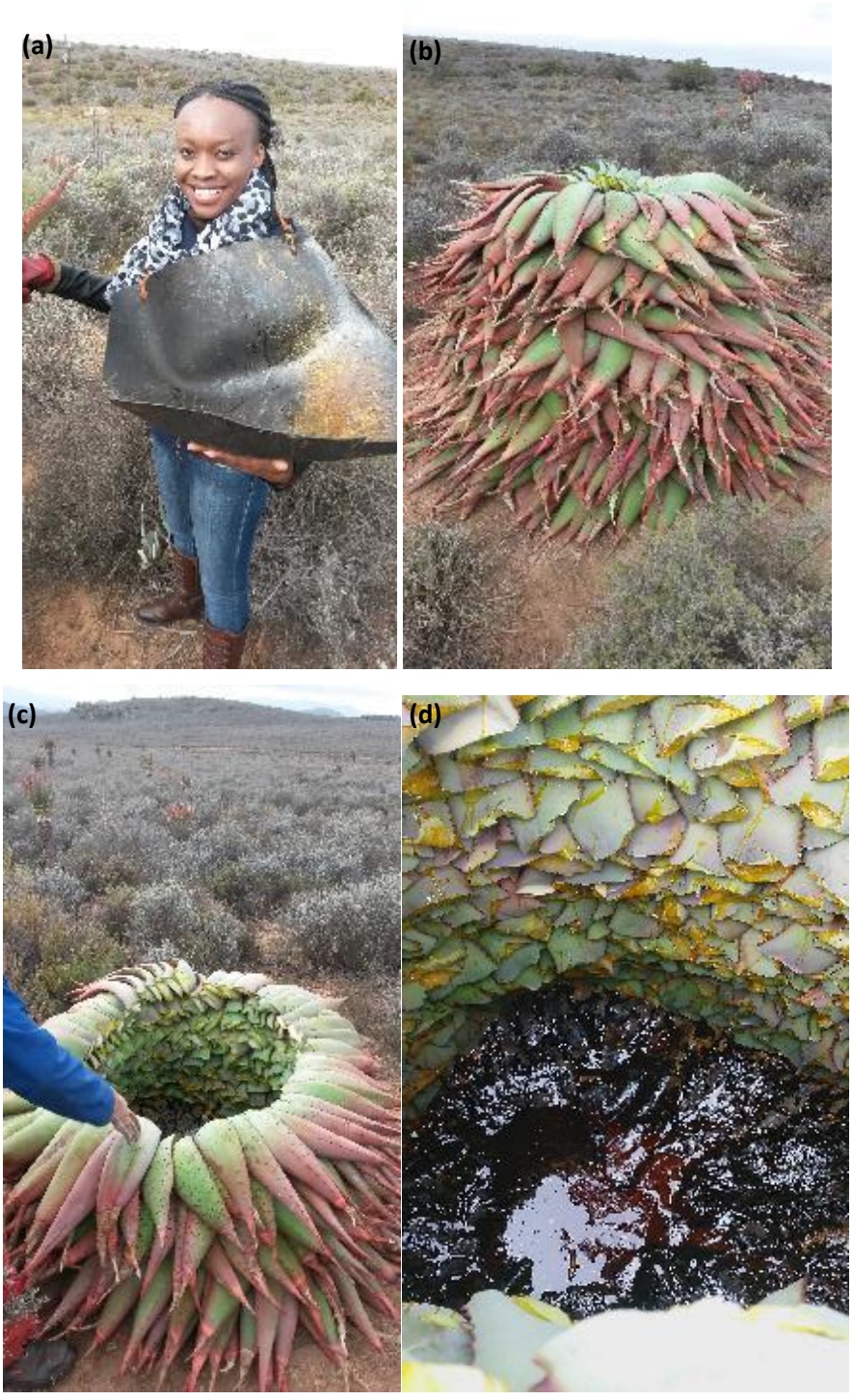


Figure 20: (a) container for collection of aloe leaves, (b) hip-height stack of *Aloe ferox* leaves in Uniondale, Western Cape (c) draining of *Aloe ferox* leave exudate and (d) aloe exudate collected from the aloe stack (pictures from this assignment).

Tappers will then collect the exudate and pass it through a sieve into a clean container which has been supplied by the company that they will sell the product to. Boiling, in most cases, is conducted by the

company, which purchases the exudate as this allows for quality control and for the company to ensure consistency in product. The respondents thus do not show any significant deviation in the method of harvests from that shown in the literature.

6.3 Method of wild harvesting Frequency and Quantity of Wild Harvesting of *Aloe ferox*

According to the literature, an *Aloe ferox* crop is normally ready for harvesting after 18 months. The frequency of harvesting in the literature shows a wide range, from once a year to every 24 months. Merlin (2009) indicated that on average, trained harvesters collected leaves from a plant every 1.8 years while harvesters taught through local knowledge would tap plants more frequently at 1.5 years. Knapp (2008) also indicated that plants are harvested on an 18-month to 3-year cycle. The research by Merlin (2009) indicated that trained aloe tappers are aware that plants require sufficient time to regenerate as opposed to aloe tappers who were taught by others. Both groups however, were aware that not all the leaves should be harvested from a plant as this would inhibit future growth.

The number of leaves that are removed from a plant, at any one time varies from 6 to 15 leaves. (DAFF, 2013; Merlin, 2009). Merlin (2009) further indicated that an average of 24 leaves is required to obtain one litre of raw leaf exudate and two tons of fresh leaves are required to yield a kilogram of *Aloe ferox* powder (Grace, 2011). Cooking of approximately 2000 litres of raw bitters sap is required to provide 1 ton of crystalline bitters.

In this study, the Eastern Cape harvesters indicated harvesting more frequently, from 2-3 months but generally 8-10 months. Western Cape interviewees indicated that from one plant they harvest every 12 months (humid areas) and 18 months in (non-humid areas). This process ensures the healthy growth of the plant. This frequency and quantity of wild harvesting of *Aloe ferox* was however determined by the socio-economic conditions (money) of the harvester, the geographic (soil type, location) conditions of the plants and climatic (weather) factors. Indications are that the number of leaves harvested is however, directly dependent on climate, with more leaves collected in high rainfall areas. Harvesters tend to harvest based on the level of income which they wish to generate. Harvesting can be higher when individuals need to pay for households activities and items such as school fees; school books and clothes; festive celebrations etc. Harvesting can therefore be higher over the December period and other festive occasions. The location of the plant also determines the frequency of harvesting.

Harvesters in this study indicated they collected 4-5 leaves from smaller plants, increasing to 10-15 leaves as the plant grows. However, this number has been indicated to reach as high as 20-30 leaves from a plant in certain conditions. The number of leaves which are left on the plant eventually determine the number that can be harvested. In the Eastern Cape sites, harvesters do not remove the top rosettes of leaves which protect the growth point of the plant, while the Western Cape harvesters, using their harvesting experience, seem to leave approximately 16 leaves around the growth point. Sixteen leaves are approximately the top four rosettes of leaves which surround the growth point of the plant.

Analysis of the harvested plants in the Eastern Cape sites (Figure 21) show that the number of leaves remaining on harvested plants ranges from no leaves to ≥ 20 leaves. Figure 21 shows that the majority (85 % at Site 1 and 64 % at Site 2) of plants had less than 16 leaves on the plant after harvesting. The average number of leaves left on plants in these two sites was estimated to be 11.

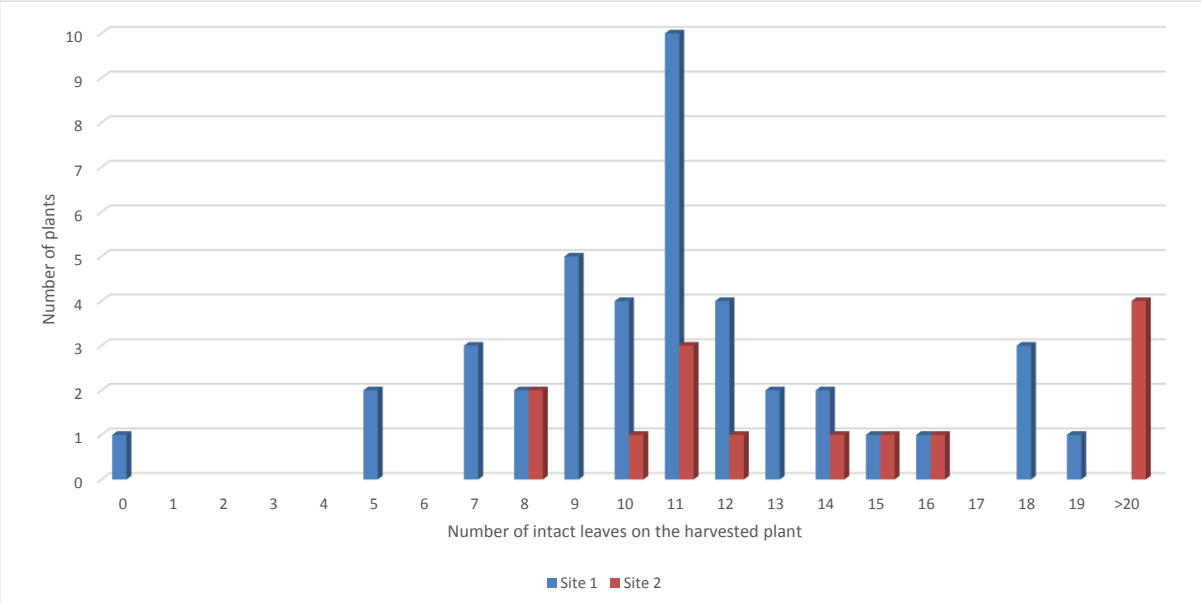


Figure 21: Number of harvested plants showing the number of remaining leaves on the plant after harvesting, at two sites in the Eastern Cape.

Rapid assessment of the number of leaves left on harvested plants in the Western Cape site indicated that the majority of plants inspected had 16 or fewer, leaves remaining on the plant after harvesting. It is interesting to note that from photographic evidence, the plants harvested from the Western Cape appear healthier than those of their Eastern Cape counterparts (Figure 22). Whether this can be attributed directly to the fewer leaves remaining on the Eastern Cape plants or due to other conditions

such as climatic, rainfall, season remains questionable. It may be likely that the extent of harvesting has impacts on the quality of the plants and may adversely affect phenological aspects related to plant growth and development.

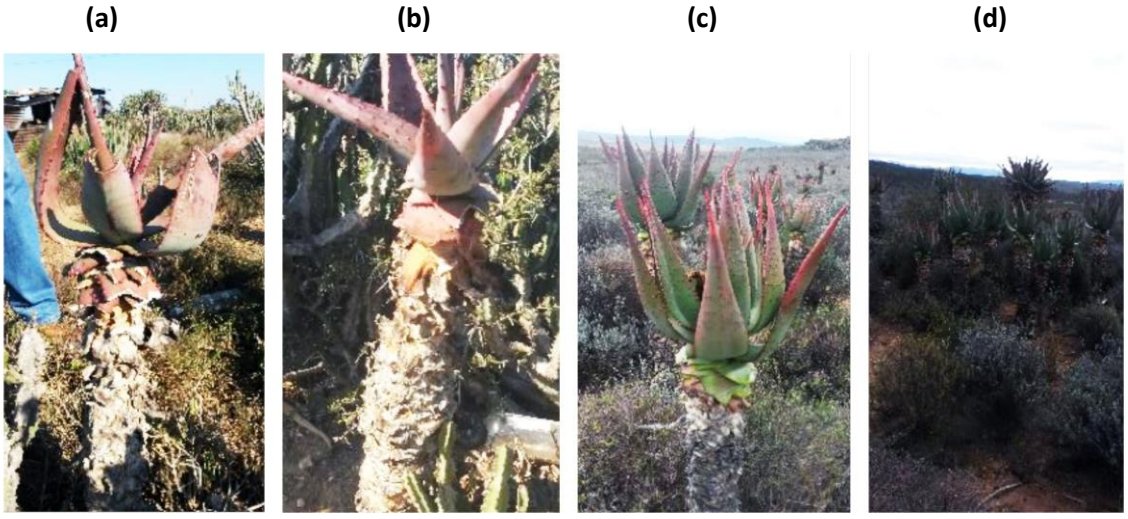


Figure 22: Harvested plant at (a) Site 1 and (b) Site 2 in the Eastern Cape and plants at (c) and (d) plants at harvested site in the Western Cape (photographs from this assignment)

Good harvesters (tappers) on average, would collect 1 000 leaves (one leaf weigh 700g to 1kg) which produce a 20-25 litre bucket of aloe liquid (sap) in a day. However, if weather conditions have an impact (rain or wind) for example, the leaf collection might range from an average 300 to 600 leaves a day (making 10-15 litre bucket of sap).

A few harvesters are selling the dried leaves to grind into aloe powder but since this is still a very limited market, this is only done on request. Generally, tapped leaves are left in the veld for animal consumption.

6.4 Height of harvested plants

One of the key characteristics of *Aloe ferox* is that the age of the plant, unlike a tree, cannot be determined by the height of the plant. Older plants may be short, while younger plants may be much taller. Shackleton and Gambiza (2007) advise that harvesting of small, pre-productive (=<50cm) individuals and taller individuals (>2.5m) should be avoided. However, these recommendations were made in the absence of sufficient data in determining sustainable harvest levels. Small plants, between 20 and 50 cm in height, were consistently harvested in the wild (Merlin 2009).

Eastern Cape harvesters indicated that they would harvest plants once they reached approximately 50 cm (''knee high'') until they reach a height where the tappers are no longer able to reach the leaves.

Analysis of the harvesting data from the two sites in the Eastern Cape indicate that plants from 44cm to almost 2 meters were harvested. Plants above 2 meters were observed to show no harvesting after a certain point in the plants lifecycle.

Interestingly harvesters indicated that small plants (50 cm to 1,5 metres) provide significantly more leaf exudate than the taller plants.

One respondent did however indicate that ''*in some cases you might find shorter plants to be more matured than the taller plants. Therefore, tappers often use their own discretion in identifying the plants that need to be harvested*.''

6.5 Seasons and climate

Interestingly, the literature has documented various seasons in which harvesting occurs. Merlin (2009) indicates that harvesting in the Eastern Cape occurred in the summer months (wet season) and less so or not all in the winter months (dry season). Hence, harvesting declines between June and August. Merlin (2009) also indicated that harvesters recognised that collecting in winter months yields less sap per unit effort than summer months.

The reason for this seasonality is attributed to weather changes. This could be attributed to the seasonal changes. Merlin (2009) indicated that the ideal conditions to harvest *Aloe ferox* are hot, sunny days whereas cold, windy or wet days influence the flow of leaf exudate collected. An observation, supported by the harvesters, showed that windy weather seals up the incision on the harvested leaves, preventing sap flow. Wet weather on the other hand impacts on the cooking

process, as rain increases the moisture in the leaf exudate and thus more cooking is required to reach a moisture content of <6 % in the solid.

Harvesters in the study, both in the Eastern and Western Cape, indicated that season and climate play a significant role in the frequency and quantity of leaves harvested. Season and climate were also recognised by respondents to have an impact on the quantity and quality of leaf exudate provided by the leaves.

Harvesters further mentioned that under drought and extremely cold and frost conditions; harvesting is very limited as the content of leaf exudate is generally low. Tappers have been known to harvest leaves in full moonlight, as these may be the best weather conditions to facilitate maximum leaf exudate collection and higher aloin content.

7. THE EXTENT OF CULTIVATION OF ALOE FEROX

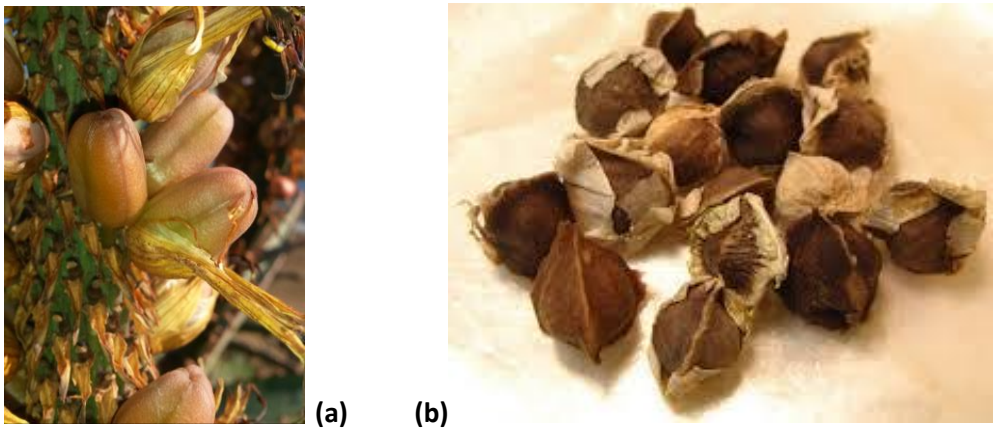
Aloe cultivation takes place in a number of provinces in South Africa with approximately 50 % of *Aloe ferox* believed to be cultivated in the Eastern Cape, 30 % in the Western Cape (Uniondale and Albertinia) and 20 % in KwaZulu-Natal. However, the majority, 80 %, of all aloe processing is done in the Western Cape (Wesgro, 2006).

Literature reveals that the *Aloe ferox* is not a demanding species to cultivate, and has no special requirements (Knapp, 2008). It can be grown in a cool/warm glasshouse and put outside for the summer. It is best grown in free-draining compost, which should be soaked and allowed to dry out, in-between watering. In some areas of the Western Cape (Oudtshoorn) plants are being cultivated and there seems to be uniformity in the response of plants to being grown under cultivation. Knapp (2008) indicated that the species was widely cultivated for its ornamental properties.

Participants in this study indicated that *Aloe ferox* can be grown using its seeds and propagated from cuttings from plants (vegetative reproduction). It is however, more common to grow *Aloe ferox* from seed, as the use of cuttings is limited by the single stem characteristic of the plants.

Cousins and Witkowski (2012) indicate that tall, single-stemmed species such as *Aloe ferox* do not habitually form plantlets along their stems. Hence, if the growing tip of the plant is damaged or destroyed the plant is unable or very reluctant to re-sprout (Smith *et al*., 2008). Propagation by cuttings is therefore, not as popular as growth from seeds. If cuttings are used, they are collected from the side branches (if any) or the stems of matured plants. The stem cutting should be about 15 to 18 cm long and be planted in such a way that a two-third portion of the cutting is underneath the soil.

Fruits of the plant are typically three-angled, oblong capsules (Figure 23(a)) which dry and dehisce when ripe (Figure 23(b)) (Cousins and Witkowski, (2012). Seeds of *Aloe ferox* are triangular, black and range in size from 0, 3 to 0, 5 mm (Bairu et al., 2009).



(a) **(b)**

Figure 23: *Aloe ferox* (a) fruits and (b) seeds (taken from http://alkebulanis.com/site/)

According to an interviewee in this study, seeds are easily purchased from local suppliers and are readily available on the internet. This is confirmed by a search for the price of *Aloe ferox* seeds on the internet, indicating a price range of 82 cents per seed to R1, 41 per seed (Table 3).

Table 3: Prices of *Aloe ferox* seeds from various internet sources

Price per packet	Estimated price per seed	Source
R9 for 10 seeds	90 cents	http://www.seedsforafrica.co.za/collections/succulent-seeds/products/aloe-ferox)
R15 per packet or R18 per 100g	-	http://www.silverhillseeds.co.za/byname.asp
€ 1.98 for 20 seeds	R1,41[2]	http://www.seedaholic.com/aloe-ferox-cape-aloe.html
$3.95 for 50 seeds	82 cents[3]	https://www.horizonherbs.com/product.asp?specific=314
R4,50 for 5 seeds	90 cents	www.bidorbuy.co.za
R4 for 5 seeds	80 cents	www.bidorbuy.co.za
R8,50 for 10 seeds	85 cents	www.bidorbuy.co.za
R6 for 5 seeds	R1,20	www.bidorbuy.co.za

The Albertinia and Uniondale cultivators in this study indicated that they obtain their seeds directly from the aloe plants in the wild. *Aloe ferox* seeds can be collected during the winter or spring flowering season. They place these seeds in a punnet filled with a layer of gravel covered by a mixture of wood

[2] Assuming a 14,288 Euro to rand exchange rate
[3] Assuming a 10.3503 dollar to rand exchange rate

bark and sand (Figure 24a). Seeds are scattered on the surface of the mixture, and lightly covered, watered daily but ensuring that overwatering does not occur. Cultivation is important as an ex-situ conservation strategy but plants grown from seed often exhibit differences as the plants would no longer be clonal. Populations growing under similar climatic conditions are however, likely to be similar in their chemical composition. Cultivation in a monoculture set up may also lead to plants being more prone to diseases which need to be monitored. These predictions do need to be tested and the quality-quantity of metabolites are monitored using metabolomics approaches. This is important for purposes of quality control and the standardisation of natural products produced from Aloe.

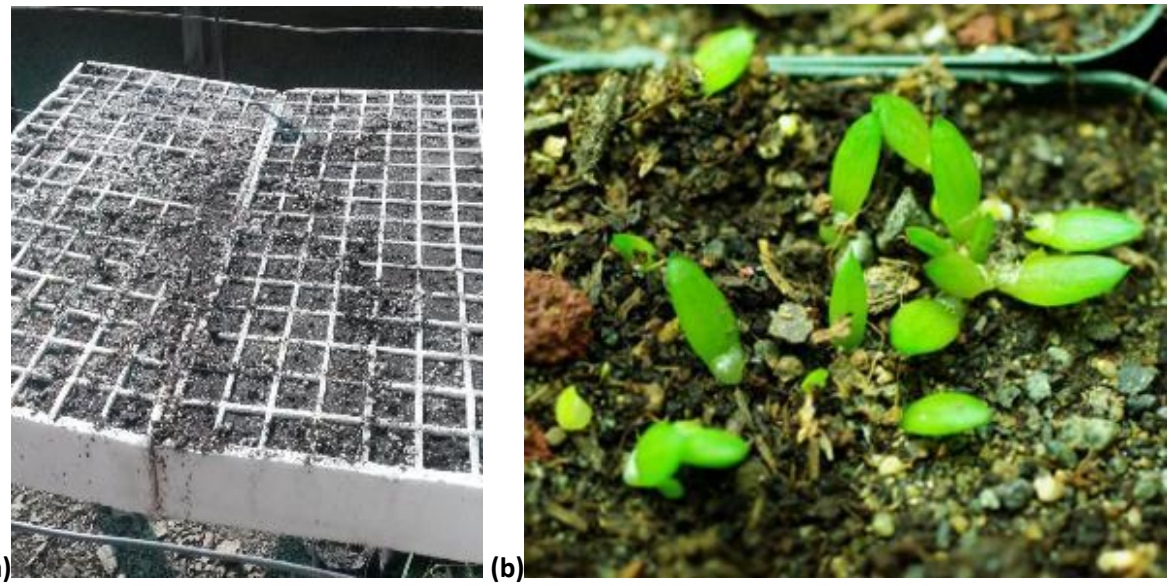


Figure 24: *Aloe ferox* (a) seed planting in punnets and (b) young seedlings (taken from https://www.horizonherbs.com/product.asp?specific=314#)

The location and temperature, at which seeds are sown, play a significant role in the germination process. In a laboratory situation, seeds of *Aloe ferox* showed better percentage germination (greater than 70 %) between 15 and 30^{0}C (Bairu *et al*., 2009). Bairu *et al.* (2009) also attributed the large range of germination temperature to the wide distribution of this species in South Africa. The highest percentage (78 %) of *Aloe ferox* seeds germinated was at 25^{0}C under constant dark conditions (Bairu *et al*., 2009). Bairu, (2009) indicates that optimal temperature for *Aloe ferox* seed germination is in-fact 21,5^{0}C. The responses from the interviewees in this study support the findings by Bairu (2009) and colleagues. Interviewees mentioned that the majority of seeds germinate at temperatures of 22 to 24°C.

According to an interviewee, germination of *Aloe ferox seeds* occurs within 7-14 days of planting (Figure 24b). Literature shows that temperature also has a vital influence on early developmental stages of the seedlings. *Aloe ferox* seedlings grown in alternating temperatures of 15^0C to 30^0C showed the best shoot and root growth and an increasing number of leaves (Bairu *et al*., 2009).

Similarly, the literature indicated that watering level in the soils is important for the growth of *Aloes* (Bairu *et al.*, 2009). Laboratory trials have shown that watering of *Aloe ferox* seedling three times a week enhances most growth parameters, where watering only once a week demonstrated a decline in shoot and root length, number of roots, and the fresh weight of seedlings (Bairu *et al*., 2009). Literature suggests that regular water frequencies are crucial for growing *Aloe ferox* seedlings.

(a) **(b)** **(c)**

Figure 25(a-c): Cultivation steps of *Aloe ferox* (pictures from this assignment)

Figure 25a shows the aloe plants after 1 year of propagation. Plants are then transplanted into 1 kg bags containing a well-drained mixture of sand and compost (Figure 25b). Aloe plants are ready for planting in the field 3-4 years after propagation (Figure 25c), planted in spring/summer. At this age, plants have not yet developed the characteristic stem of the *Aloe ferox*, showing as a series of succulent leaves close to the soil (Figure 25c). Plants of this age sell for approximately R65. Sales of *Aloe ferox* to the public and landscapers is highly variable, with interviewees in the study indicating that it was difficult to estimate the number of plants sold per year.

Literature shows that the overall process of growing *Aloe ferox* from the seeds usually takes four to six years before maturity (flowering stage) and the first harvest of leaves (Botha *in litt.,* 1992 in Newton and Vaughan, 1996). Each leaf weighs roughly 1.5 kg to 2 kg at the time of harvest.

The first commercial plantations of *Aloe ferox* were established in 1976 by Dr Muller on Vinklaagte farm near Albertinia in the Western Cape (Chen *et al*., 2012). Recent cultivation plantations take the form of crop-like plantations with *Aloe ferox* planted and grown in rows, 3 metres apart (Figure 26). This makes it easier for the harvesters/tappers to harvest and is also for control purposes. Cultivation in the Western Cape Province occurs in the Uniondale, Albertinia, all the way to Swellendam region. However, in the Swellendam region, cultivation and propagation is largely for the nursery and landscaping markets.

Figure 26: Row plantations of *Aloe ferox* in Albertinia, Western Cape (picture from this assignment)

In the Uniondale region, cultivation takes a different form. Since *Aloe ferox* plants naturally grow in groups (Figure 27) cultivation in the region will mimic this process. Approximately 10 000 aloe plants have been purchased for this purpose and planting will occur in this manner to ensure organic certification for the organization.

Figure 27: *Aloe ferox* occurring naturally in groups in Uniondale, Western Cape (picture from this assignment)

In the Eastern Cape Province trials for cultivation of the species have been conducted in various areas of the province. However due to the high abundance of the wild species, the low aloin content and limited demand for the species; cultivation for current markets has not been demonstrated to be economically viable in this province (Knapp, 2008).

7.1 Factors which can affect cultivation

7.1.1 *Aloe ferox* diseases

Aloe ferox is prone to a variety of diseases, including aloe cancer (also called galls), leaf spots, bacterial infections and aloe rust. A few of these will lead to the rapid demise of the plants, or will certainly spoil their appearance (Table 4). The work of Zapata *et al*. (2013) show strong susceptibility of Aloe to fruit pathogenic fungi including species of *B. cinerea, P. digitatum, P. expansum and P. italicum.*

Table 4: *Aloe ferox* diseases (taken from van Wyk *et al.*, 1997; Herbert, 2006)

Aloe ferox diseases	Symptoms	Control
Aloe cancer	Aloe cancer (also called galls) causes severe deformation of the leaves or inflorescences.	The infected areas should be removed with a sharp knife, taking care not to infect other plants and the wounds should be treated with a registered insecticide.
Crown Gall	Crown Gall is caused by a bacterium and by rapid proliferation of the cells of the plant, the bacterium providing the stimulus for the over-development.	
Aloe rust (Uromyces Aloes)	Aloe rust is caused by a rust fungus that leaves black spots on the upper and lower leaf surfaces of aloe plants. The first signs of rust are small, orange-yellow spots on the leaves. These soon become larger and appear on both surfaces of the leaves and eventually burst open to form a black and yellow scaly crust.	Treatment with systemic fungicides is very effective. In severe infection, the use of antibiotics is advised. The best way to address the problem is to cut away the diseased leaves and immediately burn them, or paint each spot with an oil or bitumen mixture, thereby preventing fungus from spreading.
Rot	An early sign of rot is plants that do not grow and form new leaves during a season or two. The bases of the leaves near the centre of the rosette may become blackened, or the leaves begin to sag, losing their firmness and becoming spongy and rotted, resulting in the eventual collapse of the plant.	The centre part, which has been affected, should be carefully cleaned out and then treated with a registered insecticide.
Leaf spots	The spots are often black. They may be very large and unsightly. Sometimes the spots increase very quickly.	
Bacterial Infections	These may be shown up as leaf-spots, rots, wilts or blights.	Healthy cultivation is advocated for control of bacterial disease, and the use of copper compounds as protective sprays may be effective. Several antibiotics, like streptomycin are also now being used widely as protective sprays.
Soil deficiencies	Discolouration of the leaves caused by a lack of chlorophyll (chlorosis) or plants becoming shrivelled and plants not flowering is sometimes the result of insufficient nourishment or lack of trace elements in the soil.	It may be advisable to have the soil tested by an expert.

7.1.2 Animal Impact

Animals are another factor which may impact on cultivation of *Aloe ferox*. For example, one interviewee in Uniondale mentioned that 6 years ago they planted about 34 000 *Aloe ferox* plants but the plantation has failed due to damage by baboons (Figure 28).

(a) **(b)**

Figure 28: Plantations destroyed by the baboons, Uniondale (pictures from this assignment)

8. TRADITIONAL USE AND KNOWLEDGE OF UTILIZATION

Harvesters from the Eastern Cape indicated, in this study, that they believed the wild plants of this species were still in abundance in the provinces, particularly in the rural and communal areas of the province.

The *Aloe ferox* plant is highly prized by communities on communal land, due largely to the value of the leaf exudate and gel. Tappers indicate a long history with the species, with their parents having being involved in the tapping and trading of the leaf exudate.

Traditional knowledge associated with *Aloe ferox* is held in families involved in the harvesting and use of the species, with knowledge of harvesting and use passed from generation to generation. For example, one harvester mentioned that he has been harvesting aloe since he was 15 years of age and he was taught by his parents as to how to harvest the plants. Other harvesters also indicated a similar history with the species.

Traditional use of *Aloe ferox,* included medicinal use by chewing the leaf to sooth stomach-ache. Leaves of the plant are also used to heal broken skin and wounds by applying the sap to the affected area. Harvesters in the study did indicate that historic uses of *Aloe ferox* are not currently being applied at the extent that they were in the past.

Knowledge of the traditional medicinal uses of *Aloe ferox* have been transferred and applied in the mainstream pharmaceutical and cosmetic industries, both local and internationally, and have been extensively researched (Grace *et al*., 2013). Although traditional exudate harvesting and preparation methods continue to be practised with few contemporary adjustments, the processed *Aloe ferox* is now commonly used in manufactured food products such as confectionary and fruit juice blends (Grace, 2011) as well in the pharmaceutical and cosmetic industries.

9. COMMERCIALISATION OF ALOE FEROX

The seminal work of Newton and Vaughan (1996) provided the first examination of the stakeholders involved in the *Aloe ferox* industries in South Africa and the distribution of benefits between them. The seemingly good economic profitability of the current *Aloe ferox* industry has prompted interest from government and development agencies seeking opportunities for local level enterprise development for poverty alleviation in rural areas.

Newton and Vaughan (1996) clearly stated that *Aloe ferox* plays a significant role in the lives of a large number of people living in rural areas around South Africa. The findings in their report were based on aloe tapping in the Western Cape. The socio-economic benefits of the *Aloe ferox* industry in South Africa are spread widely (Newton and Vaughan, 1996), from the poorest people whose only source of income is derived from Aloe tapping, to itinerant agricultural workers and other part-time aloe tappers, their families and communities. In the Western Cape, the potential annual income for a full-time tapper was estimated to be R10000 (US$1400) in 1992 but, due to a complex debt cycle and lack of empowerment, this was seldom, if ever, realised (Newton and Vaughan, 1996).

The bitter latex of *Aloe ferox* has been used in Africa and Europe as a laxative medicine and is considered to have bitter tonic, anti-oxidant, anti-inflammatory, antimicrobial and anticancer properties (Chen *et al.,* 2012). Other commercial uses of *Aloe ferox* are outlined in Table 5.

Table 5: The uses of the *Aloe ferox* derivatives (taken from Chen et al., 2012)

Derivative	Use
Non-bitter Gel	The leaf parenchyma of *Aloe ferox,* known as 'aloe gel', has become a popular ingredient in cosmetics, herbal remedies and food supplements taken orally and applied to the skin. It is used in similar ways to the related species *Aloe vera* The first *Aloe ferox* gel was produced in South Africa in 1994 (O' Brien et al., 2011). However, studies on the gel components are limited (Mabusela *et al.,* 1990; O' Brien *et al.,* 2011). Commercial preparations of the gel have been reported to heal certain chronic leg ulcers and improve some cases of eczema in addition to providing significant relief in acute sunburn (van Wyk and Gericke, 2000). The use of the non-bitter gel of *Aloe ferox* as a food supplement is a modern development (Van Wyk 2011a, 2011b): no documentation of *Aloe ferox* used as food is found in the literature except for the production of jam (preserve) by Cape farmers (Palmer and Pitman, 1972; Fox and Norwood Young, 1982; Palmer, 1985; Rood, 1994a; Rood, 1994b). The health benefits of beverages and fortified food products containing the leaf parenchyma of *Aloe ferox* have been described but much more research is needed to adequately explain the value of aloe health drinks as a "functional food" (van Wyk, 2013).

Derivative	Use
Leaf Exudate	More recently, Chen *et al.,* (2012) indicate that the *Aloe ferox* is a popular ingredient in skin care products and tonic drinks (Kleinschmidt, 2004). *Aloe ferox* is added to cosmetic products such as cleansers, moisturisers, shampoos, suntan lotions, and sunburn screens. Aloesin shows promise as a pigmentation-altering agent for cosmetic or therapeutic applications (Jones et al., 2002; Yagi and Takeo, 2003). The exudate has potent laxatives and purgatives rich in anthraquinones, of which the main compound is aloin. Used for cleansing, antiseptic, moisturizing and anti-inflammatory properties (Fourie, 2005). The Food and Drug Administration (FDA, 2002) has permitted the use of *Aloe ferox* as a direct food additive for human consumption as a natural flavouring substance. Aloe is also listed by the Council of Europe as a natural source of food flavouring. Pharmaceutical: *Aloe ferox* has been included as a main ingredient in a patent composition for oral administration for the purpose of weight management by appetite reduction (Buchwald-Werner, 2008).
Racemes (Flowers)	The species is widely cultivated for its ornamental properties (Oldfield, 1997) and propagates with ease, with plants reaching maturity (flowering stage) within four to six years (Botha in litt., 1992 in Newton and Vaughan, 1996).
Leaf Ash	Repels insects when planted as a live fence. The leaf ash is also used as an insect repellent and can be dusted onto stored maize or cowpea at a concentration of about 5 % w/w as reported for *Aloe marlothii* (Fourie, 2005).

Chen *et al*. (2012) indicates that *Aloe ferox* has been marketed as having:

- Anti-oxidant effect
- Anti-inflammatory activity
- Antimicrobial activity
- Anti-cancer activity
- Antimalarial activity
- Permeation-enhancing effect
- Antihelmintic activity

The ‘aloe bitters’ emanating from the boiling of the leaf exudate is commercially traded in South Africa in two forms (Figure 29);

- A dark-brown crystalline ‘lump’ concentrate (traded as aloe solid) which results from boiling the raw aloe bitters. Aloe solids can be crushed to smaller crystalline shapes - traded as aloe crystal; or

- The yellow-brown powdered bitters produced from mechanically grinding the crystalline aloe (Newton and Vaughan, 1996; Merlin, 2009).

(a) **(b)**

Figure 29: Image of (a) *Aloe ferox* bitter crystals and (b) *Aloe ferox* powder bitters (pictures from this assignment)

In addition, aloe is traded as a Green Leaf Aloe Powder which is produced from leaves which, after the exudate is removed, are sun-dried before being milled into a fine powder.

A recent entry into the *Aloe ferox* industry is aloe 'gel', which is derived from the mesophyll layer of the leave of the plant (Grace *et al*., 2009). Recent metabolomic analyses have indicated that this gel is largely composed of polysaccharides which include glucomannans, galactose and galacturonic acid polymers (Grace *et al*., 2013). The processed derivatives of the leaf mesophyll, which often require advance extraction technology to pulp the leaves to remove the gel (Newton and Vaughan, 1996), can be found as products sold as *Aloe* gel fillet, concentrated- and crude gel, decolourised- and/or pasteurised gel, freeze- or spray-dried powdered gel (Waller et al., 2004). It is estimated that to produce 1 kilogram of powdered *Aloe ferox* gel, two tons of fresh leaves are required (Newton and Vaughan, 1996). Similar products are made using whole leaves (Grace, 2011).

Newton and Vaughan, in 1996, estimated the rural industry supported by wild-harvested *Aloe ferox* to be worth R4 million per annum to rural harvesters. Shackleton and Gambiza (2007) projected that in 2006, this wild-harvested *Aloe ferox* industry would be R8-9 million per annum (assuming no growth in the industry). If growth in the industry is included in the estimate, Shackleton and Gambiza (2007) projected that in 2006 the value of the rural supported *Aloe ferox* industry would be in the region of R12-15 million per annum.

In 1992, it was estimated that in the Western Cape the potential annual income that a full-time tapper could expect was in the region of R10, 000 (US$1400) (Newton and Vaughan, 1996). *Aloe ferox* leaf

exudates have been used as a currency for obtaining credit and offsetting debt in local stores, or to purchase food in town which are central to the *Aloe ferox* industry (Newton and Vaughan, 1996).

In 1996, Newton and Vaughan estimated that the formal *Aloe ferox* industry in South Africa yielded an estimated 400 tons of dried aloe leaf exudates per annum, the bulk of which is exported, and the remainder used in non-scheduled medicines or placed in stored reserves. Newton and Vaughan (1996) further estimated a 300 ton yield which is informally (potentially illegally) traded annually from the Eastern Cape.

In the Department of Environmental Affairs (undated) market sizing of the extent of the bioprospecting of *Aloe ferox,* at least 17 South African organisations were found to trade in the solid, crystal, powder and gel form of the resource.

The bulk of commercially harvested *Aloe ferox* is for the export market, with very little secondary or tertiary processing in South Africa (Newton and Vaughan, 1996; Sachedina and Bodeker, 1999; Merlin, 2009).

Recent estimates of the larger *Aloe ferox* industry, which takes into account the retail chain, suggests that the value of the industry to be between R150 million per annum (US$20 million) to R675 million per annum (US$90 million) (Shackleton and Gambiza, 2007; Grace, 2011). Newton and Vaughan's 1996 survey of retail sales of *Aloe ferox* found that it is one of the most frequently sold medicinal and chemical 'packed line' (non-schedule products). The average monthly number of packets of aloe powder sold was 23, usually in 25 g packets for the powder and 15g packets for the crystal aloe. Using these data, Newton and Vaughan (1996) estimate between 0.95 tons of aloe product sold per month (11.4 tons per year) per outlet.

The survey of *Aloe ferox* products within retail, specialist and health stores in South Africa, conducted by Department of Environmental Affairs (undated), shows that 26 % (146) of the 549 products in the retail database contain this indigenous plant resource. This indigenous resource was by far the most utilised in retail and specialist stores. Table 6 shows that almost half of these products were cosmetic including face, body, hand and sun creams, toners and facial cleansers; a quarter were complementary medicines including products used as laxatives, to treat gastrointestinal ailments, dietary and herbal supplements and immune boosters. Almost a quarter of the products containing *Aloe ferox* were personal hygiene products including shampoos, soaps and mouth products (toothpaste, mouth wash).

A small number of products contained *Aloe ferox* as a flavourant, including in slimming tea and in drinks.

Table 6: Number and percentage of products containing A*loe. ferox*, by category, from the survey of retail and specialist stores in South Africa.

Product Category	No. of products	Percent of *A. ferox* products
Food flavourant	7	5%
Complementary medicines	37	25%
Cosmetic	69	47%
Personal hygiene products	33	23%

Aloe ferox products can be found in retail stores, specialist stores (such as Clicks, Dischem), health shops, supermarkets and also pharmacies. A relatively large number of products are also sold through the internet.

Aloe is an important horticultural species and both fresh and dried flowers may also be used for ornamental purposes. Dried aloe flowers have been used to display jewellery (personal observations, Barrydale jewellery stores) and also it may be utilised in flower arrangements.

Many individuals and organisations both locally and internationally confuse *Aloe ferox* and *Aloe vera*, often attributing *Aloe ferox* resources, products and uses to *Aloe vera.* This has both negative and positive implications to the growth of the *Aloe ferox* market, in that *Aloe vera* market could take precedence over the market recognition of Aloe *ferox*. At the same time, the *Aloe ferox* market could benefit from market recognition of the benefits of Aloes, based largely on recognition of the benefits of *Aloe vera* products. Box 1 below provides a short summary of the *Aloe vera* market and value chain, indicating some of the similarities and differences with the local *Aloe ferox* market.

Box 1: *Aloe vera* market and value chain

Scientific and common name	*Aloe vera* is known by a number of names in the literature, including *Aloe barbadensis* Mill; *Aloe vera* L. var. littoralis Konig ex Bak and *Aloe vera* L. var. chinensis Berger (Ahlawat and Khatkar, 2011).However, according to the International Rules of Botanical Nomenclature, *Aloe vera* (L.) Burm f. is the legitimate name for this species. (Bradley 1992; Newton 1979; Tucker *et al*., 1989; Ahlawat and Khatkar, 2011). The species epithet *vera* means "true" or genuine" (Sharma *et al.,* 2013) The common names for aloe vera include burn plant, first aid plant or medicine plant (Ahlawat and Khatkar, 2011).
Origin	*Aloe vera* has been recognised for its medicinal value for several thousand years, having been recorded as being used by the ancient cultures of India, Egypt, Greece, Rome and China. In

	biblical times the Egyptians hailed *Aloe vera* as the plant of immortality, while the Chinese have called it their elixir of youth (Ahlawat and Khatkar, 2011). Although no naturally occurring populations are currently known, *Aloe vera* is believed to have originated in northern Africa as it is closely related to aloes occurring in northern Africa (Sharma *et al.,* 2013).The species is now widely naturalized, occurring in temperate and tropical regions of Australia, Barbados, Belize, Nigeria, Paraguay and the US (Bhardwaj, 2012; Sharma *et al.,* 2013).
The resource and harvesting	*Aloe vera* is a hardy, perennial, tropical, drought-resistant, succulent plant belonging to the Liliaceae family (Bhardwaj, 2012). The plant is stemless or has a very short-stem, reaching heights of 60-100cm at maturity. Each plant has 12-16 green to grey-green leaves in a rosette (Ahlawat and Khatkar, 2011, Bhardwaj, 2012). Leaves can have a flecked appearance on the upper and lower surface. The leaves, weighing 1.5kg-3kgs at maturity, are up to 0.5 m long and 8–10 cm across at the base, tapering to a point, with serrated leaf margins (Ahlawat and Khatkar, 2011). The leaves of the *Aloe vera* plant are covered with a thick cuticle, beneath which epidermal and mesophyll layers are present (Ahlawat and Khatkar, 2011). The flower of the *Aloe vera* plant, which appear in the second year of growth, is red, yellow, purple or pale striped, being present most of the year (Ahlawat and Khatkar, 2011; Bhardwaj, 2012). Like the *Aloe ferox* flower, the *Aloe vera* flowers grow on long (90-150cm) racemes which originates from the centre of the basal leaves (Ahlawat and Khatkar, 2011). The fruit of the *Aloe vera* plant are triangular capsule containing numerous seeds (Ahlawat and Khatkar, 2011). The plant matures when it is about 4 years old and has a life span of about 12 years. Leaves of *Aloe vera* are harvested by pulling back on the green leaf and cutting at the white base of the leaf (Chandegara and Varshney, 2013). The plant can be harvested every 6–8 weeks by removing 3–4 leaves per plant (Ahlawat and Khatkar, 2011). The *Aloe vera* leaves after harvesting must be sound, undamaged, mold free and mature (3–4 years) in order to keep all the active ingredients in full concentration and should reach the processing plant within 1 hour of harvesting (Lawless and Allen 2000).
Cultivation	Large scale agricultural production of *Aloe vera* is undertaken in Australia, Bangladesh, Cuba, the Dominican Republic, China, Mexico, India, Jamaica, Kenya, Tanzania and South Africa, along with the USA (Sharma et al., 2013). *Aloe vera* is found to grow in hot humid and high rainfall conditions, with well drained soils (Biswas, 2010). Propagation of *Aloe vera* is significantly different to the process of *Aloe ferox.* It is difficult to grow aloe *vera* from seed, hence Gantait *et al*., (2014) indicated that *Aloe vera is* traditionally propagated using lateral shoots, from a mother plant, as planting materials. A one to two metre long branch is cut from the mother plant and planted in soil with adequate moisture. This process can lead to problems in the cultivation of the species as the number of lateral shoots per mother plant is limited and also variable over time (Gantait *et al.,* 2014). Generally, in conventional production systems of *Aloe vera*, 3–4 lateral shoots are obtained per mother plant per year.
Processing	The processing of *Aloe vera* is much more mechanised than the processing of *Aloe ferox* in South Africa. Harvested leaves are transported, in refrigerated trucks to be processed at the processing plant. Little processing takes place in the fields. Primary processing: Once harvested and transported to the processing plant, the fillet and the mucilage are collected from the aloe leaf for further processing (Ahlawat and Khatkar, 2011). To produce a fillet, the leaf base, the tapering point of the leaf top, the short sharp spines located along the leaf margin as well as the top and bottom rind are removed with sharp knife (Ahlawat and Khatkar, 2011) . The fillet is then washed with deionized water and transferred

to the refrigerated pulper, where the aloe juice is removed from the fillet (Ahlawat and Khatkar, 2011).

To produce the powder, the fillets are either dehydrated or homogenized.

a. Dehydration: pure intact *Aloe vera* gel fillets are washed to remove traces of aloin, placed in a humidity chamber to maintain desired levels of relative humidity and temperature and the dried material then ground to powder and packed (Ramachandra and Srinivasa Rao 2008; Ahlawat and Khatkar, 2011).
b. Homogenization and enzymatic treatment: in this process, the washed leaf fillet is then crushed or ground at room temperature (25 °C) in commercial high speed grinder. The crushing or grinding should be completed within 10–20 min in order to avoid the enzymatic browning.

To produce the aloe juice, crushing, grinding or pressing of the entire leaf is required to produce a liquid. This is followed by various steps of filtrations and stabilization (hot or cold) to preserve the biological integrity of the active ingredient which exerts the reported physiological effect upon ingestion or topical application. The Aloe *vera* juice is conveyed to a holding tank and kept for 24 h to decant. Holding tank is also refrigerated for preserving the bioactivity of sensitive molecules of *Aloe vera*. *Aloe vera* juice is packed in amber coloured glass bottles to avoid the effect of light on the sensitive bioactive agents. Relative humidity and temperature are two most important environmental parameters that affect product quality.

10. CONSERVATION STATUS OF ALOE FEROX

Aloe ferox does not seem to be particularly vulnerable based on the information available in Donaldson (1989) and it is not currently listed in the IUCN Red List of Threatened Species 2006 (Anon., 2006b). However, Victor and Scott-Shaw (2006) stated that *Aloe ferox* was classified as 'Least Concern' in the Red List of South African Plants, as there has been concern that leaf harvesting may affect growth, reduce flowering, and reduce resilience to drought (Donaldson, 1989).

The 2008 National Protected Areas Expansion Strategy for South Africa differentiates protected areas from conservation areas in the country.

Protected areas are areas formally declared as protected in the National Environmental Management: Protected Areas Act (NEM: PAA) (South Africa, 2003). The key provisions in NEM: PAA recognise a number of protected area types (Table 7) in the country, with two level of protected areas namely (1) *national protected areas* which are a special nature reserve, a nature reserve or protected environment which is managed by a national organ of state; or which falls under the jurisdiction of the Minister for any other reason and (2) *provincial protected areas* which are nature reserves or protected environments that are managed by a provincial organ of state; or which falls under the jurisdiction of a province for any other reason.

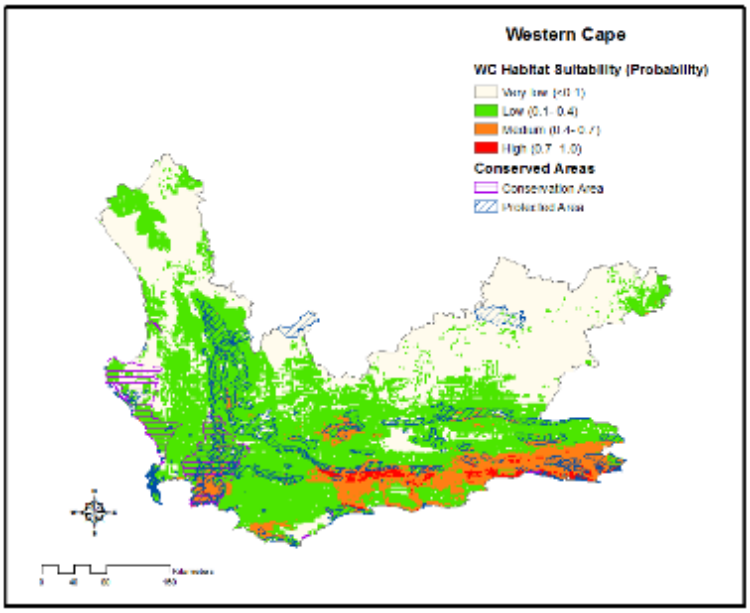
Table 7: Categories of protected areas recognised by NEM: PAA and other legislation in South Africa (South Africa, 2003)

Protected area type	Declared as per requirement of	Declared by	Level of management control	Management authority
Special Nature Reserve	*NEM: PAA*	Minister	Highest	Any suitable person, organisation or organ of state
Nature Reserve	*NEM: PAA*	Minister or MEC	High	Any suitable person, organisation or organ of state
Protected Environment	*NEM: PAA*	Minister or MEC	Lowest-land use controlled	Any suitable person, organisation or organ of state
World Heritage Sites	*NEM: PAA or World Heritage Convention Act (Act 49 of 1999)*			
Marine Protected Areas	*Marine Living Resources Act (Act 18 of 1998)*			
Protected Forest Area forest nature reserves and forest wilderness areas	*National Forests Act (Act 84 of 1998)*			
Mountain Catchment Areas	*Mountain Catchment Areas Act (Act 63 of 1970)*			

Four other pieces of legislation also make provision for declaration of formal protected areas in the country, namely World Heritage Convention Act (Act 49 of 1999), Marine Living Resources Act (Act 18 of 1998), National Forests Act (Act 84 of 1998) and Mountain Catchment Areas Act (Act 63 of 1970).

Conservation areas on the other hand, are areas of land not formally protected by law but informally protected by the current owners and users and managed at least partly for biodiversity conservation (South Africa, 2010). The Protected Areas Act has, since 2003, made it possible for contract agreements to be used in the wider range of contexts of conservation areas; where the land concerned remains in private hands and conserved under a formal contract between the landowner and an environmental authority. The landowner agrees to restrictions on use of the land and the protected area agency commits to various forms of assistance with management.

Figure 30 provides a map, by province, of the areas of *Aloe ferox* distribution which experience some level of protection of the resource. These protected areas and conservation areas are situated in the eastern parts of the Western Cape, throughout the Eastern Cape and in the southern parts of the KwaZulu-Natal provinces.



(a)

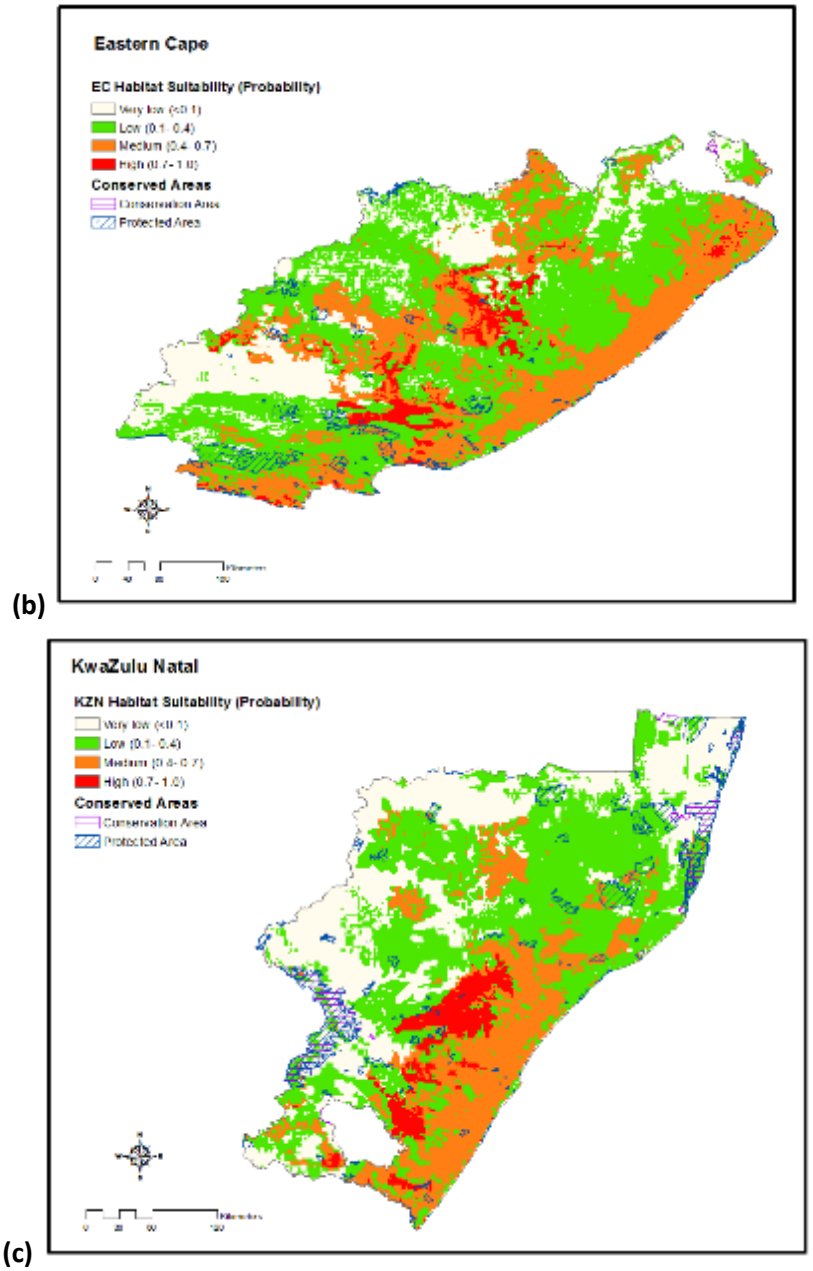


Figure 30: Map indicating areas of protection of *Aloe ferox* in (a) Western Cape; (b) Eastern Cape and (c) KwaZulu-Natal (maps from this assignment)

Of particular concern from Figure 30 is that very little of the high suitability habitat of *Aloe ferox* fall within the conservation and protected areas of the country.

Appendix 1 provides details of the protected areas and conservation areas which fall within the range of *Aloe ferox* in South Africa. Current estimates are that the total area of *Aloe ferox* range which has legal protection in the country is 513 440 hectares, while conservation area of *Aloe ferox* range is

estimated at 217 662 hectares. This is a total area of 731 102 hectares of the *Aloe ferox* range which is under some form of biodiversity-friendly management in the country. This is however only a small area of protection when compared to the entire land area of South Africa or the total protected/conserved area of the country. Table 8 shows that despite *Aloe ferox* distribution covering a large land area of South Africa; extending over at least three provinces, this only includes 5 % of South Africa's protected and conserved areas. The area of *Aloe ferox* that is in protected and conserved areas only covers 1 % of the terrestrial area of the country.

Table 8: Estimated total area of the *Aloe ferox* range within protect areas, as a percentage of all protected/conserved area in the country and as part of the terrestrial area of the country [to be updated in the final report, by province].

TOTAL OF ALOE FEROX RANGE UNDER SOME FORM OF CONSERVATION (Hectares)	PERCENT OF SOUTH AFRICA PROTECTED/CONSERVED AREAS	PERCENT OF LAND AREA OF SOUTH AFRICA
731102, 596	5 %	1 %

11. SUSTAINABLE HARVESTING OF ALOE FEROX

Aloe ferox responds well to harvesting if sufficient control and management of harvest is provided, allowing plants sufficient time to recover (Anon, 1998). However, major considerations of the effect harvesting has on reproduction of plants must be considered, as this may cause long-term impacts on the wild populations. Greengrass (2004) concluded that as a result of harvesting, plants produce fewer flowers. This is attributed to the significant correlation between number of leaves and flower production. Long term effects or reduction in reproductive potential could lead to local extinctions of harvested populations (Greengrass, 2004). Data collected from this study appears to support this notion that in areas where harvesting is extensive and largely uncontrolled, the quality of the plants deteriorates and the number of plants in flower during their flowering season is lowered. Those plants which are not extensively harvested appear to be able to maintain their normal growth and development entering into a reproductive stage more readily.

A simple estimation of the minimum and maximum harvesting practices of harvesters in the Eastern Cape is provided in Table 9 below. Harvesters in the Eastern Cape study indicated that a good harvester (tapper) on average, would collect 1 000 leaves in a day, which make 20-25 litre bucket of aloe liquid (sap) in a day. This is estimated to between 40-50 ml of sap collected per leaf. However, if weather conditions impact (rains or windy) for example, the leaf collection might range from an average 300 to 600 leaves a day, making a 10-15 litre bucket of sap (estimated to between 30-40 ml of sap per leaf). These estimated quantities of exudate per leaf are similarly to those of Merlin (2009), who indicated that an average of 24 leaves is required to obtain one litre of raw leaf exudate – amounting to 41, 6 ml collected from each leaf.

Table 9: Estimation of exudate (litres) per *Aloe ferox* plants harvested.

	Low(l)	Average(l)	High(l)
From a single leaf	0,03	0,04	0,05
Average reported number of leaves harvested per plant	17,0	17,0	17,0
Amount of exudate per plant	0,51	0,68	0,85

Using the latest permitted harvesting data in South Africa, provided by Department of Environmental Affairs, an estimated 38 565 litres of aloe was collected in the last reporting period. Using the estimate

of the number of litres of exudate collected per plant, this would amount to an estimated 45 371 - 75 618 (average 56 713) *Aloe ferox* plants being harvested in this reporting period. Donaldson (2003) estimated the total population size for *Aloe ferox* being over 100 000 individuals, current harvesting estimates would be 45 %-76 % (average 57 %) of plants being harvested during the reporting period.

The same permitting system indicates that 650 394 harvesters are involved in the collection of this leaf exudate, which interestingly amounts to an estimated 59 ml of exudate collected per harvester in this reporting period (or just over 1 leaf per harvester). This could perhaps be attributed to the sporadic manner in which harvesters engage in harvesting or due to harvesters providing exudate to more than one permit holder in the reporting system (i.e. double reporting of harvesters).

The current SABS Aloe raw material standards (SANS 368:2008) indicate that only 8-12 leaves should be removed from any plants, which based on the calculations shown in Table 10, would allow the *Aloe ferox* population to sustain collection from 5563-9271 plants per harvester per annum.

Table 10: Estimation of maximum number of plants, which should be recommended for harvesting per harvester, per day or per annum.

	Low	Average	High
Average estimated litres exudate from single leaf (l)	0,04	0,04	0,04
SANS recommended leaves harvested per plant	8,0	10,0	12,0
Litres of exudate per plant (l)	0,32	0,40	0,48
Estimated litres exudate per harvester per day (l)	10,0	17,5	25,0
Estimated number of plants harvested per harvester per day	31,3	43,8	52,1
Estimated plants harvested per harvester per year (assuming harvest only half a year)	5562,5	7787,5	9270,8

Perhaps more relevant is that the top 4 rosettes of leaves should not be removed from the plant, leaving approximately 16 leaves protecting the growth point of the plant. In some parts of the Eastern Cape, these recommendations are not put into practise with harvesters either leaving fewer leaves on the harvested plant (Figure 31a) or harvesting to a point where the plant dies (Figure 31b). From the data collected in areas of the Eastern Cape, it is clear that harvesting is highly unregulated and extensive with some plants being left with much less than 16 leaves. In instances where, the frequency of plants with lower than 16 leaves protecting the growth point, over 90 % of the plants are not reaching their flowering stage and show no signs of having flowered. This study thus supports the SANS recommendation that 16 or more leaves be left around the growth point of the plant during harvesting.

(a) **(b)**

Figure 31: (a) A non-flowering plant which has been harvested and now only has 9 leaves remaining. In the background, within the same population, plants that have a higher number of leaves which are likely more difficult to reach for harvesters are in flower and (b) Remains of an Aloe plant which has been harvested entirely leading to its mortality (pictures from this assignment).

This literature indicates that the smaller classes of plants should not be harvested, including small, pre-reproductive individuals (Shackleton and Gambiza, 2007). Results concur with this recommendation as the smallest sexually mature plant was 43 cm. However, flowering was more common in plants which were >70cm in height. Interestingly, the current SABS Aloe raw material standards (SANS 368:2008) indicate that plants should be at least 70 cm in height before they are harvested, based on sexual maturation heights of plants in this study.

Zapata et al. (2013) discuss extensively the effects of harvest season on the chemical constituents of Aloes. Time of harvesting needs to be a consideration as the harvesting of plants during their flowering season or close to flowering season may negatively impact the reestablishment of populations. Recent studies have shown that there is a strong correlation in terms of the harvest season and aloin content with it increasing from winter to summer. This increase is thought to be linked to higher levels of radiation. The total phenolic content which is linked to antioxidant activity is also highly influenced by temperatures with extremely low or high temperatures resulting in a stress effect which leads to higher production. Higher levels of polyamines were also indicated in the summer months further reiterating the impacts of climate on the quality of chemical profiles on Aloe species.

Harvesters in the Eastern Cape indicated harvesting from 2-3 month to every 8-10 months. Visual assessment of harvested plants in the Eastern Cape where harvesting is more frequent do show impacts on the development of the plants, with plants looking visually unhealthy when compared to harvested plants in the Western Cape (harvesting is less frequent at 18 months as indicted by interviewees).

Of major concern is the low flowering of plants in the harvested sites which were visited in this study. Although this may be a reflection of conditions in this year, it could also be a reflection of the impact of harvesting of plants. Based on the PCA (Figure 14) model, it appears that those plants within the Eastern Cape where harvesting is extensive, flowering becomes lowered and in the Western Cape, all populations which were not harvested had a high incidence of flowering plants. There may be regional differences in terms of climactic conditions but there is a strong correlation which alludes to the impacts of harvesting on flowering dynamics in Aloe.

Department of Environmental Affairs should consider instituting long-term study site monitoring, of harvested sites to determine whether this practice is a once-off or whether harvested plants continue to not flower on an annual basis. If it relates to harvesting impacts, it will be necessary to perhaps extend the frequency of harvesting from plants to allow the plant to flower between harvests – this would ensure that the population profile is maintained and sustains the population. In general, physical disturbances during the flowering season of plants may affect the general phenology of plants linked to their reproductive stage which is a highly sensitive stage of a plants growth. It appears that in areas where the harvesting frequency is high, harvesting is occurring irrespective of the time of year or stage for the plant. This needs to be monitored closely.

Community projects which may lay a better foundation for harvesters may be one way of controlling illicit exploitation of Aloe species. Also, in areas where poverty is rife the concomitant development of an Aloe industry where farming of the resource is encouraged may be an alternative to the generation of a livelihood so as to decrease uncontrolled wild overharvesting. This would require a systematic development of the industry linked to various skills training, at the environmental to production levels. Ex-situ cultivation may therefore in those cases offer a means of commercialization whilst sustainably conserving the resource.

SANS 369: 2008 also recommends that only leaves 30 cm in length be collected from plants. This is based particularly on the limitations of gel from the smaller leaves, showing that gel firmness and gel

yield of small leaves tend to be rather low (O'Brien *et al*., 2011). Similarly, one could assume that smaller leaves have been harvested at the upper plant rosette where immature leaves are found – these leaves should not be harvested to protect the growth point of the plant.

Sound and effective policy implemented by well-structured and well-equipped conservation agencies backed by government, is pivotal for supporting conservation and optimising the sustainable use of any natural resource in South Africa (Child, 2003; Grace, 2011)

Red-listing of aloes elsewhere in Africa is vital for identifying important conservation hotspots, implementing conservation action plans for rare and threatened taxa, and initiating long-term monitoring projects. *Aloe ferox* is protected under CITES and is listed on Appendix II of the convention and therefore requires export permits.

Summary of key recommendations:

- Current harvesting levels do not seem to have impacted significantly on the presence of *Aloe ferox* within its predicted range. The plants are abundant in certain areas of this range.
- To protect the growth point, the top 16 leaves (top 4 rosettes) of a plant should not be harvested.
- Plants smaller than 70 centimetres or sexually immature plants should not be harvested.
- The leaves collected from a plant (at any one time) should be limited to the SANS recommendation of 8-12 leaves.
- Plants harvesting cycles should be no shorter than 12 months to allow plants to recover and for leaves to reach harvestable lengths (>30cm).
- SANS 369: 2008 recommends that only leaves 30 cm in length collected from plants should be implemented – this will also improve yields from leaves.
- Time of harvesting needs to be a consideration as the harvesting of plants during their flowering season or close to flowering season may negatively impact the reestablishment of populations. Department of Environmental Affairs should consider instituting long-term study sites monitoring of harvested sites to determine whether harvested plants continue to not flower on an annual basis.

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13. APPENDIX 1: STAKEHOLDER QUESTIONS

The cultivation and harvesting assessment should be conducted at the same time as the abundance and distribution assessment. This fieldwork will include contacting stakeholder in the harvesting/cultivating of *Aloe ferox* and requesting whether fieldworkers may visit sites of harvesting/cultivation activities. As the site, fieldworkers should capture the following details from cultivators/harvesters:

- The form of *Aloe ferox* which is being sources (Mossel Bay/Western Cape vs Eastern Cape/PE Aloe)
- Where the plants are harvested
- Ownership of the land on which harvesting occurs
- Number of leaves harvested per plant
- Why do you harvest this number of leaves per plant
- When would you harvest a plant again
- Quantity of 'sap' per leave or per X number of leaves
- Number of plants harvested in a day
- Height/age of plants harvested
- Frequency of harvesting from a plant
- Method of harvesting
- Where did you learn to harvest plants in that manner
- Use of leaf remains
- Container size containing 'cooked' sap
- Average price received for the container
- Number of containers sold per day/week
- Are you aware of any cultivation of plants and by whom

Similarly, with cultivators the chief discussion topics included:

- How do you propagate the plants – seed, cuttings, leaves
- Where do you get the seeds, cutting, leaves
- How many plants do you propagate per year

- Do the plants have to reach a certain age/size before you sell them
- The form of *Aloe ferox* which is being cultivated (Mossel Bay/Western Cape vs Eastern Cape/PE Aloe)
- Where are the plants are cultivated
- Ownership of the land on which harvesting occurs
- Please describe the cultivation requirements and process
- Do the plants need to reach a certain age/size before you harvest from them
- Number of leaves harvested per cultivated plant
- Why do you harvest this number of leave per plant
- When would you harvest a plant again
- Quantity of 'sap' per leave or per X number of leaves
- Number of plants harvested in a day
- Frequency of harvesting from a plant
- Method of harvesting
- Where did you learn to harvest plants in the manner
- Use of leaf remains
- Container size containing 'cooked' sap
- Average price received for the container
- Number of containers sold per day/week
- Are you aware of any cultivation of plants and by whom

14. APPENDIX 2: TABLE A: SITE INSPECTION SHEET

Plant number	Waypoint number	GPS Coordinates	Plant Height (mm)	Photograph number	Number of living intact leaves	Is the plant damaged (describe the damage)	...	Is the plant flowing or has the plant flowered (in seed or remains of rosette visible)	Number of rosettes of flowers	Predominant flower colour
1		S E								
2										
3										

15. APPENDIX 3: TABLE B: PROTECTED AREAS AND CONSERVATION AREAS WITHIN THE ALOE FEROX DISTRIBUTTION

RESERVE NAME	TYPE OF PROTECTED AREA	PROTECTED AREA CATEGORY	PROVINCE	HECTARES	MANAGEMENT AGENT
The Penhurst Rly State Reserve	Local Nature Reserve	Formal_A	Eastern Cape	7,1	Department of Agriculture, Fisheries, and Forestry
Addo Elephant National Park	National Park	Formal_A	Eastern Cape	27293,8	South African National Parks
Bontebok National Park	National Park	Formal_A	Western Cape	3,416	South African National Parks
Camdeboo National Park	National Park	Formal_A	Eastern Cape	18971,7	South African National Parks
Garden Route National Park	National Park	Formal_A	Western Cape	121885	South African National Parks
Mountain Zebra National Park	National Park	Formal_A	Eastern Cape	7020,6	South African National Parks
Baviaanskloof Nature Reserve	Provincial Nature Reserve	Formal_A	Eastern Cape	144853,2	Eastern Cape Parks Board
Boosmansbos Wilderness Area	Provincial Nature Reserve	Formal_A	Western Cape	3675,2	Cape Nature
Caledon Nature Reserve	Provincial Nature Reserve	Formal_A	Free State	3772,93	Free State Provincial Government
Commando Drift Nature Reserve	Provincial Nature Reserve	Formal_A	Eastern Cape	3015,5	Eastern Cape Parks Board
Cycad Provincial Nature Reserve	Provincial Nature Reserve	Formal_A	Eastern Cape	227,7	Eastern Cape Parks Board
De Hoop Nature Reserve	Provincial Nature Reserve	Formal_A	Western Cape	34000	Cape Nature
Doreen Clark Nature Reserve	Provincial Nature Reserve	Formal_A	KwaZulu Natal	5,82	Ezemvelo KZN Wildlife
Doringrivier Wilderness Area	Provincial Nature Reserve	Formal_A	Western Cape	9520,26	Cape Nature
Dwesa-Cwebe Wildlife Reserve & Marine Sanctuary	Provincial Nature Reserve	Formal_A	Eastern Cape	4450	Eastern Cape Parks Board
East London Coast Nature Reserve	Provincial Nature Reserve	Formal_A	Eastern Cape	2638,6	Eastern Cape Parks Board
EC Soetkraal Provincial Nature Reserve	Provincial Nature Reserve	Formal_A	Eastern Cape	0	Eastern Cape Parks Board
Formosa Provincial Nature Reserve	Provincial Nature Reserve	Formal_A	Eastern Cape	22903,4	Mpumalanga Tourism and Parks Agency

RESERVE NAME	TYPE OF PROTECTED AREA	PROTECTED AREA CATEGORY	PROVINCE	HECTARES	MANAGEMENT AGENT
Fort Fordyce Nature Reserve	Provincial Nature Reserve	Formal_A	Eastern Cape	532,3	Eastern Cape Parks Board
Gamkaberg Nature Reserve	Provincial Nature Reserve	Formal_A	Western Cape	9428	Cape Nature
Gamkapoort Nature Reserve	Provincial Nature Reserve	Formal_A	Western Cape	9191,77	Cape Nature
Geelkrans Provincial Nature Reserve	Provincial Nature Reserve	Formal_A	Western Cape	225,37	Cape Nature
Great Fish River Nature Reserve	Provincial Nature Reserve	Formal_A	Eastern Cape	211	Cacadu District Municipality
Groendal Nature Reserve	Provincial Nature Reserve	Formal_A	Eastern Cape	8442,7	Eastern Cape Parks Board
Groenfontein Nature Reserve (Gamkaberg)	Provincial Nature Reserve	Formal_A	Western Cape	2033,7	Cape Nature
Grootvadersbosch (Thornhill)-WWF land (Proposed Reserve)	Provincial Nature Reserve	Formal_A	Western Cape	0,6	Cape Nature
Hamburg Nature Reserve	Provincial Nature Reserve	Formal_A	Eastern Cape	808,8	Eastern Cape Parks Board
Hluleka Wildlife Reserve & Marine Sanctuary	Provincial Nature Reserve	Formal_A	Eastern Cape	609	Eastern Cape Parks Board
iGxalingenwa Nature Reserve	Provincial Nature Reserve	Formal_A	KwaZulu Natal	1517,3	Ezemvelo KZN Wildlife
Impendle Nature Reserve	Provincial Nature Reserve	Formal_A	KwaZulu Natal	8742	Ezemvelo KZN Wildlife
Indhloveni Nature Reserve	Provincial Nature Reserve	Formal_A	KwaZulu Natal	29,8	Ezemvelo KZN Wildlife
Island Nature Reserve	Provincial Nature Reserve	Formal_A	Eastern Cape	495,2	Eastern Cape Parks Board
Karkloof Nature Reserve	Provincial Nature Reserve	Formal_A	KwaZulu Natal	2800	Ezemvelo KZN Wildlife
Keurboomsrivier - Seemeeu Broeikolonie	Provincial Nature Reserve	Formal_A	Western Cape	33,3	Cape Nature
Keurboomsrivier Nature Reserve	Provincial Nature Reserve	Formal_A	Western Cape	994	Cape Nature
Krantzkloof Nature Reserve	Provincial Nature Reserve	Formal_A	KwaZulu Natal	588,4	Ezemvelo KZN Wildlife

RESERVE NAME	TYPE OF PROTECTED AREA	PROTECTED AREA CATEGORY	PROVINCE	HECTARES	MANAGEMENT AGENT
Kruisrivier (Broomvlei) Nature Reserve	Provincial Nature Reserve	Formal_A	Western Cape	183,5	Cape Nature
Kwa Yili Nature Reserve	Provincial Nature Reserve	Formal_A	KwaZulu Natal	695,8	Ezemvelo KZN Wildlife
Malekgonyane (Ongeluksnek) Wildlife Reserve	Provincial Nature Reserve	Formal_A	Eastern Cape	10225	Eastern Cape Parks Board
Marutswa Nature Reserve	Provincial Nature Reserve	Formal_A	KwaZulu Natal	267,6	Ezemvelo KZN Wildlife
Marwaqa Nature Reserve	Provincial Nature Reserve	Formal_A	KwaZulu Natal	357,1	Ezemvelo KZN Wildlife
Mbumbazi Nature Reserve	Provincial Nature Reserve	Formal_A	KwaZulu Natal	47,4	Ezemvelo KZN Wildlife
Mehlomnyama Nature Reserve	Provincial Nature Reserve	Formal_A	KwaZulu Natal	162,5	Ezemvelo KZN Wildlife
Midmar Nature Reserve	Provincial Nature Reserve	Formal_A	KwaZulu Natal	2 857	Ezemvelo KZN Wildlife
Mkambati Nature Reserve	Provincial Nature Reserve	Formal_A	Eastern Cape	7432,4	Eastern Cape Parks Board
Mount Currie Nature Reserve	Provincial Nature Reserve	Formal_A	KwaZulu Natal	1769,7	Ezemvelo KZN Wildlife
Mpenjati Nature Reserve	Provincial Nature Reserve	Formal_A	KwaZulu Natal	73,6	Ezemvelo KZN Wildlife
Mpofu Nature Reserve	Provincial Nature Reserve	Formal_A	KwaZulu Natal	9022,8	Eastern Cape Parks Board
Ntsikeni Wildlife Reserve	Provincial Nature Reserve	Formal_A	KwaZulu Natal	4,3	Ezemvelo KZN Wildlife
Oribi Gorge Nature Reserve	Provincial Nature Reserve	Formal_A	KwaZulu Natal	1878,81	Ezemvelo KZN Wildlife
Queen Elizabeth Park Nature Reserve	Provincial Nature Reserve	Formal_A	KwaZulu Natal	92,9	Ezemvelo KZN Wildlife
Robberg Nature Reserve	Provincial Nature Reserve	Formal_A	Western Cape	2618	Department of Environmental Affairs
Silaka Wildlife Reserve	Provincial Nature Reserve	Formal_A	Eastern Cape	400	Eastern Cape Parks Board
Skyline Nature Reserve	Provincial Nature Reserve	Formal_A	KwaZulu Natal		Ezemvelo KZN Wildlife

RESERVE NAME	TYPE OF PROTECTED AREA	PROTECTED AREA CATEGORY	PROVINCE	HECTARES	MANAGEMENT AGENT
Soada Forest Nature Reserve	Provincial Nature Reserve	Formal_A	KwaZulu Natal	496,2	Ezemvelo KZN Wildlife
Spioenkop Nature Reserve	Provincial Nature Reserve	Formal_A	KwaZulu Natal	4400	Ezemvelo KZN Wildlife
Thomas Baines Nature Reserve	Provincial Nature Reserve	Formal_A	Eastern Cape	1047	Eastern Cape Parks Board
Trafalgar MPA	Provincial Nature Reserve	Formal_A			Ezemvelo KZN Wildlife
Tsolwana Nature Reserve	Provincial Nature Reserve	Formal_A	Eastern Cape	7514	Eastern Cape Parks Board
Umtamvuna Nature Reserve	Provincial Nature Reserve	Formal_A	KwaZulu Natal	3 247	Ezemvelo KZN Wildlife
Vaalhoek Nature Reserve (Gamkaberg)	Provincial Nature Reserve	Formal_A	Western Cape	1336,9	Cape Nature
Vernon Crookes Nature Reserve	Provincial Nature Reserve	Formal_A	KwaZulu Natal	2229,8	Ezemvelo KZN Wildlife
Waters Meeting Nature Reserve	Provincial Nature Reserve	Formal_A	Eastern Cape	4055	Eastern Cape Parks Board
Xotsheyake Nature Reserve	Provincial Nature Reserve	Formal_A	KwaZulu Natal	98,3	Ezemvelo KZN Wildlife
TOTAL PROTECTED AREA				**513440,076**	
Aberdeen Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	1673	Local Protected Area
AloeRidge Local Nature Reserve	Local Nature Reserve	Formal_B	Western Cape	4,23	Local Protected Area
Blaauwkrantz Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	198	Local Protected Area
Bosberg Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	2698	Local Protected Area
Bridle Drift Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	553	Local Protected Area
Cape Recife Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	560	Local Protected Area
Die Fort Local Nature Reserve	Local Nature Reserve	Formal_B	Western Cape	114,4	Local Protected Area
Ecca Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	127	Local Protected Area
Gamtoos River Mouth Local Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	973,7	Local Protected Area
Ghio Wetland Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	61,7	Local Protected Area
Gonubie Mouth Bird Sanctuary	Local Nature Reserve	Formal_B	Eastern Cape	8,7	Local Protected Area

RESERVE NAME	TYPE OF PROTECTED AREA	PROTECTED AREA CATEGORY	PROVINCE	HECTARES	MANAGEMENT AGENT
Great Fish River Wetland Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	211	Cacadu District Municipality
Huisklip Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	318	Eastern Cape Parks Board
Kap River Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	263	Cacadu District Municipality
Kareedouw Local Authority Nature Reserve	Local Nature Reserve	Formal_B		815,9	Free State Provincial Government
Katrivier Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Western Cape	77	George Municipality
King William's Town Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	109	Buffalo City Municipality
Kowie Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	143,4	Local Protected Area
Ladismith-Kleinkaroo	Local Nature Reserve	Formal_B	KwaZulu Natal	34,5	Local Protected Area
Lady Slipper Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	40,7	Local Protected Area
Maitland Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	4405	Unknown
Nahoon Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	33	Buffalo City Municipality
Noorsekloof Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	27	Kouga Municipality
Pauline Bohnen Local Nature Reserve	Local Nature Reserve	Formal_B	Western Cape	386,6	Local Protected Area
Pledge Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Western Cape	10	Local Protected Area
Potters Pass Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	78	Buffalo City Municipality
Quacu Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	441	Eastern Cape Parks Board
Quenera Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	81	Buffalo City Municipality
Rietvlei	Local Nature Reserve	Formal_B	Western Cape	525,6	Local Protected Area
Roundhill Oribi Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	185,2	Local Protected Area
Sardinia Bay Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	319	Municipality Nelson Mandela Bay Metropolitan Area
Settlers Park Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	74,8	Local Protected Area
SKULPIESBAAI LOCAL NATURE RESERVE	Local Nature Reserve	Formal_B	Western Cape	79,1	Local Protected Area
Springs Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	931,2	Local Protected Area
Swartkops Valley Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	1029,8	Local Protected Area
Sylvic Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	73,3	Local Protected Area
Van Kervel Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Western Cape	11	George Municipality

RESERVE NAME	TYPE OF PROTECTED AREA	PROTECTED AREA CATEGORY	PROVINCE	HECTARES	MANAGEMENT AGENT
Van Stadens Wild Flower Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	300	Port Elizabeth Regional Services Council
Werner Frehse Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Western Cape	166,49	Local Protected Area
Yellowwoods Local Authority Nature Reserve	Local Nature Reserve	Formal_B	Eastern Cape	26,2	Local Protected Area
Grootswartberg Mountain Catchment Area	Mountain Catchment Area	Formal_B	Western Cape	9607	Private
Kammanassie Mountain Catchment Area	Mountain Catchment Area	Formal_B	Western Cape	30296	Private
Klein Swartberg Mountain Catchment Area	Mountain Catchment Area	Formal_B	Western Cape	32568	Private
Langeberg -Oos/East Mountain Catchment Area	Mountain Catchment Area	Formal_B	Western Cape	40663	Private
Langeberg -Wes Mountain Catchment Area	Mountain Catchment Area	Formal_B	Western Cape	63311	Private
Rooiberg Mountain Catchment Area	Mountain Catchment Area	Formal_B	Western Cape	12546	Private
Swartberg-Oos Mountain Catchment Area	Mountain Catchment Area	Formal_B	Western Cape	10504	Private
TOTAL CONSERVATION AREA				**217662,52**	
TOTAL OF ALOE AREA UNDER SOME FORM OF CONSERVATION				**731102,596**	

* forest and marine protected areas not included in table

REFERENCE:
http://bgis,sanbi,org/municipalities/municipality,asp