National Monitoring of Important Bio-traded Plants in South Africa

FINAL REPORT

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Full title:

Principles for a
suitable approach to a long-term national monitoring
programme that considers important indigenous bio-traded
species in South Africa and a regional resource assessment

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Final report: Task 1

(Task 2 as a standalone report)

This report was prepared by independent, external experts and reflects their opinions and evaluations. For: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH; and The ABS Capacity Development Initiative (ABS Compliant Bio-trade in Southern Africa)

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Executive summary

With the rapid increase in national and international trade in wild-harvested plants, South Africa is uniquely positioned to become a leader in the field of bio-traded plants. The establishment of national level management and monitoring systems is essential to ensuring long-term ecological sustainability of these resources.. A key component of these management systems is the evaluation of resources in terms of their standing stocks and productivity in relation to harvesting. This should be coupled with long-term monitoring to assess and adjust for changes so that harvests are sustainable. This report explores key issues, principles and approaches to the evaluation and long-term monitoring of stocks and flows of eleven bio-traded plant resources.

To be sustainable, harvest levels of commercially traded wild plants need to be based on a sound knowledge of the ecology, distribution, abundance, and productivity of the harvested species. In this regard, this report provides information profiling each of the eleven target species with specific reference to their sustainable use. In addition, a literature review has been conducted that describes the aims, methods, and results of all available resource assessments for each of the target species.

Acknowledgements

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Introduction

1.1 Understanding of brief

With growing demands to expand the bio trade industry in South Africa, it is becoming increasingly important that this sector complies with international and domestic Access and Benefit Sharing regulations and obligations. It must also be fundamentally ecologically, economically, and socially sustainable.

The focus of this consultancy is on the ecological sustainability of the most commonly wild-traded plants, and the principles and approaches relevant to resource assessments that can monitor for this.

This consultancy provides supporting documentation for a workshop held by ABioSA in collaboration with SANBI. The aim of the workshop is to initiate a programme that effectively monitors resource stocks and the sustainability of the most important wild-harvested bio-traded plants in southern Africa.

In the process of developing and optimising this national monitoring programme, there may be a need to standardise local, national, or regional-level approaches to particular resource assessment methods. In addition, the resource studies to be conducted through this programme should reveal changes, if any, in the condition and extent of the resource base. It should provide data and other information to enable stakeholders at intervals to draw conclusions as to the degree of sustainability.

In preparation of the above-mentioned workshop, the aim of this consultancy is to identify the principles for, and suitable approach to, establishing precise and repeatable methodologies, which are scientifically sound, technologically appropriate, and accommodating of financial realities.

Specific tasks of this consultancy are to provide documentation to identify the principles for, and suitable approach to, establishing:

Task 1: A long-term national monitoring programme that considers important indigenous bio-traded species in South Africa. This monitoring programme will necessarily address the need for resource assessments for the following species: honeybush (all wild-harvested commercial species), rooibos (*Aspalathus linearis*), *Pelargonium sidoides*, marula, baobab, buchu (*Agathosma betulina* and *A. crenulata*), Devil's Claw (*Harpagophytum procumbens), Kalahari Melon (Citrillus lanatus)* and *Aloe ferox*.

Task 2: A regional resource assessment and monitoring programme for marula (*Sclerocarya birrea* subsp. *caffra*) in southern Africa, covering the following range countries: South Africa, Eswatini, Namibia, Zimbabwe, Botswana, Zambia and secondary countries; Mozambique, Malawi, Madagascar and Angola.

Specifically, this will also include: A desktop review of past or current resource assessments undertaken or on-going in southern Africa for the listed species, international best practice review, threat analysis, available expertise and science networks for these species. It will also review any other factors that may specifically influence the character of the proposed national monitoring programme in South Africa (industry/ecological science networks, development projects, organisational mandates etc).

1.2 Limitations and approach

The TOR refers to 'the need for standardised local, national, or regional-level approaches to resource assessments' for the target species. In this regard, two issues need to be considered.

First is the scale of the assessment. The emphasis of this consultancy is placed on the national scale. In other words, a system that monitors changes in total plant stocks across its natural distribution range within South Africa (and in the case of marula, within the sub region). As will become evident later in this report, there are inherent difficulties of accuracy when assessing resource stocks at this scale, and out of necessity a GIS modelling approach will be required. Typically, to improve accuracy of models, calibration (and ground-truthing) is required, at local or landscape scales. The implications are that national scale monitoring will need to consider all three scales (see Table 1 below). In other words, a multiscale approach is required.

Secondly, the issue of standardisation needs to be considered. The need for standardised methods are important for repeat assessments to determine trends in resource stocks. However, a standardised method may not always be possible, at least for multiple species.

In this regard, it is worth noting conclusions reached by an FAO working group (FAO, 1996) that it is "virtually impossible and therefore perhaps futile to search for a generalised technique for non-timber forest product (NTFP) resource assessment". The difficulties associated with this were listed as, major differences in:

- Intended use of the survey results
- The different species life forms
- Spatial scale, and temporal scale
- Technical requirements and cost
- Statistical rigour required

In addition, the working group (FAO, 1996) pointed out that while traditional forestry resource assessment and monitoring methods are well described and developed, the direct adoption of these techniques for NTFP were seldom possible, given the differences in the target resource (Wong, 2001).

The challenge is to develop efficient single and multi-species inventory and data analysis procedures at a range of scales from local to national level. This must be done without alienating the people who will benefit from the data collected and who should be given the opportunity to participate in the proceedings (Wong, 2000; Wong, 2003).

The scale of monitoring is of critical importance to the approach adopted. Depending on the purpose of the assessment, finer scales may be needed to improve accuracy. We recognise three distinct scales: local, landscape and national/regional (see Table 1 for more detail). An integrated, multi-scale approach to national level monitoring is recommended.

1.3 Resource monitoring frameworks

1.3.1 Principles Criteria Indicators

We propose to use a Principles Criteria Indicators (PCI) monitoring framework to provide an overall context to the monitoring programme. The PCI approach has been widely adopted globally to promote, measure and monitor sustainability. Principles are fundamental statements about a desired outcome. Criteria are the conditions that need to be met in order to comply with a principle. 'Indicators' are the measurable states that allow the assessment of whether or not a particular criterion has been met.

The PCI approach is used in forestry certification globally (for example by the Forestry Stewardship Council), and in South Africa to track progress towards sustainable forest management. In terms of the National Forests Act (84 of 1998), principles, criteria, indicators and standards for sustainable forest management were developed to promote and monitor sustainable management of forests in South Africa.

There are a number international PCI frameworks that have direct relevance to the trade and monitoring of wild-harvested plants. These include the BioTrade Principles and Criteria (P&C), the Fair Wild Certification process, and the Addis Ababa Principles. BioTrade P&C were developed under the umbrella of the UNCTAD BioTrade Initiative, in line with international framework for sustainable management of traded wild resources. The principles reflect, amongst others, the aims and objectives of the Convention on Biological Diversity (CBD), Commission on Sustainable Development, Millennium Development Goals and Convention on International Trade in Endangered Species of Wild Fauna and Flora (United Nations, 2007).

Fair Wild is an initiative developed between IUCN, TRAFFIC and WWF as part of the EU-China Biodiversity Programme (ECBP) to promote the sustainable harvesting of wild medicinal plants. It is an international market-based certification programme aimed at ensuring sustainable harvesting of wild resources (Fair Wild Foundation, 2010).

We propose a national monitoring programme draws on these initiatives. It can select suitable principles and criteria that best align with South African legislation, policy directives and mandates of organisations (SANBI, DEFF) involved in monitoring and regulating the trade in wild-harvested plants. A PCI framework provides an overall context for policy alignment and international best practice, as well as a placing emphasis on a holistic approach that considers the ecological, social, and economic components of sustainability.

1.3.2 Drivers- pressure- state- response (DPSIR) monitoring

According to the DPSIR framework there is a chain of causal links starting with driving forces (economic sectors, human activities) through pressures (emissions, waste) to states (physical, chemical, and biological) and impacts on ecosystems, human health and functions, eventually leading to political responses (prioritisation, target setting, indicators). Describing the causal chain from driving forces to impacts and responses is a complex task, and tends to be broken down into sub-tasks, e.g. by considering the pressure-state relationship (see Figure 1 below).

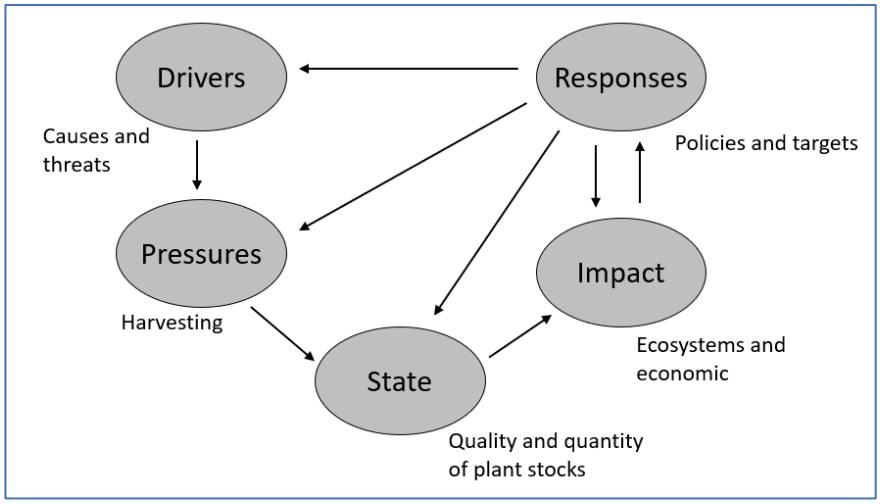

Figure 1 The DPSIR framework typically used for state of environment reporting (adapted for this context)

This is a useful and holistic monitoring framework that considers cause effect relationships that may impact on the trade in wild-harvested plants from an economic, policy and sociological viewpoint.

1.3.3 Ecosystem service value chains

Over the last decade, the ecosystem services (ES) concept has gained considerable attention as a framework that could reconcile the needs of biodiversity conservation with economic growth and societal benefits derived from natural resources.

Ecosystem services are the contributions of ecosystems to benefits in economic, social, cultural, and other human activities. Wild-harvested plants are considered a provisioning service that has a cascade of events from stocks, flows and evaluation of goods. The economic value of the provisioning services is dependent on the ecosystem state and function of the underlying ecosystems in which the wild plants stocks occur, namely the supporting services (see Figure 2 below).

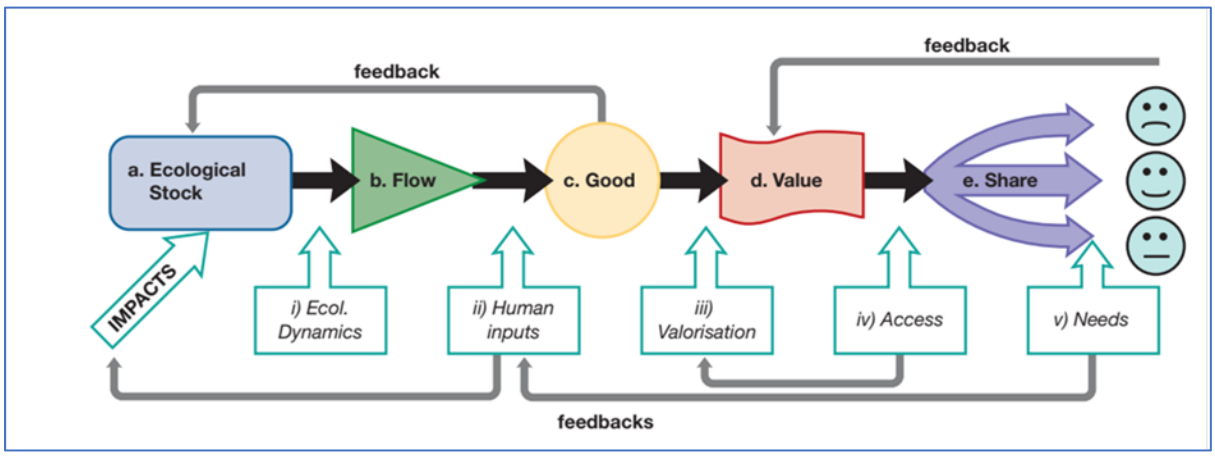

Figure 2 Ecosystems service cascade as a framework for monitoring wild resources

Within an ecosystem services framework, monitoring for sustainability needs to consider the broader context and state of the ecosystem supporting services, as well as the cascade of the value

chain that arises from the use of these plants. This approach can be used to identify strategic points where monitoring of indicators can provide an early warning system for over-harvesting and non-sustainable use.

2 Considerations for national level resource assessments

2.1 The importance and implications of scales of monitoring

In Table 1, below, the implications of the spatial scale of the resource assessment are considered. Depending on the purpose of the assessment, larger scale assessments should include input from lower scales (ground based) to improve accuracy. We recognise three distinct spatial scales: Local, landscape and national/regional. Monitoring can be conducted at any scale, however it is recommended that an integrated multi-scale approach is used for long term, national level, repeat monitoring.

Table 1 Resource assessment scales can occur at different spatial and time scales

Spatial scale	Time scale	Key tools	Who?	Administrative scale	Key limitations	Main advantages
Local	Annual, bi-annual	Sample plots/transects	Community Research NGO Industry boards/collectives	Community, village forest section, farm	Limited samples size, time consuming	Easy to replicate. Additional data collected as well as impact yield. Suitable for small species.
Landscape	2-5 years	Arial imagery, drones, Google Earth, road counts, LiDAR	Local government Researchers NGOS	Forest management unit, local community, district administration	May require ground truthing. Only certain species detectable.	Habitat condition, landscape process analysis (erosion, overgrazing)
Regional/national	5 years +	Satellite imagery, GIS modelling (Max ENT)	National government SOE's Researchers NGOS	Provincial, national, regional	May only be feasible for certain species (trees or clumped distribution). Requires ground truthing. Absolute determination may not be possible.	Possible to develop national level standardised methods. For policy formulation, national quotas, trade agreements.

2.2 Monitoring at different stages of the value chain

A value chain analysis for traded wild plant resources can provide clues as to data collection points, that can supplement a ground-based monitoring programme. An example of a generic value chain is given in the Figure 3 below.

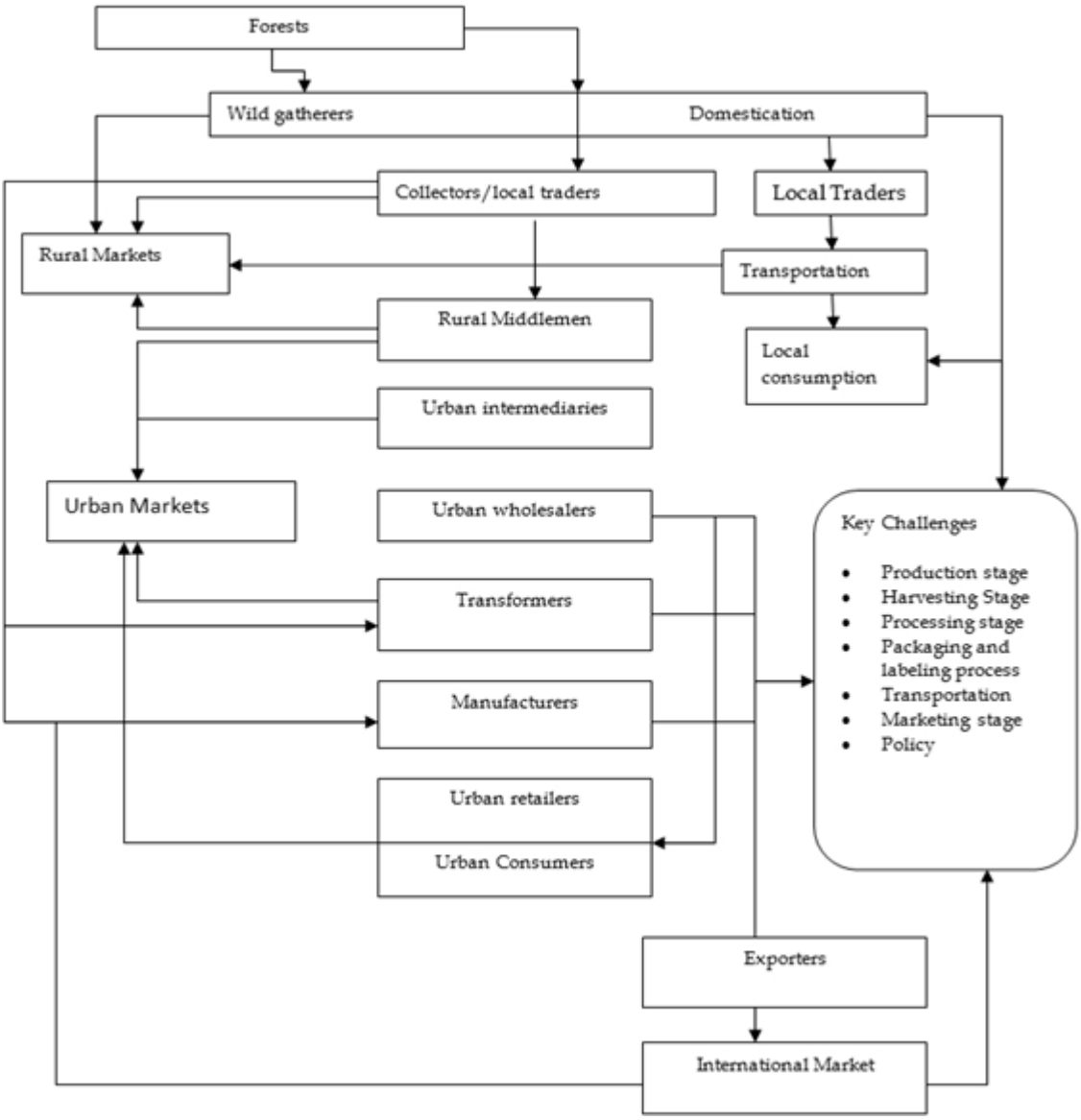

Figure 3 A generic hypothetical value chain that be used to identify strategic data collection points

2.3 Monitoring of trade data

It is recommended that population monitoring of all species be supplemented by trade data analysis. This includes total annual quantities of material exported. Discrepancies between export and imported quantities, as reflected in records for CITES listed species (CITES Trade Database, UNEP World Conservation Monitoring Centre, Cambridge, UK) signify a need for further investigation into possible illegal trade.

It is recommended that population monitoring of all species be supplemented by data on quantities collected and traded along the product value chain. Table 2 below is a generalised overview of data and potential data sources along a generalised plant bio-trade value chain.

Table 2 Generalised overview of data and potential data sources along a generalised plant bio-trade value chain

Value chain	Quantity data (weight/vol/monetary)	Sources	Limitations
Producers Wild Farms	Annual production	Government: Permit quotas. Producer associations: Levies/production records. Export control boards.	Illegal harvesting. No permit system in place. Non-members of producer associations. No ECB for the product.
Intermediaries	Annual intake/ purchases	Intermediary records	Records unavailable/non-disclosure
Processors	Annual intake Annual outgoing (volume/weight conversion rates)	Processor records required by permit system. Processor records, or if unavailable, can be inferred from incoming if conversion rate known.	Conversion rates may vary. Records unavailable.
Local retailers	Annual intake Annual outgoing	Retailer records	Records unavailable
Exporters	Annual Exports Sales	Export permit Export control boards Customs statistics CITES trade database Exporter records Producer association export records or can be inferred if the ratio of export to domestic distribution is known for the species.	Only required for CITES listed species. Not species specific. No ECB for the product. Not CITES listed. Records unavailable. Ratios may change over time.
Importers	Annual imports Sales	CITES trade database. Eurostat trade data online Importer records.	Omissions and errors in CITES reports. Not CITES listed. Records unavailable.

Although these data are patchy and may have significant errors and omissions, they may be useful in signalling need for further investigation where discrepancies are evident, as well as indicate trends. Discrepancies between harvest quotas reflected on permits and quantities processed may signify a need for further investigation into possible illegal harvesting; while discrepancies between export and import quantities signify possible illegal trade. Trends such as a sudden increase in export volumes may signify the need for more intensive monitoring of areas where harvesting is known to be taking place.

Potential monitoring data points along the value chain for honeybush tea, *Pelegonium sidoides* and *Aloe ferox,* are explored in Tables 3, 4 and 5 below.

Table 3 Honeybush tea monitoring data points along value chain

Data source	Type of data available	Access/limitations
Permit system Quotas issued Processor wet intake	Eastern Cape DEDEAT operates a permit system. Suppliers required to have an annual permit for an estimated allowed harvest tonnage for wild and cultivated species, held by the landowner or the harvest manager. Four of the six main processors are located in the Eastern Cape. EC DEDEAT permit system requires processors to record wet tonnage brought in and check the source of the material against the supplier's permit allowance (should match with permit quantities allocated by EC).	No permit system in Western Cape
Producer Associations Levies Annual production Annual sales	South African Honeybush Tea Association (SAHTA). Eight or nine processing plants in operation. Six are members of SAHTA and pay levies per kg of tea processed.	Non-members of SAHTA
Intermediaries	No intermediaries	
Processor records	EC processor intake records for permit checking (see above)	Not available in Western Cape
Domestic distributors Annual distribution **Exporters** Annual exports	Cape Tea Company, Khoisan Tea (buyers and exporters), Processors who sell locally and export: Cape Honeybush Tea, Melmont, Agulhas tea, Honeybush Natural Products, Honey Blossom Tea Traders, Independent Honeybush Producers Langkloof.	Records not available
Export control boards	Perishable Products Export Control Board (PPECB). Annual export.	Not species specific
Export Permit	Not required	
CITES trade database	Not CITES listed	
Importer Records Annual imports Annual sales	Multiple importers Eurostat trade data	

Table 4 Pelargonium sidoides monitoring data points along value chain

Data source	Type of data available	Access/limitations
Producer permits	No permit required (not on NEMBA TOPs list)	
Producer associations	No producer association	
Intermediaries	Gowar Enterprises	Non-disclosure
Processors	BZH Export and Import Parceval	Non-disclosure
Domestic distributors Annual distribution	Parceval	Non-disclosure
Exporters Annual export	Parceval	Non-disclosure

Export permits	Not required (not CITES listed)	
Export control boards Annual exports	None? Export permit records	
CITES trade database	Not CITES listed	
Importer Records Annual imports Annual sales	Schwabe Germany Eurostat trade data	Non-disclosure

Sources: Government Gazette, 2013; van Niekerk, J. & Wynberg, R. 2012.

The *P. sidoides* BMP notes the paucity of data on quantities harvested, processed, and exported. "Lack of information is currently one of the biggest challenges impeding sustainable management of this trade" (Government Gazette, 2013).

Table 5 Aloe ferox monitoring data points along value chain

Data source	Type of data available	Access/limitations
Producer permits	No permit/quota system?	
Producer associations	Aloe Council of South Africa - not a producer association and does not collect data on production or levy production	
Intermediaries	Multiple – some willing to provide data	
Processors	Multiple - some willing to provide data	
Domestic distributors Annual distribution	Five National and regional suppliers to pharmacies	Data difficult to obtain – competition
Exporters	Multiple to multiple countries	
Export permits	Export permits are required	
Export Control Boards Annual exports	Not covered by PPECB?	
CITES trade database	CITES trade database records available World Conservation Monitoring Centre	
Importer records	Importer records required by CITES Eurostat trade data	

Sources: Newton and Vaughan, 1996

2.4 Threat analysis and selection of monitoring sites

Threat analysis is important for establishing protocols for the long-term sustainable use of a species. Harvesting may be unsustainable if it is accompanied by other threats such as climate change, or livestock grazing pressure. In Table 6 below, the most important drivers of change are listed and scored. Ideally these should be spatially represented across the distribution range to map threats for each species. A zero to three scoring system is used to indicate the severity of the threat for each species considered.

2.4 Considerations of genetic diversity

There is an increased need to monitor changes in the genetic makeup and diversity of bio-traded plants. This is important not only for the conservation of the species but also for ensuring the quality of the harvested products, which can vary with genetic differences (chemovars) within a species.

Early farmers selected for traits either deliberately or unintentionally that made wild plants more suitable for human needs. These included characteristics that improved yield, made agricultural production easier (loss of seed dormancy; retention of seed on the plant), or improved product quality (Gepts, 2004).

With the increased trend for the cultivation of a number of bio-traded plants (such a buchu, honeybush, rooibos, devils' claw, and Kalahari melon) there is likely to be increased active or passive genetic selection for desirable traits. These traits may not necessary be beneficial for the survival of the species in the wild. This risk of genetic contamination and genetic erosion of wild stocks from semi-domesticated cultivars is very real and requires ongoing monitoring.

Genetic erosion is the loss of genetic diversity within a species. It can happen very quickly, due to catastrophic events, or changes in land use leading to habitat loss. But it can also occur more gradually and remain unnoticed for a long time. One of the main causes of genetic erosion is the replacement of local varieties by modern varieties. Genetic diversity is important to a species' fitness, long-term viability, and ability to adapt to changing environmental conditions.

Arguably, only one of the target bio-traded species can be considered as fully domesticated. This is Kalahari melon (*Citrullus lanatus*) - the ancestor of all cultivated watermelons. A number of our target species may qualify in certain regions as being 'wild tendered', where there has been some selection of sex, fruit size and taste. The marula is a good example of this. The ongoing selection of chemovars (for specific taste, such as in honeybush and rooibos, and for essential oils, such as in buchu) are resulting in semi-domesticated varieties, that may differ from the wild stocks (Tony Cunningham personal communication).

Domesticated plant species are those whose breeding systems have been so changed through genetic or phenotypic selection that they have become dependent upon sustained human assistance for their survival. Wild and domesticated species are at opposite ends of a continuum (Cunningham, 2001).

Table 6 Analysis of main drivers of change for target species. Key: 0 = not relevant; 1 = potentially or minor; 2 = possess some threat; or significant but highly localised areas; 3 = major threat across a significant part of the species range. ? = high level of uncertainty

Threats	*Aloe ferox*	Baobab	Marula	Honeybush	Buchu (*A. betulina*)	Buchu (*A. crenulata*)	*P. sidoides*	Kalahari melon	Devil's claw	Rooibos
Habitat loss and conversion	2	0	2	2	1	1	2	0	1	2
Legal resource use/overharvesting?	2 (?)	1	2	2	2	1	2	0	1	2
Illegal harvesting unpermitted	2 (?)	1	1	1	2	1	2 (?)	0	1	2
Subsistence use	0	0	0	0	0	0	1	0	1	1
Increase in fire frequency/intensity	2	0	1	2	2	2	1	0	0	2
Invasive alien species	1	0	0	2	1	1	1	0	0	1
Bush encroachment	2	0	1	0	0	0	1	0	0	0
Diseases, pathogens	1	1	0	0	1	1	1	0	?	1
Introduced genetic material	0	0	0	1	0	0	0	0	0	2 /3
Soil erosion, sedimentation	1	0	0	1	0	0	1	0	1	1
Livestock trampling, overgrazing	2	2	1	2	0	0	2	0	0	2
Wild herbivores	2	2	2/3*	0	0	0	1	0	0	2
Other wildlife (baboons etc)	1	2	0	0	0	0	?	0	0	2
Climate change (rainfall temp, frost)	2	2	1	1 (C.i) 2 (C. s.)	2	2	1	0	0	2
Threats to pollinators	0	2 (?)	1	0	1	1	?	?	?	

* With high elephant impact

Where suitable spatial surrogates for specific threats can be identified, these can be spatially modelled and represented within a GIS. Complex spatial threat modelling using multi-criteria analysis approaches as typically used in conservation planning (see Figure 4 below for example) can be used if data and time permit. However, in most cases this may not be necessary, and a generalised surrogate for threats and drivers of change such as land use/land cover/land tenure may be adequate.

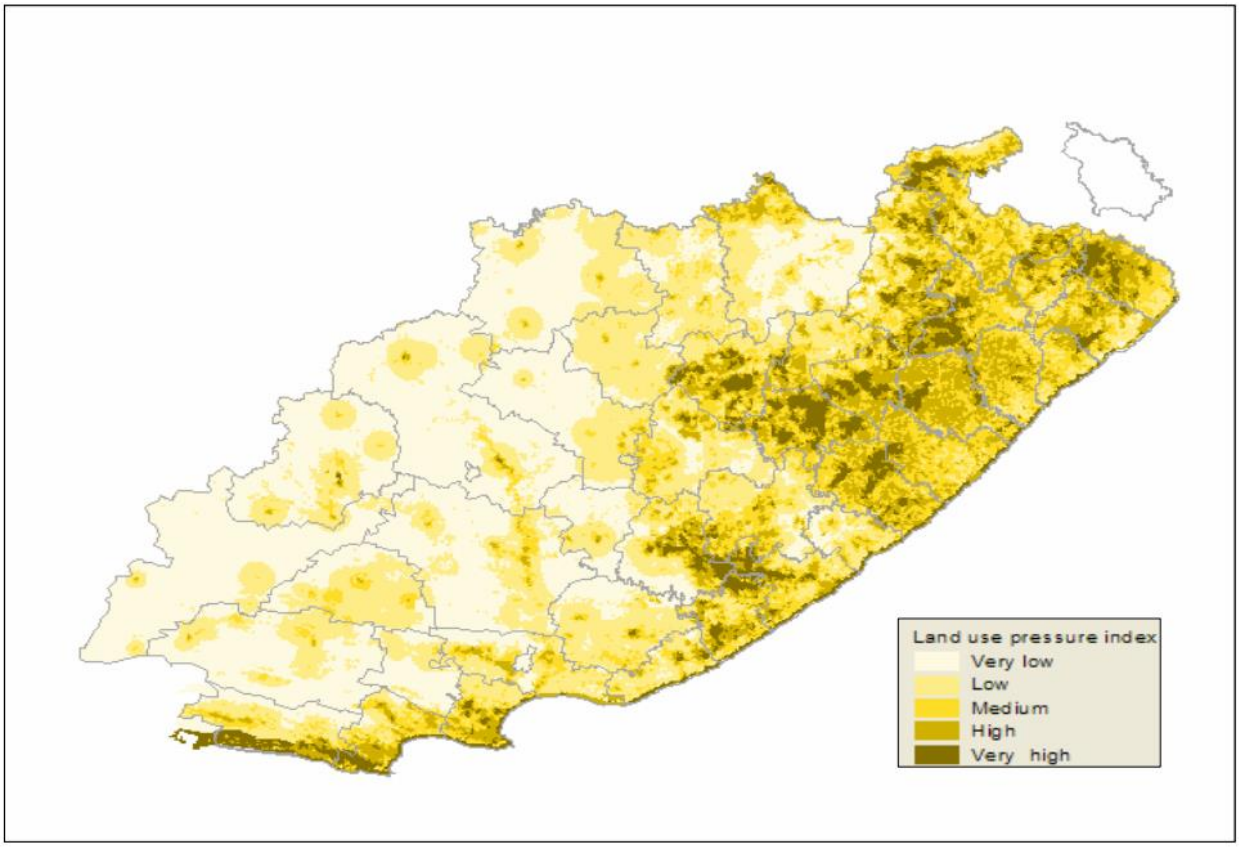

Figure 4 Spatial multi-criteria land use pressure (threat) modelling as used in conservation planning for the Eastern Cape, (Berliner & Desmet , 2007)

3 Developing principles and approaches to national resource assessment and monitoring

3.1 Key questions to consider

Monitoring should be part of an adaptive management programme that allows for monitoring results to feedback into a management response (for example detecting possible overharvesting and adjustment of guidelines, permits and quotas). Monitoring results should also inform how the monitoring programme is designed and implemented.

In designing a monitoring programme there are several general questions that need to be asked:

- What is the purpose of monitoring and what level of detail and accuracy is required? (e.g: to quantify directional change/determining the causes of this change)
- What is the priority concern/s? Is it around over-utilisation, poor recruitment, climate change, or a concern that utilisation may affect climate change response?
- How will cultivation of the species be considered in the need for and design of a monitoring programme?
- What aspect of the plant's life cycle is impacted by the pressure, and what can be measured and at what scale? Are assessments of the species' population structure, recruitment, mortality, harvesting yields needed?
- Over what time scales do you want to detect change (how long will it take for harvesting pressure to impact the species)?
- What are the target species' specific life form attributes (is it long lived, or short-lived, how does it propagate, what part is harvested)?
- How important are changes in the population age structure distribution?
- Can less rigorous, qualitative type monitoring be used, and can local user groups be involved?
- What are the key drivers/threats of change for the target species, other than harvesting pressure? Can these be spatially represented; do they closely correlate with land use/land type?

Answering the general questions posed above are key to address a number of more specific questions around the design of a monitoring programme such as:

- What scale of monitoring and technological tools are best suited to spatial and time scales (satellite technology, drones, multispectral image analysis, LiDAR, ground-based permanent plots etc) and how to integrate across different scales if a multi-scale monitoring approach is taken?
- What indicators and methods of verification are needed to standardise and enable comparisons across different monitoring events and regions for particular "functional groups" of harvested species?
- How and where to select the ground-based monitoring plots, how many and what sizes.
- What type of sampling units to use, for example PCQ for large trees, line transects, belt transects, quadrats? Can rules of thumb such as 1 survey per 100ha or 1 per 10 000ha be used?
- What and how many land use/land types are needed to stratify monitoring samples site (protected areas, communal, private conservation, state)?
- What is the ideal frequency of monitoring? This will depend on the need and the methods used, for example aerial survey could be semi-automated (using web-based approaches such as Global Forest Watch) or to coincide with harvesting intervals.
- Consider using rapidly developing technologies of remote sensing including LiDAR (Light Detection and Ranging). These tools may be able to assess bark damage by people or elephants, secondary effects of wood-borer attack and so on. Aerial views using high resolution RGB imagery and 'deep learning' methods can be used to detect large tree canopies and therefore species density. High resolution multi-spectral imagery (e.g: Red Edge values) are typically used in phenotyping in agriculture for the measurement of plant health.

3.2 Designing a monitoring programme based on species functional groups

Leaving aside taxonomic classifications, various shared attributes of the targeted species may allow clustering into functional monitoring groups that may share similar monitoring approaches. For example, it is simpler to assess resource stocks and yields of large, long-lived species in pure stands than smaller short-lived species occurring in a vegetation of high diversity. The latter will be particularly complex and time consuming to assess and monitor (see for example Cunningham, 2001). Table 7 below examines attributes of target species that could form the basis for functional monitoring groups.

Table 7 Target species attributes used to consider functional groupings for monitoring

Species	Life form /size	Longevity (yrs)	Reproduction	Distribution	Resilience to overharvesting
Marula	Tree	100-200	Seeds	Scattered wide	High
Baobab	Tree	500-2500	Seeds	Scattered wide	High
Aloe ferox	Small tree	20-60 (?)	Seeds/shoots	Clumped /wide	High -medium
Honeybush *C. intermedia* *C. subternata*	Shrub	5-10 (?) 30 Fire interval dependent	 Re-sprouter Re-seeder	 Widespread, clumps Clumped, localised	 Medium Low
Buchu	Small shrub	5-10 (?)	Seeds	Clumped, localised	Medium
Pelargonium	Small shrub	10-40 (?)	Roots and seeds	Scattered, localised	Low
Rooibos	Small shrub	5-10 (?)	Seeds Re-sprouter	Production mainly from cultivated plants. Small quantities harvested from wild.	High – medium (wild populations)
Devil's claw	Creeper	2-5 (?)	Tubers and seeds	Clumped, localised	Medium - low
Kalahari melon	Creeper	Annual	Seeds	Production based on cultivation	Medium (to high if enough seeds of the oil seed variety are retained for planting each year)

From the above analysis species may be logically grouped into six monitoring group types (see Table 8 below).

*Table 8 Suggested functional groups with specific implications for monitoring**

Group	Species	Implications for monitoring
1. Large long-lived trees, widely distributed and scattered	Baobab, marula	Remote sensing, modelling with ground truthing of sample sites & bark damage assessments in permanent plots
2. Small trees, clumped and widely distributed	*Aloe ferox*	Integration of monitoring across all scales
3. Small shrubs, localised, scattered or clumped. Cultivation a key factor	Honeybush, buchu, rooibos	Representative ground-based monitoring only. Stratified ground-based monitoring of wild harvested populations. Consider involving harvester collectives.
4. Small tuberous, herbaceous plant, low densities (roots harvested)	*Pelargonium sidoides*	Ground based monitoring only. Permanent plots. Comparison between heavily harvested vs (remote) unharvested locations may be possible. Low density (0.3 – 1 plant per m^2 in areas where this species occurs).
5. Low growing tuberous creepers localised, mainly wild harvest (of tubers)	Devil's claw	Localised ground-based monitoring only (recording is primary tubers are taken as well as secondary tubers). Note that growth/population dynamics is best in disturbed sandy areas & reduces with bush encroachment.
6. Low growing annual, extensively cultivated.	Kalahari melon	Many varieties with different uses recognised by local farmers. Interspecific genetic variation. Need for resource monitoring to be assessed given reliance on cultivation as an annual crop. A key issue is whether farmers retain enough seed of the oilseed producing variety to plant the following year (or whether they sell all their seed stocks for cash).

* with assistance from A. B. Cunningham, personal communications 2020

These monitoring functional groups will also display similar sensitivities to overharvesting and response times to change. These can be arranged according to a gradient with shorter lived shrubs on the one end and long-lived trees on the other. The latter will also be detectable using remote sensing, while the former will most likely not. See Figure 5 below.

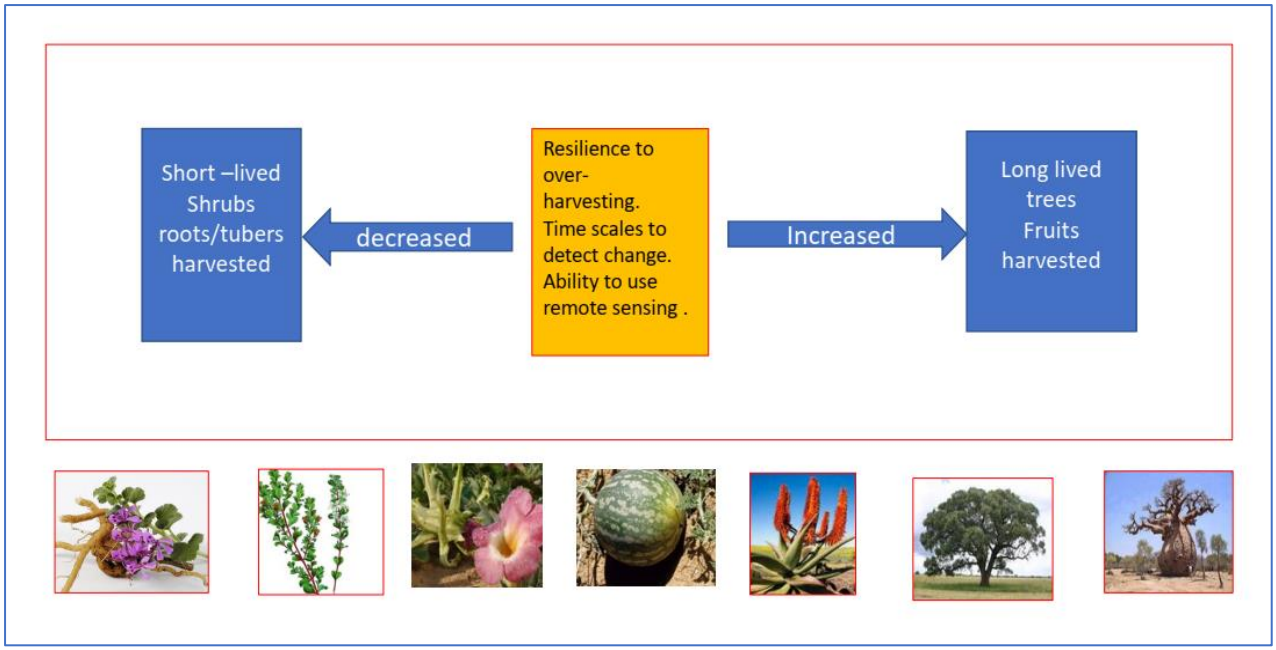

Figure 5 Resilience to over harvesting and time scales to detect change for bio-traded plants

3.3 General steps towards assessing and monitoring a resource

A number of generalised steps can be identified in the process of developing a resource assessment and monitoring programme. These are outlined in Table 9 below.

Table 9 Steps towards assessing a resource and identifying monitoring sites

Objectives	Methods	Scale	Tools
Determine distribution range of target species from actual records	SANBI data bases (BIODAT SA; GBIF locality records) Historical distribution records from the PRECIS Database, National Herbarium. Online resources e.g., iNaturalist. Other records from industry. Expert mapping.	Macro	GIS
Develop species distribution models	Frequency of records per unit area MaxEnt probability of occurrence, see below	Macro	GSI modelling (MaxEnt)
Improved distribution range based on secondary data analysis	Analysis of data from expert mapping and field mapping	Macro and integration of scales	GSI modelling. Remote sensing imagery. GIS using multi spectral/RGB imagery and potentially 'deep learning' algorithms.
Selection of monitoring super sites	First order level treatment representivity, based on stratification	Meso (landscape)	GIS

	of land use/land tenure classes, or alternatively density classes		
Selection of permanent monitoring sample sites within each super site	Second order level treatment representivity based on identified drivers of change (grazing gradient). Use plots representative of either/or 1) land use/land types 2) important drivers of change (the latter may be complex and a statistical nightmare)	Meso/Micro	Statistical analysis, induction. Drone surveys. Analysis of multi spec and/or RGB imagery with 'deep learning' algorithms. LiDAR surveys.
Monitoring of sample sites	Ground based and/or remotely sensed. Experimental design for adequate replication and statistical significance, avoiding pseudoreplication.	Micro (ground)	Drones. Fixed point photography. Permanent plots, line transects.
Extrapolation of data from transects to estimate population densities and overall population size	Using ground data to calibrate GIS model to calibre high, medium, low densities across all distribution range. Include harvest records.	Integration of scales	GIS, statistical analysis

3.4 Multiscale approaches using nested plots within super sites

A multiscale monitoring approach can be adopted to account for multiple variables occurring across a range of scales that can result in directional change in stocks of wild plants. In Figure 6 below an illustration of a multiscale approach to monitoring across multiple time and space scales is shown with the required spatial resolutions for spectral imagery.

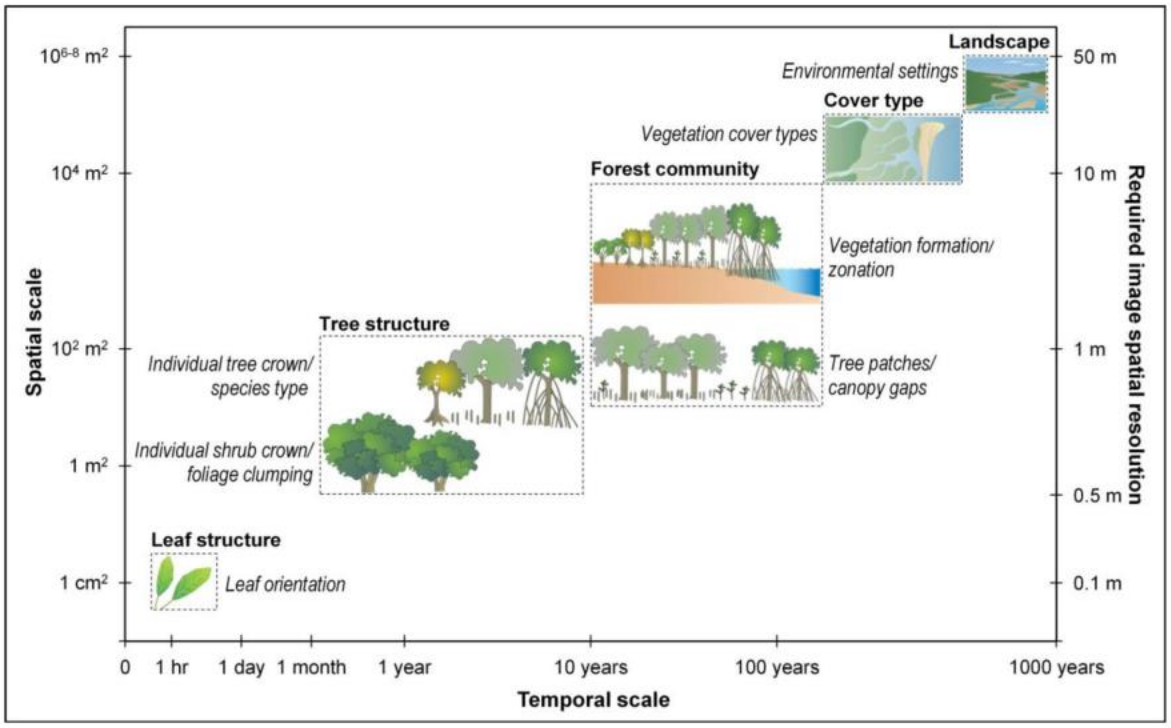

Figure 6 Multiscale approaches to monitoring across a range of time and space scales and the required image spatial resolutions

The integration across multiple scales of monitoring can be facilitated by using large scale monitoring sites (or super sites) containing smaller nested plots and with a stratified random sampling design.

For a species with known variations across its distribution range, it is advisable to sample each subpopulation independently. This is known as stratification. Within each subpopulation a simple random sampling method is then applied in each stratum. The objective is to improve the precision of the sample by reducing sampling error. It can produce a weighted mean that has less variability than the arithmetic means of a simple random sample of the population. The diagram below illustrates the different kinds of sampling.

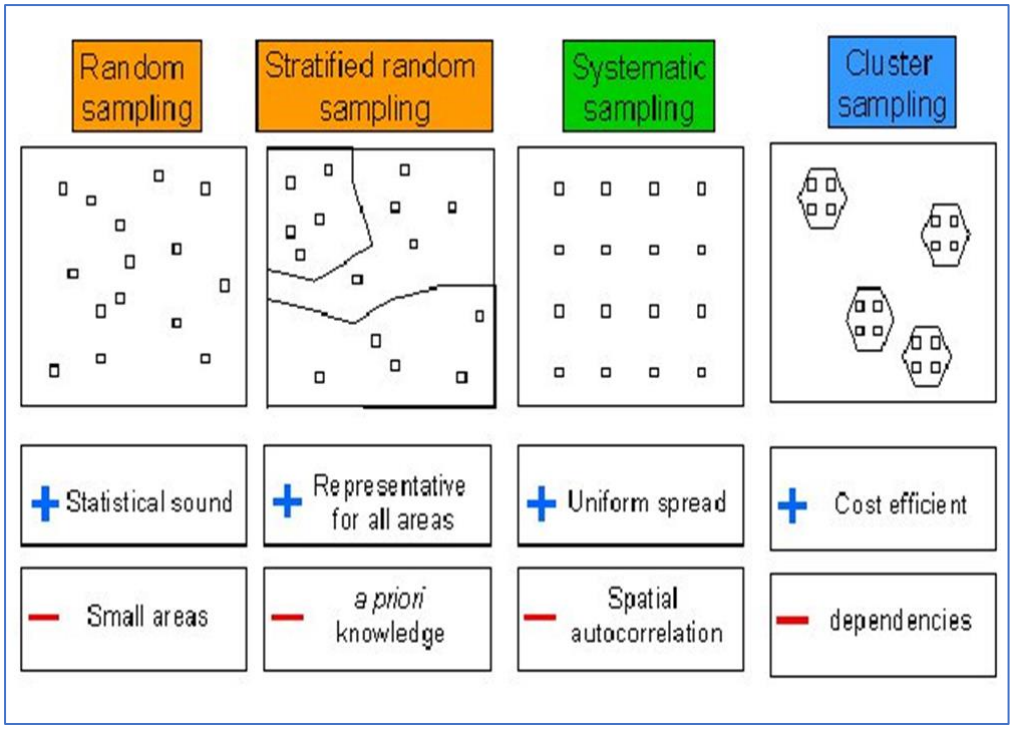

Figure 7 Different forms of experimental design with and without stratification and randomisation of sampling

Super sites enable several strata to be considered. These are large scale monitoring plots that when added together should represent at least 10 percent of the distribution area of a target species. The boundaries of a super site should contain at least one consistent variable such vegetation type, soil type or fit into a sub-water catchment unit. In addition, each super site should be large enough to contain first and/or second order 'treatments' such as level of harvesting, or land use/land tenure. Importantly, super sites allow for a multiscale monitoring approach, where remote sensing, drone images, LiDAR monitoring and ground-based monitoring can be integrated within each super site. See Table 10 below.

Table 10 Multiscale approach to resource monitoring using nested plots across all scales

Monitoring unit	Approximate size range	Main tools	Stratification (treatments) at each scale
Super sites	100 -10 000 ha	Remote sensing imagery	Harvesting pressure (high/medium/none)
Plots	1 -10 ha	Drone, LiDAR	Land use/land tenure
Sub plots	100 m² or 500m²	Ground based	Biotic gradients

A number of criteria can be used to select ideal monitoring super sites (see for example Smit et al., 2013), such as:

- Based on geographical units such as sub catchments
- Contain one form of land use or vegetation type, soil patterns etc.
- Easily accessible from as many sides as possible
- Sites with existing research data
- In or close to existing research sites or facilities (such as the Wits Rural Facility (WRF) or SAEON sites)
- Sites where more than one target species occurs (see Figure 8 below)

Strategically located super sites will provide the most efficient and cost-effective areas to invest limited research money. Ideally these sites will contain multiple target species as well as overlaps with data-rich, existing research sites, such as those used by SAEON. See map below.

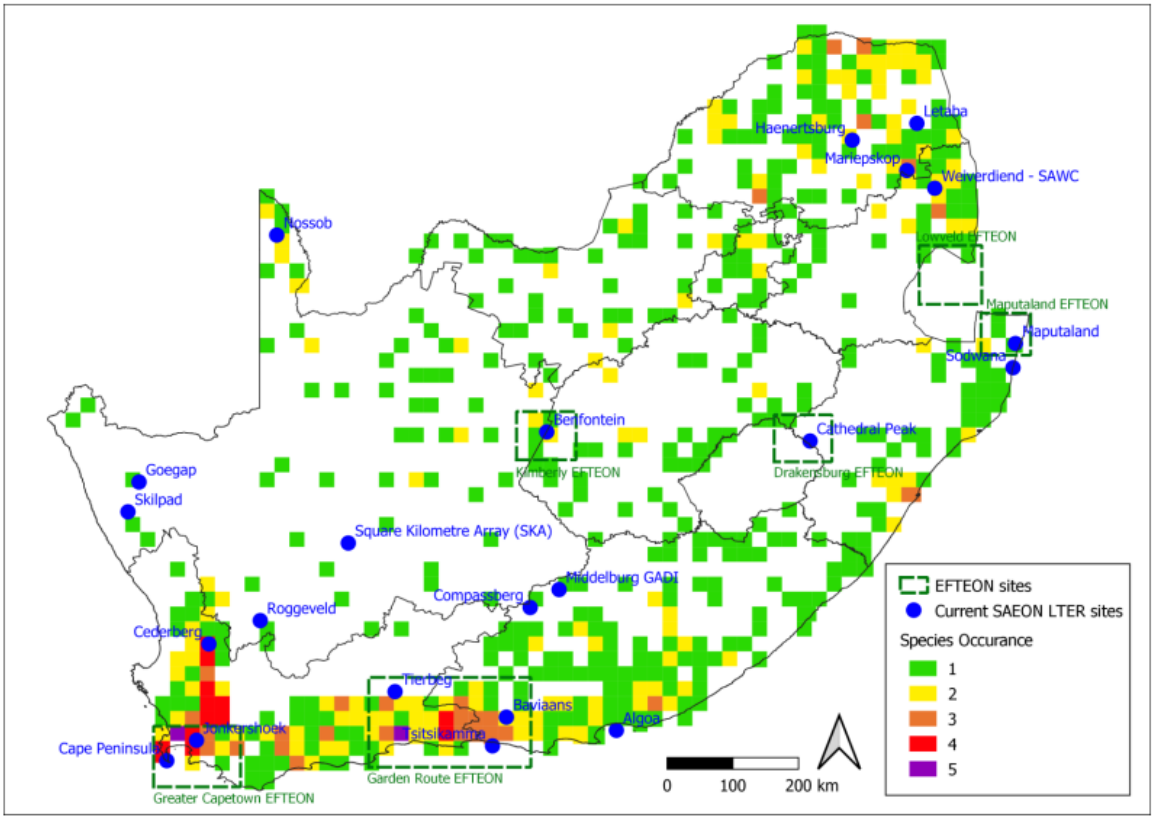

Figure 8 Number of bio-traded target species occurring in quarter degree squares and overlap with SAEON LTER and draft EFTEON sites.

The influence of other variables other than harvesting pressure, may also be drivers of change. Many of these are strongly associated with different forms of land use/land tenure. For this reason, it is suggested that land use/land tenure classes be used as spatial surrogates for drivers of change. The use of super plots can also be selected based on representative sampling across land use/land types zones, these include:

- Private land and commercial farms
- Formally protected areas (best natural state, but impacted by wild herbivores)
- Communal land
- Other state land not formally protected

Additional considerations in the selection and stratification of sample sites include:

- Known or modelled density classes (may be based on rainfall gradients)
- Other known biotic and abiotic drivers of change
- Harvesting pressure (commercial harvesting or community use)
- Accessibility and logistical considerations such as distance to roads, or, in or near existing research and monitoring sites
- The need to avoid pseudoreplication

A note on pseudoreplication. This refers to artificially inflating the number of samples or replicates. As a result, statistical tests performed on the data are rendered invalid. To avoid this, select a sample of each type using random or stratified random sampling. These will be the replicates for examining 'treatment' effect and ensure adequate sample size. If 'non-responses' are anticipated from some units (for example uncooperative farmers) select a larger sample to allow for this. Measure the response variable with sufficient precision within each primary unit. Analyse the data using the average value for each primary unit to evaluate the 'treatment' effect.

The concept of super sites as large multi-scale monitoring plots containing sets of nested plots is illustrated in Figure 9 below.

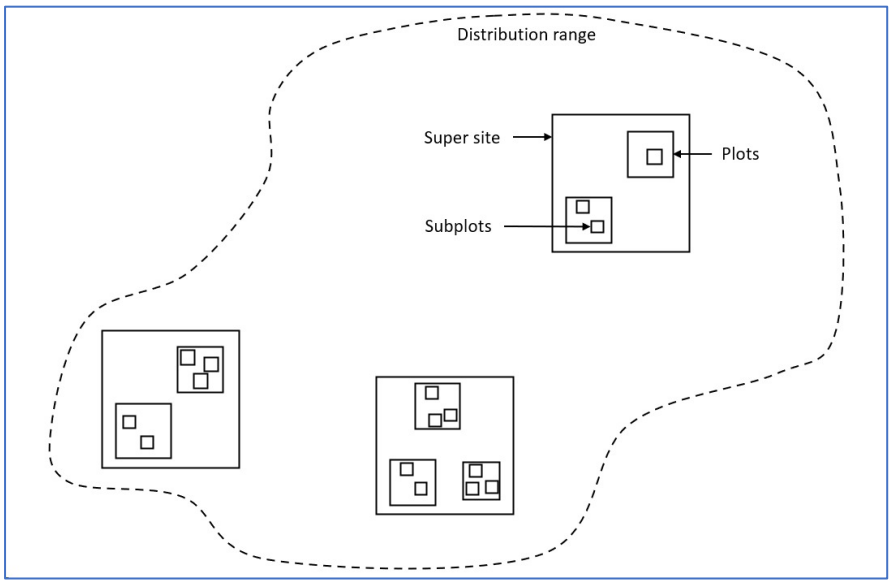

Figure 9 Super sites for monitoring change across a plant species distribution range, using nested plots

3.5 Recommended indicators to monitor sustainability

Deciding on the metrics to use to evaluate the extent and causes of changes in stocks of bio-traded plants and if current use is sustainable requires careful consideration.

Ideally, measurements need to be sensitive enough to detect changes in both stocks, flows and supporting ecosystems of the resource. This is a so-called ecosystem services approach to resource monitoring and is conceptually illustrated in Figure 10 below.

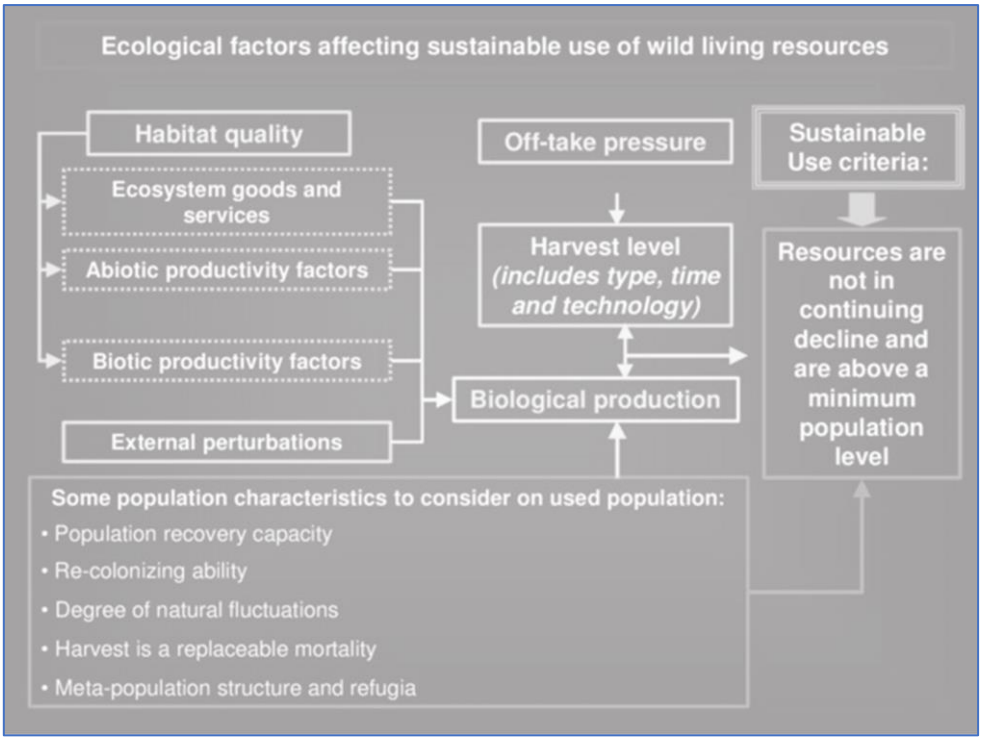

Figure 10 Components of an ecosystem service approach to sustainability monitoring of a harvested resource

Table 11 below shows the minimal set of monitoring indicators that could be used to assess sustainability of a resource. Ideally, additional biotic and abiotic variables that indicate the health and integrity of the host ecosystem should be measured as well.

Table 11 Monitoring indicators

Monitoring components	Indicators
Total stocks	Plants/ha, distribution extent.
Population health	Recruitment rates, population size and population structure.
Quality of the natural habitat	Extent of land use change, degradation, biodiversity loss, soil erosion, alien plant infestation etc.
Productivity of the resource	Yield per hectare, or per plant, size and weight of harvested part.
Harvesting pressure	Kilograms per plant, tons per hectare, tons per year.
The quality of the harvested resource	Size of fruit, chemical composition of part harvested or other quality factors.

Early warning indicators of over-utilisation may include:

- Lower yields per harvesting effort
- Higher prices of goods over time
- Use of replacement, less desirable species as resource becomes depleted
- Use of less easily harvested parts of plants, smaller and poorer quality

For intensively managed resources, it may be useful to consider monitoring resource use efficiency. This would include the potential of the resource to be managed at maximum sustained yield vs actual yield, and the social and economic benefits relative to the environmental impacts.

3.6 When to use remote sensing (decision tree)

A decision tree has been developed to assist in deciding on when to use remote sensing. The GIS methods for species mapping depends on several variables such as the scale of the study area, the structure of the species population and the level of accuracy required. Therefore, the methods used should be determined on a species-by-species basis (see Figure 11 below)

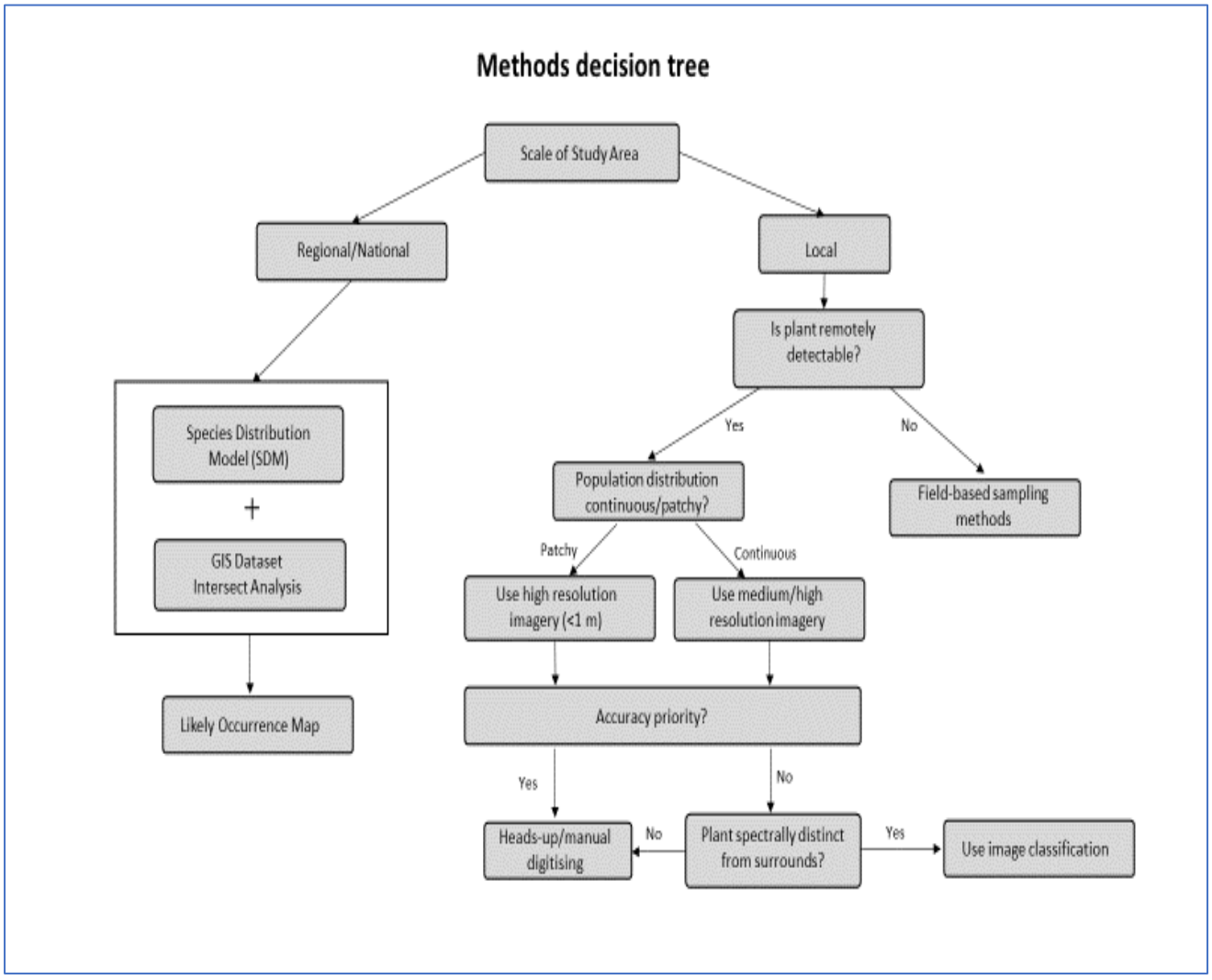

Figure 11 Decision tree for the use of remote sensing

3.5 Who manages and monitors? Institutional mandates and roles

A national long-term monitoring programme requires collaborative efforts between a network of actors and organisations including collectors, producer and marketing associations, industry players, researchers, non-governmental organisations, and state authorities. Table 12 below provides an overview of the main organisations involved in the bio-trade sector, their mandates, and potential roles in a national monitoring programme.

Table 12 Organisation mandates and roles in a national monitoring programme for bio-traded species

Organisation	Relevant legislation/policy	Mandate	Suggested role in national monitoring programme
SANBI	NEMBA South Africa's Strategy for Plant Conservation BABS	Monitor and report regularly to the minister on the status of biodiversity, sustainable use of indigenous biological resources, and threatened species. Coordinate the preparation of the national biodiversity frameworks/bioregional plans. Provide logistical, administrative, and financial support for the proper functioning of the scientific authority.	Coordinate research and monitoring. Report on conservation and sustainable use of indigenous biological resources. Assist the development of biodiversity management plans for bio-traded species. Curation and storage of monitoring data.
DEFF	NEMA, Nagoya Protocol, ABS policies Convention on Biological Diversity (CBD) Bioprospecting, ABS regulatory framework	To provide leadership, alignment and adherence to national and international policy and legislation around environmental management, conservation, and the sustainable use of natural resources	Regulation and policy implementation around formalising bio-trade and bioprospecting. Administering permitting systems. Curation and storage of monitoring data.
Universities Research institutes CSIR Consultants	N/a	Multi-disciplinary research and technological innovation for industrial and scientific development	Research and innovation in methods of monitoring, harvesting, processing and potential uses of bio-traded plants
SAEON	?	To detect, understand and predict environmental change in South Africa, achieved through six regional research nodes, each with their own observation sites and research infrastructure	Monitor the role of climate change on bio-traded plants. Certain bio-traded plants considered as ecological indicators of change.

ABioSA	?	ABS-compliance. Implemented by GIZ. Collaborate and support DEFF. Investment funding. Technical assistance, financial support, and policy dialogues. Development of sector development plans for selected species.	Accessing international markets. Investment funding. Sector level approaches to bio-traded plants. Secure co-funding. Engage with potential investors. Contracting of consultants. Investment in product develop.
TRAFFIC (Trade Records Analysis of Flora and Fauna in Commerce)	MOU with CITES	Monitor and investigate wildlife trade, information in support of effective conservation policies and programmes. Works in close collaboration with governments and CITES Secretariat.	Strengthening the implementation and enforcement of CITES. Trade monitoring (import and export of bio-traded species).
Industry/producer associations /councils		Responsibly promote the respective industries and protect the interests of the consumer and industry stakeholders	Promote responsible harvesting and sustainable resource management amongst producers. Support development of sustainable harvesting guidelines and protocols. Collaborate in resource assessment and monitoring (management unit to national). Provide information on harvesting sites and quantities.
Certification schemes Fair Wild, Organic	Non-statutory. Market based sustainability monitoring and assurance.	Ensuring sustainable harvesting of wild resources. Connect producers to markets and improved prices.	Principles, criteria and indicators to measure sustainable harvesting of bio-trade species. Promote sustainable harvesting by collectors/ producers. Monitoring data.
Bio trade Principles and Criteria (UNCTAD)	Convention on Biological Diversity (CBD). The Commission on Sustainable Development. Millennium Development Goals.	BioTrade Principles and Criteria (P&C) are an international framework for sustainable management of traded wild resources	BioTrade P&C provide an overall framework for a long-term monitoring programme of bio-traded species. The P&C define the essential environmental, economic, and social components against

			which to assess sustainability.
Bilateral and multilateral development assistance agencies			Linkages to international networks, best practice, and expertise. Financial and technical assistance for resource assessment and monitoring programme.
Species working groups	NEMBA (BABS)	Open forum for interested and affected parties. This includes government, conservation and bioprospecting industries, public entities and research institutions focusing on conservation and sustainable utilisation of respective bio-traded species.	Development of sustainable harvesting and management practices. Lead role in development and oversight of biodiversity management plans for bio-traded species. Ensuring a system for resource inventory, assessment, and monitoring of collection impacts is in place.

There are several overlapping organisational mandates that imply a joint responsibility for the monitoring of bio-traded plants. In particular, these include SANBI, DEFF, SAEON, NGOs and industry. There is a need for collaborated and coordinated efforts between these various organisations.

4 Summaries of target species assessments

4.1 *Aloe ferox*

National or regional (southern Africa) level resource assessments conducted
A resource assessment report is available for this species (DEA, 2014). However, this assessment failed to present accurate, quantitative estimates on the national status of the *A. ferox* population. A partial resource assessment was done by Melin et al. (2017). A revised resource assessment for this species has been commissioned and will be available by the end of this year (Prof. A. Palmer personal communication, October 2020). This will evaluate the extent of the resource, the suitability, drivers of change and the indentation of key monitoring sites.

Resource assessments at lower scales
Not available.

Resource assessment key findings
There is a lack of robust data on the national population size and trends of the *A. ferox* population. Current information on abundance and trends is localised, anecdotal or outdated. This situation will be improved by a recently commissioned study which will assess the size of the resource base and to inform a programme for the monitoring of *A. ferox* sub-populations at key sites.

Current status regarding a biodiversity management plan, CITES listing and NDF
There is currently no management plan for *A. ferox* but DEFF has recently initiated a process to develop a biodiversity management plan (non-detriment findings, 2019). *A. ferox* is listed on CITES Appendix II. There is a gazetted non-detriment findings report available (2019) that indicates the harvest and international trade in *A. ferox* is non-detrimental and poses a low to moderate risk to the population in the wild.

Key principles and approaches to developing a long-term monitoring programme for this species
It is not feasible to remotely sense the total stock in South Africa. Monitoring focuses on establishing population health, trends, and the impact of harvesting on the population. Use a stratified random sampling design that accounts for major threats/drivers of change to locate nested ground and/or remote monitoring sites.

The approach should geographically describe the distribution of the species as accurately as possible using presence/absence record data, in conjunction with GIS/modelling approaches such as MaxEnt, and ground-based surveys such as road count transects. It should model or spatially describe drivers and threats across the species distribution range. Areas of high/medium/low threat should be divided into land use/land tenure classes. Representative monitoring sites should be selected within each land use/land class category/threat categories.

It is recommended that population monitoring of *A. ferox* resources be supplemented by trade data analysis. This includes total annual quantities of material exported. In addition, data for imported material should be collected for major importers (such as EU member states) that are obliged to report imported CITES listed species for the CITES trade database (UNEP World Conservation Monitoring Centre, Cambridge, UK). Where discrepancies between export and imported quantities are identified, further investigation needs to be made into possible illegal trade. See for example the CITES significant trade review process.

4.2 Baobab

National or regional (southern Africa) level resource assessments conducted
No national level resource assessments could be found for South Africa.

Resource assessments at lower scales
Venter and Witkowski (2010, 11) assessed baobab resources at local scales for fruit production across five land-use types (nature reserves, rocky outcrops, plains).

A number of local resource assessments were done in Namibia, Benin, Kenya and Zimbabwe.

Resource assessment key findings
Under zero to moderate livestock numbers, populations are able to tolerate fruit harvest rates of between 33-90% (Venter, 2012). However, predicted lowering of rainfall due to climate change with likely negative impacts on fruit yields and recruitment, may change this. Poor seedling recruitment, episodic recruitment and eaten by livestock in communal areas (Venter and Witkowski, 2013). The near absence of regeneration is attributed to intensification of agriculture, increased frequency of bush fires, and grazing by livestock, in particular goats.

Current status regarding a biodiversity management plan, CITES listing and NDF
Not available.

Key principles and approaches to developing a long-term monitoring programme for this species
See section 3 of this report.

4.3 Buchu (*A. betulina*)

National or regional (southern Africa) level resource assessments conducted
No national or regional studies have been done.

Resource assessments at lower scales
Very few local level studies have been done, and these largely assess communally-owned mountain land, and cultivated fields on small and large-scale farms.

Resource assessment key findings
There is a lack of robust data on the national population size and trends of *A. betulina* in the wild. Little information is available on local abundance or trends. Studies in 2016 and 2009 found the population to be decreasing, occurring over 4624 km² in more than 40 locations (Raimondo et al., 2009; Trinder-Smith and Raimondo, 2016). Buchu has been cultivated since 1927. Cultivation was expanded in the 1990s to reduce pressure on wild populations. A project by the Agricultural Research Council was launched in 1999 to formalise buchu cultivation. Cultivation has reduced pressure on wild populations to sustainable levels (Muller, 2015). With many years of cultivation, usage intensity can be determined from the number and extent of *A. betulina* farms in the Western Cape, where harvesting pressure is likely to be highest.

Current status regarding a biodiversity management plan, CITES listing and NDF
The population is listed as 'least concern', with decreasing population trends in 2009 and 2016. Currently no management plan for *A. betulina* exists, and it is not listed by CITES. No NDF report exists for this species.

Key principles and approaches to developing a long-term monitoring programme for this species
Buchu has been cultivated since 1927, with increased cultivation attempts in the 1990s to reduce pressure on wild populations. Most of the product is harvested from the wild, which is a threat, as is illegal harvesting of leaves at the wrong time of year (before seeding), or repeat severe harvesting, and fires.
Total traded stocks should be monitored and include a breakdown of wild vs cultivated. Remote sensing should be used to identify and monitor cultivated buchu. Remote sensing can also be used to assess changes in the condition of vegetation with wild stocks.

4.4 Buchu (*A. crenulata*)

National or regional (southern Africa) level resource assessments conducted
No national or regional studies have been done.

Resource assessments at lower scales
Very few local level studies have been done, and these largely assess communally-owned mountain land, and cultivated fields on small and large-scale farms.

Resource assessment key findings
There is a lack of robust data on the national population size and trends of the *A. crenulata* population. Very little information is available on local abundance or trends. Studies in 2016 and 2009 found the population to be decreasing, occurring over 6400 km² in more than 20 locations (Raimondo et al., 2009; Trinder-Smith and Raimondo, 2016). Buchu has been cultivated since 1927, with increased cultivation attempts in the 1990s to reduce pressure on wild populations. A project by the Agricultural Research Council launched in 1999 to formalise buchu cultivation. Cultivation has reduced pressure on wild populations to sustainable levels (Muller, 2015). With many years of cultivation, usage intensity can be determined from the number and extent of *A. crenulata* farms in the Western Cape, where harvesting pressure is likely to be highest.

Current status regarding a biodiversity management plan, CITES listing and NDF
The population is listed as 'least concern', with decreasing population trends in 2009 and 2016. Currently no management plan for *A. crenulata* exists, and it is not listed by CITES. No NDF report exists for this species.

Key principles and approaches to developing a long-term monitoring programme for this species
Monitoring of Total traded stocks should be monitored and include a breakdown of wild vs cultivated. Remote sensing should be used to identify and monitor cultivated buchu. Remote sensing can also be used to assess changes in the condition of vegetation with wild stocks.

4.5 Devil's claw (*Harpagophytum procumbens*)

National or regional (southern Africa) level resource assessments conducted
Distribution mapping and resource assessment of Devil's claw populations in South Africa was carried out by Hachfeld (2003) and expanded on by Raimondo et al. (2005). Both studies mapped distribution of the species in South Africa and estimated abundance in a total sample of 89 square kilometre plots. Data on harvest volumes, post-harvest recovery rates and sustainability was also collected. Density counts in the sample plots cannot be extrapolated to accurately determine the total population size of Devil's claw in South Africa, according to Hachfeld (2003).

Resource assessments at lower scales

An assessment has been conducted by the North West Department of Agriculture, Conservation and Environment (NWDACE) Devil's claw harvesting project. The findings were not available during this review.

Resource assessment key findings
Hachfeld (2003) and Raimondo et al. (2005) mapped distribution of the species in South Africa and areas of dense concentration where commercial harvesting takes place. A baseline for future monitoring of plant distribution and abundance was established. The impact of harvesting was assessed in sample plots. Threat of overharvesting was assessed to be low taking into account the findings that: a small proportion of the population in South Africa is harvested; an average of 70% of plants harvested were not killed; the species has a highly persistent seed bank and is a weedy pioneer species that thrives in disturbed environments.

Current status regarding a biodiversity management plan, CITES listing and NDF
No biodiversity management plan. Not listed by CITES. Listed under NEMBA as 'protected'.

Key principles and approaches to developing a long-term monitoring programme for this species
The 2003 and 2005 resource assessments provide a good basis for setting up a regular (5 yearly?) national resource assessment and monitoring programme, based on three key components:

i) Resource assessment. GPS co-ordinates can be used to locate the same transects for repeat abundance counts. Increased ground-based sampling and use of GIS modelling can be implemented to develop improved species distribution and abundance information. Remote sensing could have a role to play in monitoring of general habitat condition where this species occurs.

ii) Harvest areas and volumes. Work with TRAFFIC to design and implement a trade monitoring programme measuring domestic and international trade volumes and value. Re-visit Raimondo et al. (2005) to establish long term monitoring of harvesting sites and volumes. Discrepancies in trade and harvest volumes can be used to improve accuracy of monitoring.

iii) Systematic demographic monitoring to determine the long-term impacts of different harvesting techniques on population viability. Focus on areas where the plant is harvested in the NW province, not throughout the species range. Assess the monitoring programme set up by NWDACE Devil's claw harvesting programme as a basis for on-going monitoring.

4.6 Honeybush

National or regional (southern Africa) level resource assessments conducted
A partial resource assessment was done on *C. subternata* by W. van der Walt (MSc thesis, submitted for examination, 2020).
A resource assessment on *C. intermedia* was done by G.K.McGregor (to be submitted, 2021) for PhD research, and for WC DEADP (2017).

Resource assessments at lower scales
There are farm management plans for 10 farms (by NGO Living Lands) plus mapping and predicted resource yields for about 35 permitted farms (EC DEDEAT). These are not in the public domain. Mostly for *C. intermedia*.

Resource assessment key findings
The average yield per *C. intermedia* plant is about 400g, with a range of 100g to 1500g.
The plant density per hectare ranges from 300 to 3400.

The average yield per *C. subternata* plant is about 750g, with a range of 100g to 2000g.
The plant density per hectare ranges from 100 to 5000 (post-fire).

Current status regarding a biodiversity management plan, CITES listing and NDF
Both species are listed on the TOPS draft list (2019) – not finalised.
The BMP draft is due to be published in December 2020.
Both species are listed as declining but of least concern.
Both are well represented in protected areas (30% of range of *C. subternata*, 39% of range of *C. intermedia*).

Key principles and approaches to developing a long-term monitoring programme for this species
C. intermedia is the mainstay of the wild harvesting industry. Wild-harvested honeybush makes up about 70% of the annual honeybush crop. *C. intermedia* makes up 85% of the wild harvest and *C. subternata* 10 %. The cultivated sector has been successful in some areas with some species, but overall has not been as successful as anticipated. *C. intermedia* is still considered to be the finest quality tea, and being what the market knows, represents what much of the market wants. Therefore, it will remain an important component of the industry. It is harvested almost entirely on private land (except for illegal harvest).

Given the nature of the industry, it is possible to use the existing industry structure for monitoring, bearing in mind the following:

- On many farms the plant is sustainably harvested. But on farms where landowners are careless, or where there are absentee landlords and/or on state land (protected areas *etc*), illegal harvesting is a problem.
- Local knowledge holders are an invaluable source of information on local trends (eg: fire history, drought, changes in yield) and should be involved in monitoring. Many harvesters and farmers keep good records of yields per locality.
- Given the age of the industry, many sites have only been in use for around 20 years,ie: have only been harvested four or five times and long-term monitoring trends may not yet be visible.
- The EC DEDEAT permit system has created a system of accountability for the wild harvest as it includes the processors and the harvesters (in the EC).
- SAHTA's role: Many harvesters, landowners and processors are members of the organisation. SAHTA is committed to and involved in promoting sustainable harvesting.
- Guidelines exist for developing management plans and many farms have implemented them. Results will be seen in time.
- Long-term monitoring sites could be set up in reserve areas and on existing farms which implement management plans.

4.7 Kalahari melon (*Citrillus lanatus*)

National or regional (southern Africa) level resource assessments conducted
None located.

Resource assessments at lower scales
None located.

Resource assessment key findings
N/a

Current status regarding a biodiversity management plan, CITES listing and NDF
The species is not under threat and has no national or international listing. It does not qualify for a biodiversity management plan.

Key principles and approaches to developing a long-term monitoring programme for this species
Kalahari melon is widely cultivated throughout warm areas of the world. In South and southern Africa the species occurs across a wild to cultivated continuum. This comprises of a number of land races that are the result of hundreds of years of selective breeding by local farmers. It is traditionally grown as an intercrop with grains including sorghum. In Namibia, three main cultivated land races have been identified corresponding to selective breeding by local farmers for fresh fruit, cooking, and seed for oil production (Maggs-Kölling & Christiansen, 2003) although Rodin (1985) records seven locally named varieties (in OshiWambo).

Careful consideration should be given to the purpose of a monitoring programme for the species, taking account of the wild to cultivated continuum, multiple land races and dominant threats.

4.8 Marula

National or regional (southern Africa) level resource assessments conducted
Combrinck & Mulle (2002) used GIS modelling to determine potential distribution of marula in South Africa using nine bioclimatic variables. Results show improved accuracy of predicting distribution than a previously used TSSG model of von Maltitz (1995).

Resource assessments at lower scales
There have been a large number of resource assessment studies at local scales, primarily taking place in nature reserves and national parks, as well as in and around rural villages. Aerial photographs, transects, and studies of known trees were primarily utilised. A number of studies assessed population structure and found this to be skewed towards seedlings and saplings with limited recruitment into adult trees.

Many studies indicated a decline in resources in recent years, despite a finding by Emanuel et al. (2005) determining that 92% of fruit could be harvested without negatively impacting the population. Density varied from two to 115 trees per hectare, with protected areas having more trees per area.

A single tree was found to produce up to 596 kg of fruit (Botelle et al., 2002), and cultivated trees were found to have a sex ration skewed towards females. It is not clear if these trees are actually cultivated (as in systematically planted) or wild trees that are cared for, or 'tended'.

Resource assessment key findings
Local studies have been quite comprehensive in terms of distribution, yield, harvesting impact, and sustainability. However, these do not cover the extent of the marula distribution and are largely focused on areas known to produce large yields, possibly giving a skewed view of sustainability. No national or regional studies have been done.

Within these localised areas, most studies found marula trees or yields to be decreasing. Trees occur in national parks and in agroforestry systems where they have not been chopped down. Use near to villages and in agroforestry systems is higher than in national parks. The highest area of production is in the Ba-Phalaborwa Valley in Limpopo. Use in national parks is restricted but does occur. Knowing

the area under marula cultivation - as well as the area within the marula range under grazing systems, arable land and conservation protection - will give a better indication of usage intensity across the species range. *Current status regarding a biodiversity management plan, CITES listing and NDF*

The population is listed as 'least concern', with decreasing population trends according to the literature but not national-scale studies. Currently no biodiversity management plan for marula exists, and it is not listed by CITES. No NDF report exists for this species.

Key principles and approaches to developing a long-term monitoring programme for this species

See section 3 of this report and the task 2 report (regional monitoring programme for marula.)

4.9 *Pelargonium sidoides*

National or regional (southern Africa) level resource assessments conducted

i) A regional resource assessment was conducted for the entire range in South Africa and Lesotho (De Castro et al., 2010).

The entire range was mapped using herbarium specimen data and known areas of occurrence from harvesters. One hundred and three sites were sampled in suitable habitat across the species range to estimate the number of plants per 100 ha plot. Certain areas were not covered, and the report recommends follow up.

ii) Parceval/Schwabe National Resource Assessment (2018).

Parceval commissioned and owns this report. They are currently working with SANBI to produce a synopsis of the 2010 and 2018 resource assessments. This synopsis will be made available under guidance by SANBI.

Resource assessments at lower scales

No information obtained.

Resource assessment key findings

De Castro et al. (2010) provides a good baseline of species range, density distribution and the impact of harvesting. They concluded that the risk of unsustainable harvesting is low because the species is widespread and abundant throughout much of the range; harvesting takes place in a small proportion of the range; and post-harvest recovery is good (over 80% recovery) except in areas close to townships where it is at risk of being over harvested, and in a few of the sample locations where poor harvesting practices resulted in site disturbance and low recovery. Later research into post-harvest suggest these recovery rates may be an overestimate and that much longer recovery time is needed (Motjotji, 2011).

The species is at risk from habitat conversion and degradation in certain parts of the range.

The more recent resource assessment conducted by the industry is not in the public domain and therefore could not be assessed here or used as the basis for a long-term monitoring programme.

Current status regarding a biodiversity management plan, CITES listing and NDF

A biodiversity management plan has been gazetted. Currently *P. sidoides* is not included in any of the CITES appendices. It is listed at protected species under NEMBA.

Key principles and approaches to developing a long-term monitoring programme for this species

De Castro et al. (2010) provides a good basis for a setting up a regular (five yearly) national resource assessment and monitoring programme. The monitoring programme should ideally be scheduled to

feed into the five yearly revision of the *P.sidoides* biodiversity monitoring plan (monitoring results to come out at least 2.5 years before the next BMP is due for publication).

Key elements of National Monitoring Programme

i) Resource assessment. Increased sampling and use of remote sensing to develop improved species distribution and abundance information. ii) Harvest areas and volumes. There is an important need to update and improve information on current harvesting areas and volumes. Work with TRAFFIC to design and implement a trade monitoring programme measuring domestic and international trade volumes and value. Discrepancies between export and imported quantities suggests the need to investigate possible illegal trade. Discrepancies between trade and harvest volumes suggests need to interrogate and improve monitoring approaches.

iii) Monitoring of impact of harvesting. Establish plots to monitor the impact of harvesting and other threats including loss of habitat and habitat degradation. Do stratified random sampling targeting areas where harvesting and other threats are known to be highest.

4.10 Rooibos (*Aspalathus linearis*) (Wild rooibos only)

National or regional (southern Africa) level resource assessments conducted

The known and potential distribution of wild rooibos has been mapped in herbarium records and a climatic envelop approach (Malgas et al., 2010). No resource assessment of wild rooibos seems to have been done.

Resource assessments at lower scales

None found.

Resource assessment key findings

No resource assessments for wild rooibos seem to have been conducted.

Current status regarding a biodiversity management plan, CITES listing and NDF

No BMP, Not CITES listed.

Key principles and approaches to developing a long-term monitoring programme for this species

The key consideration in designing a monitoring programme for rooibos is that almost all the total production comes from cultivated stocks. Wild harvesting takes place only in two areas: in the mountains of the northern Cedarberg above Wupperthal and in the Suid Bokkeveld (Malgas and Ottle, 2007). Wild rooibos populations are under severe threat as a direct result of the expansion of rooibos cultivation into their habitats, grazing pressure and to some extent over-harvesting (Wynberg, 2016).

Key elements of National Monitoring Programme:

i) Conduct a wild rooibos resource assessment and mapping of threats.

ii) Design a monitoring programme with stratified plots to take account of key threats including land clearance, poor veld management, gene pool contamination from cultivated varietals and over-harvesting. Engage local collectors, through existing structures (Wuppertal Rooibos Association and Heiveld Cooperative) and their support partners (EMG in Suid Bokkeveld) in the design and implementation of the monitoring programme.

5 Target species profiles and review of resource assessments

5.1 *Aloe ferox*

Table 5.1.1: *Aloe ferox* species profile

Data categories	Data fields	Information summary
Species life history	Life form	Long -lived, single- stemmed succulent plant that can grow to h
	Reproductive type	*Aloe ferox* has a weed like ecology and is believed to be a pione degraded areas. The relatively large distribution range of *A. fero* has good dispersal efficiency (wind -dispersed).
	Age at first fruiting	Time taken from seed germination to the first harvest of aloe le
	Yield of harvested part per plant (and per ha) or per year	Total legal harvest is approximately 400 t/year, although an add undocumented for South Africa (Protabase Record).
	Propagation	Seeds and cuttings (The side branches or basal sprout are remo off.
	Domestication and cultivation	Cultivation occurs mainly in the Western Cape, however it only portion of the total production.
	Pattern of distribution	Restricted and fragmented distribution from the Western Cape Eastern Cape, into the south-eastern Free State. Total distributi 000 km². Distinction between the harvesting (and cultivation) p done predominantly on private farmland, and the Eastern Cape under traditional authority (DEA , non-detriment finding report
	Ecological role	Aloes are an important component of many dryland ecosystem to recolonise degraded vegetation and may act as a nurse plant Relatively fire resistant. Aloes produce copious amounts of nect abundance of avian and insect species across southern Africa d alternative food sources are scarce. Some larger mammals, par as a food source, particularly during droughts (Cousins and Wit
Use	Part used	Leaves/sap
	Harvesting techniques and frequency	Harvesting is done in winter, thereby ensuring that the plant is common method of harvesting is manual leaf cutting. Only 10 t adult *Aloe ferox* plant are harvested once a year. The leaves are as possible (NDA, 2013).
Management	Management plans	Currently there is no management plan for *A. ferox* but the Dep recently initiated a process to develop a biodiversity manageme 2019).
	Studies on harvesting pressure (legal and illegal)	A resource assessment report is available for this species (DEA, accurate, quantitative estimates on the national status of the *A* assessment for this species has been commissioned and will be (Prof. A. Palmer personal communication, October 2020). This v resource, the suitability, drivers of change and the indentation
	Studies to determine sustainable harvest levels/ harvest guidelines	Some harvesting guidelines are provided in the DEA (2014) Reso South Africa. The industry is also required to comply with the South African N standard for *A. ferox*, developed by the South African Bureau of how the plants can and should be harvested based on historica generations of tappers (*Aloe ferox* non-detriment findings, 201

	Current monitoring	The principal method of monitoring harvesting presently is thro *A. ferox* captured within the CITES trade database. There is curr
Conservation	Threats/drivers of change	There is a possible threat from over-utilisation and habitat loss (considered limited and reversible). Reintroduction of large her rhinoceroses and kudu causes loss of larger specimens, while liv recruitment. Climate change has been identified as a potential drought, higher fire intensities and extremely high temperature mortality, as well as lower seed production and recruitment in a detriment findings, 2019). Reduction in recruitment has also been observed in association There are high levels of illegal trade, possibly almost equivalent There is non-sustainable harvesting in communal areas. (*Aloe fe*
	Trends over last ten years	Anecdotal information suggests that there has been an overall limited local extirpations being reported in communal areas in t recruits and improved growth rates have been observed in harv unharvested populations (*Aloe ferox* non-detriment findings, 20 It is estimated that 7.8% of the distribution of *A. ferox* occurs w
	Status (red listed/CITES/NDF)	*Aloe ferox* is included in Appendix II of CITES. In terms of Article permit shall only be granted for an Appendix II, after a Scientific advised that such an export will not be detrimental to the survi
	Ecological Experts	The Aloe Council of South Africa, academics, SANBI, TRAFFIC
Institutional aspects	Key actors and mandates (Government, industry, NGO)	The Aloe Council of South Africa SANBI CITES DEA
	Projects /networks	The Aloe Council of South Africa's key objectives include fosteri investing in and uplifting rural tapper communities, ensuring su plants, environmental protection, promoting scientific research industry, to protect the interest of the industry in South Africa b standards for aloe products.
	Certification	The Aloe Council of South Arica defines professional certificatio for all aloe products.

Table 5.1.2: *Aloe ferox* review of resource assessments

Location	Part used	Scale of assessment	Aims & method	Results/findings	Reference
South Africa	Leaves	National	Estimated from distribution records.	The species is estimated to extend across an area of 10 000km^2.	Donaldson (1989)
			Estimate the amount of *Aloe ferox* currently being harvested and traded. Quantify the biological impact of harvesting on local plant populations at a local community level.	Monitoring CITES trade data for *Aloe ferox* in isolation of socio-economic, biological and political factors would not adequately determine its sustainability.	

				Levels of international trade have been shown to have increased over time. The impact and intensity of overexploitation of *A. ferox* has been observed at local community level.	
South Africa/global		Global trade	Assessment of the global trade in *Aloe ferox* with special emphasis on the EU commission states. Not a resource assessment per say but provides an estimate of the extent of the resource based on amounts harvested. Also serves a base line for tracking trends in exports. A detailed analysis of the *Aloe ferox* industry in South Africa, including comprehensive trade data analysis, was conducted by TRAFFIC in 1996 (Newton and Vaughan, 1996).	Discrepancies occur between EU member states and South Africa's reported trade. Between 1994 and 2003, South Africa reported exporting over 3000 t of extract worldwide, although importing countries reported importing only about half this quantity from South Africa.	TRAFFIC, 2006
South Africa	Leaves	National	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	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.	DEA, 2014 Resource Assessment for *Aloe ferox* in South Africa.

			of cultivated material to the market; and lastly to evaluate the sustainability of current utilisation and provide recommendations on sustainable off-take quotas for areas of occurrence. Methods included: stakeholder interviews and field assessments. The distribution was determined using a MaxEnt habitat suitability model with, rainfall, climate zones, frost occurrence, and temperature.	This study failed to provide quantitative and robust details on population trends especially in relation to harvesting impacts, nor was it able to assess the size of the resource base and to inform a programme for the monitoring.	
South Africa			The aims were: Determine and map the current distribution of *A. ferox;* undertake field surveys to estimate and map the relative abundance/density and subpopulations; map what proportion of the *A. ferox* population occurs on privately owned land, or on state land and in communal or conservation areas; map the impacts of harvesting across the range; note and quantify any other potential threats impacting on subpopulations; design a monitoring programme to monitor and evaluate the trends in the resource base and harvesting impacts.	(Work still in progress) Preliminary results include: The identification of monitoring sites. The identification and explanation of threats or drivers of change. This was used to identify 444 potential monitoring sites. These are divided up into a number of super sites. It included the development of probability of occurrence and density probability surface.	Palmer and Weideman (2020)

			Methods included: A stratified random sampling approach, whereby sample points are preferentially allocated to map regions based on the probability of *A. ferox* presence, and defined by land use/land cover characteristics and climatic predictors. The sampling approach maximises the allocation of sample points to areas in which *A. ferox* is most likely to occur based on proximity to known harvesting locations, and ensures sampling representivity across the range of land tenure categories. To achieve this, a continuous "probability" surface will be developed in a GIS environment based on the intersection of a range of readily available climatic and land use/land cover predictors of *A. ferox* 's distribution. These include The South African National Landcover dataset (2014), the National Vegetation Map (Mucina & Rutherford, 2006), and Frost duration (Schulze et al., 2008). In addition, population surveys		

			were conducted of different land users and owners to establish use, threats, population densities etc. This will be used to identify those populations that are the most vulnerable.		

5.2 Baobab

Table 5.2.1: Baobab species profile

ories	Data fields	Information summary
e history	Life form	Baobab is a long-lived, slow-growing tree in the wild and has a lifespan of hundreds to thousands of years.
	Reproductive type	Baobab is fruit pollinated by bats and moths. It has hermaphroditic flowers (both male and female parts in the same flower). However, local communities refer to male and fe trees, with males producing fewer fruit.
	Age at first fruiting	Approximately 100 - 200 years (in naturally occurring trees).
	Yield of harvested part per plant (and per ha)	Fruit: The fruit per adult tree in Benin, varied between 57.1 and 157.4 fruit per tree in different cli zones (Assogbadjo et al., 2005). Fruit production per adult tree in communal land in South Africa was in a range of 77.1 ± 13 & Witkowsk, 2011). Bark: The yield is variable but return harvest times of every 6-10 years produces around 25 kg dry per adult tree. The kilograms of dry weight per ha is 8 -100 kg (Romero, et al., 2001).
	Propagation	Seeds, as well as vegetatively. The soil temperature needs to be at least 28˚C for germinatio occur.
	Domestication and cultivation	In Mali, local agroforestry research has perfected grafting techniques with close to 100 perc success rate. Already more than 5 000 trees in more than 100 farmer orchards have been gr stock from trees with extremely high vitamin C content (Lost Crops of Africa: Volume III, 200
	Pattern of distribution	Widespread in low-lying hotter, dryer frost-free areas, where the average annual temperatu 30°C. They are common in mopane woodlands.
	Ecological role	Considered as a keystone species. This is supported by the presence of beehives, bat roosts nests observed on the trees. Conservation of this species is therefore important in maintain stability in the ecosystem.
	Part used	Fruit pulp, seeds, bark, leaves
	Harvesting techniques and frequency	Once a year the fruits are knocked off with poles or allowed to fall to the ground. The bark i on one side.
ent	Harvesting guidelines available	The Baofood project (undated) has a training manual for improved harvesting and handling fruits (for Kenya). EcoProducts runs sustainable harvesting workshops in South Africa (Welford et al., 2015). A Venter and Witkowski (2013) model estimated that 98% of fruit can be harvested sustaina
	Studies on harvesting pressure (legal and illegal)	Mudavanhu (1998) looked at the impacts of bark harvesting on the population structure of in the Save-Odzi Valley area.

	Determination of sustainable harvest levels	Fruit: From zero to moderate livestock numbers, populations are able to tolerate fruit harvest rat between 33-90% (Venter, 2012). However, predicted lowering of rainfall due to climate change will likely have negative impa fruit yields and recruitment may change this. It is recommended that active planting and pr seedlings should take place to mitigate current and future negative impacts facing the baob population (Venter & Witkowski, 2012). Bark: A formula for sustainable bark harvesting in Zimbabwe was developed by Romero et al. (200 An assessment of bark regeneration rates was conducted by Romero et al. (2001). Accordin equation, harvested patches on baobab trunks recover to their pre-harvesting bark thickne years. Bark yield studies for different tree classes done by Romero et al. (2001) found: Dry weight, not harvested before: In kg/tree: 4.7 (dbh = 0-50) 23.9 (dbh = 51-100) 68.9 (dbh = 101-150) Dry weight, regenerated bark: In kg/tree: 5.4 (dbh = 0-50); 15.1(dbh = 51-100) 25.9 (dbh = 101-150)
on	Threats /drivers of change	Climate change related die-offs of large old trees in southern Africa and Madagascar (Patrut 2018). Predation (baboons, insects), land conversion. Poor seedling recruitment, episodic recruitment and eaten by livestock in communal areas (and Witkowski, 2013; Munyebvu, 2015). Non-sustainable bark stripping (Lisao et al., 2017). The near absence of regeneration is attributed to intensification of agriculture, increased fre bush fires, grazing by livestock and over-exploitation, especially for leaves. Poor seedling reg (SAFROGEN, undated). Disease: Mudavanhu (1998) reported that there is a strong relationship between sooty disea infestation and bark harvesting (Romero et al., 2001). Lack of proactive natural resource management initiatives, especially in response to expand markets. Baboon predation of fruit causes low fruiting rates (Venter, 2012). Pollinators are impacted by climate change, such as hawk moths in South Africa, and fruit ba other parts (S. Venter, personal communications, November 2020).
	Trends over last ten years	No data available, but there are some reports of older tree die-off in hotter, dryer areas pos to climate change (Patrut et al., 2018). There is almost no regeneration around villages. See apparently eaten and killed by cattle and goats (Venter, 2012; Romero et al., 2001; S. Vente communications, November 2020).
	Status (red listed?)	Least concern.
n sources	Key literature sources	See references.

Table 5.2.2: Baobab review of resource assessments

Location	Part used	Scale of assessment	Aims & method	Results/findings
Kenya	Fruit, pulp	Local/ catchment	Testing techniques to assess fruit yield (estimating the numbers of fruit in the canopy of a single tree): The plots were located with their centres one metre from a fruiting baobab tree with a radius measured to the middle of the furthest tree, less than 100 m from the centre.	The number of fruits per t 2 675. There was an average of 3 The density varied from o 14 trees per hectare and a crown cover from 3% to 2

			Randomised branch sampling (Jessen, 1955) is a means for randomly selecting a sample branch from a tree crown which should give an unbiased estimate of total fruit in the crown by multiplying the fruit on the branch by its probability of selection.	The structure of the baob rather interesting. The sh the number of trees per h class was a normal curve, expected inverted J-shape Tree diameter (dbh) exhib relationship with fruit nur r^2 of 0.57 which is respect leaves about half the varia unaccounted for.
South Africa	Fruit	Local / catchment	Fruit production was examined across five land-use types (nature reserves, rocky outcrops, plains, fields, and villages) and over three consecutive years. Factors assessed included differences in life-stage, tree size, land-use type, inter-annual variation, and quantifiable fruit predation.	Density of adult trees: 0.9 adult baobab trees in the whole, with no significant fruit production between The population as a whol fruit/ha. Stem diameter (dbh), crow area were too poorly rela to allow the use of these of fruit production. Trees adults) produce little fruit Fruit production in comm South Africa of 77.1 ± 13.9
Benin	Fruit	Climatic zones of Benin	A survey was done using mega transects at a number of selected sites. In each zone, an estimate was made of pulp, seed and kernel production from 1200 fruits harvested from 30 individuals in the Sudanian zone.	Mean fruit production in 57.1 and 157.4 fruit per tr climatic zones. Density of adult trees vari baobabs per km^2. The higher the clay and cr soil, the better the produc
Kenya			The study tested methods for assessing baobab fruit production in Kenya	Stem diameter and crown as indicators of fruit prod production was extremely They suggested that visua primary or randomly selec be the most accurate and
Namibia			The population was assessed in Kunene, Omusati, Otjozondjupa and Zambezi regions in northern Namibia. Data was collected from 240 trees in randomly selected baobab clusters. The stem girth at breast height (gbh, converted to stem diameter), height and crown diameter were recorded. Density and population structure were based on a fixed number of 15 baobab plants around the sampling point because of the variable distance between trees in the clusters. Plot size was	Highest stem density (6.7 observed in Omusati regio stems per ha) in Otjozond The population is currentl in Namibia. The study recommends p propagation of baobab se maintain viable populatio Sustainable harvesting pra is also recommended.

			determined from the distance from the random sampling point to the 15th plant.	
Botswana	Bark	Local / village	The study focused on 72 baobab trees in and around the village of Gweta examining local usage and harvesting practices and exploring their correlations with the health of the trees.	Results suggest that baob current form is detriment trees and may not be sust term. The recommendation from methods of fruit, bark, and promote the protection of trees occur in order to facil
Zimbabwe	Bark	Local / village	The study aimed to determine the impacts of bark harvesting, regeneration times and sustainable harvest levels. It also examined tree densities and regeneration of trees used by the villagers of Gundyanga, Mutsiyo and Nhachi. Nine random 0.5 ha plots were established (three plots per village). In these, the diameter at breast height (dbh in m) of all baobab trees was measured.	Baobab tree densities and were established (8.41 tre extent of harvesting (99% sampled had evidence of Mudavanhu (1998) also fo regeneration in the study Times of bark and fibre qu after harvesting were calc year experiment (six and pre-harvesting conditions An equation was designed volumes of and fibre qual
South Africa	Fruit	Local / land use types	Population dynamics, fruit production, phenology and recruitment were investigated in five land-use types, namely nature reserves, rocky outcrops and plains, representing natural land-use types; and fields and villages representing human-modified land-use types.	The density of trees was c transects. Fruit and flowe 106 trees over two to thre viability and seedling/sap were determined. Villages and fields had hig (2.16 and 1.13 plants/ha), outcrops (0.96 and 0.83 p Population analysis of all indicated low recruitment Mature fruit production w and fields (89 and 88.26 fr reserves, plains and rocky 28.64m and 12.56 fruit/tr

5.3 Buchu (*A. betulina*)

Table 5.3.1: *A. betulina* species profile

Data Categories	Data fields	Information summary
Species life history	Life form	Multi-stemmed, perennial woody shrub growing to 1m.

	Reproductive type	Insect-pollinated, resprouts after fire, ballistic seed dispersal.
	Age at first fruiting	N/a
	Yield of harvested part per plant (and per ha)	Yields 2-3 tons of vegetative material per hectare (Muller, 2015).
	Propagation if cultivated	Propagation from seed and cuttings is possible, but vegetative pro difficult. Soil pH, salinity, phosphate, and nitrate must be low, with Farmers remove emerging wild seedlings in between fires, and rep fare better than those left in the wild.
	Pattern of distribution	Limited to the Western Cape of South Africa, in Calvinia, Cederber Found on rocky sandstone slopes 300-700m above sea level.
	Ecological role	Food source for pollinators.
Use	Part used	Leaves and stems.
	Harvesting techniques and frequency	Harvesting is permit-regulated by Cape Nature, but illegal harvesti November to April for leaves and stems, and January to April for e occurs by hand, cutting to 5cm above the ground. Annual harvesti cultivated plants; for naturally occurring plants a three-year cycle
	Usage intensity across species range (areas of high medium and no use, % of range utilised)	With many years of cultivation, this information can be determine *betulina* farms in the Western Cape, where harvesting pressure is
	Domestication and cultivation	Buchu has been cultivated since 1927, with increased cultivation a pressure on wild populations. A project by the Agricultural Resear formalise buchu cultivation. Cultivation has reduced pressure on w (2011) lists comprehensive production guidelines.
Management	Harvesting guidelines available	Cape Nature (2015) recommends a three-year harvest cycle, from recommended. Permits are granted by Cape Nature.
	Have studies been done on Harvesting pressure (legal and illegal)?	Williams and Kepe (2008) found that 80% of local harvesters in Ela buchu populations over the last five years. Coetzee (1999) and Ho methods to be unsustainable. De Ponte Machado (2003) showed t dependent on frequency of harvesting, with three-year intervals f
	Have studies been done on the determination of sustainable harvest level models?	No
Conservation	Threats /drivers of change	Most of the product is harvested from the wild, which is a threat, the wrong time of year (before seeding), or repeat severe harvesti essential oils from overseas markets leads to unsustainable harves 2016).
	Trends over last ten years	Decreasing (Raimondo et al., 2009).
	Status (red listed?)	Listed as 'least concern', with the population decreasing as of 201 over 4624 km² in more than 40 locations (Trinder-Smith and Raim
Information sources	Key literature sources	See reference list

Table 5.3.2: *A. betulina* review of resource assessments

Location	Part used	Life form & distribution	Scale of assessment	Aims & method	Results/findings
Western interior of Western Cape: Buchu's known extent	Leaves, oils	Shrubs in scattered populations on communally-owned mountain land, and in cultivated fields on small and large-scale farms	Regional: Western Cape	Aim: Investigate the effects of changes in non-timber forest product production and cultivation on the commercial trade for different stakeholders. Thirty-one semi-structured and key informant interviews of rural communities involved as small-scale farmers (five) or harvesters (12); large-scale farmers (five); industry members (seven); and government or nature conservation authorities (two). Data were analysed through "memoing".	Buchu grows on communa land in Algeria (340ha) and It has been cultivated at A fungus), Elandskloof (10ha and Genadenberg (9ha), a outpost in Piketberg. With total extent of cultivated b Cape is 250-300 ha. The la Witelskloof Farm near Clar Mouton's Valley on the Pik (50ha) and at Hebron Esta Mountain (60ha), along wi Cederberg, Paarl, and Pike under cultivation by indus 3 tons of vegetative mater depending on age and cult
Western Cape	Leaves, stems	Not provided	Regional: Elandskloof	Aim: Determine the social dynamics of livelihoods based on buchu, as well as the harvesting practices used. A survey was conducted of 52 locals, including homeowners and small commercial farmers, using questionnaires.	500 tons of raw material is (natural and cultivated cor

5. 4 Buchu (*A. crenulata*)

Table 5.4.1: *A. crenulata* species profile

Data categories	Data fields	Information summary
Species life history	Life form	Single-stemmed, aromatic shrub growing to 2.5m.
	Reproductive type	Insect-pollinated, reseeds after fire, ballistic seed dispersal.
	Age at first fruiting	N/a
	Yield of harvested part per plant (and per ha)	Yields 4-5 tons of vegetative material per hectare (Muller, 2015).
	Propagation if cultivated	Propagation from seed and cuttings is possible, but vegetative propag difficult. Soil pH, salinity, phosphate, and nitrate must be low, with hi Farmers remove emerging wild seedlings in between fires, and replar better than those left in the wild.
	Pattern of distribution	Limited to the Western Cape of South Africa, in Ceres, Tulbagh, Wolse Betty's Bay, Caledon, Worcester and Swellendam.

		Occurs in sheltered ravines and along streams in middle mountain slo *A. betulina.*
	Ecological role	Food source for pollinators.
Use	Part used	Leaves and stems.
	Harvesting techniques and frequency	Harvesting is permit-regulated by Cape Nature, but illegal harvesting Harvesting takes place November to January. Harvesting occurs by hand, with the plant pruned to a lollipop 40cm f Annual harvesting begins 18 months after planting for cultivated plan three-year cycle is recommended.
	Usage intensity across species range (areas of high medium and no use, % of range utilised)	With many years of cultivation, this information can be determined fr *crenulata* farms in the Western Cape, where harvesting pressure is lik
	Domestication and cultivation	Buchu has been cultivated since 1927, with increased cultivation atte on wild populations. A project by the Agricultural Research Council la cultivation. Cultivation has reduced pressure on wild populations to s (2011) lists comprehensive production guidelines.
Management		Cape Nature (2015) recommends a three-year harvest cycle, from Ma recommended. Permits are granted by Cape Nature.
	Have studies been done on harvesting pressure (legal and illegal)?	No
	Have studies been done on determination of sustainable harvest level models?	No
Conservation	Threats /drivers of change	Most of the product is harvested from the wild, posing a threat in itse harvesting of leaves at the wrong time of year (before seeding), and f Raimondo, 2016).
	Trends over last ten years	Decreasing. (Raimondo et al., 2009)
	Status (red listed?)	Listed as 'least concern' with the population decreasing (2016). It cov more than 20% of individuals lost.
Information sources	Key literature sources	See reference list.

Table 5.4.2: *A. crenulata* review of resource assessments

Location	Part used	Life form & distribution	Scale of assessment	Aims & method	Results/findings
Western Cape	Leaves, stems	Not provided	Regional: Elandskloof	Aim: Determine the social dynamics of livelihoods based on buchu, as well as the harvesting practices used. A survey was conducted of 52 locals, including homeowners and small commercial farmers, using questionnaires.	500 tons of raw material is h (natural and cultivated com

Western interior of Western Cape: Buchu's known extent	Leaves, oils	Not provided	Regional: Western Cape	Aim: Investigate the effects of changes in non-timber forest product production and cultivation on the commercial trade for different stakeholders. Thirty-one semi-structured and key informant interviews were conducted, of rural communities involved as small-scale farmers (five) or harvesters (12); large-scale farmers (five); industry members (seven); and government or nature conservation authorities (two).	Buchu grows on communall land in Algeria (340ha) and I It has been cultivated at Alg fungus), Elandskloof (10ha), and Genadenberg (9ha), a M outpost in Piketberg. With la total extent of cultivated bu Cape is 250-300ha. The large Witelskloof Farm near Clanw Mouton's Valley on the Pike (50ha), and at Hebron Estate Mountain (60ha), along with Cederberg, Paarl, and Piketb *crenulata* produces 4-5 tons depending on age and cultiv

5.5 Devil's claw (*Harpagophytum procumbens*)

Table 5.5.1: Devil's Claw species profile

Data categories	Data fields	Information summary
Species life history	Life form	Creeping perennial spreading from fleshy rootstock.
	Reproductive type	Reproduces from tubers and seed.
	Age at first fruiting	Tubers are harvested, and take three years to regenerate to ha
	Yield of harvested part per plant (and per ha)	A single plant produces an average of six secondary tubers (N=2 45 g (N=21). Thus, by dividing the average dry weight (45 g) into production (dry weight) it is possible to determine the approxim the wild (Raimondo et al., 2005).
	Propagation	From seed and tubers.
	Domestication and cultivation	Private initiatives in Namibia and South Africa are now successf commercial scale (Powell, 2001). There are concerns that cultiv share of poor rural communities who harvest from wild populat
	Pattern of distribution	Restricted to the semi-arid savanna areas of Botswana, Namibia populations occur in Northern Cape, North West, and Limpopo showed that land use affects the density plants and that high gr communally owned areas favours their occurrence (Raimondo
	Ecological role	Weedy species, invader, pioneer
Use	Part used	Secondary tubers. Primary tubers are sometimes taken too, de
	Use	Devil's claw is a veritable cure-all, but only whole extracts have parts. The most important components are iridoid glycosides (n procumbide). Some of its properties are listed as: analgesic, ant inflammatory, antirheumatic, diuretic, hypotensive, laxative, pu and a febrifuge, cholelogue and bitter tonic. In western medicin rheumatism (SANBI, 2017).
	Usage intensity across species range	Wild populations are commercially harvested from communal a former Bophuthatswana). There is no known commercial harve Limpopo with limited use by local communities for self-medicat (Raimondo et al., 2005).
	Harvesting techniques and frequency	The secondary tubers are harvested from one side of the plant, the dry season. The plant should then be left for minimum of th secondary tubers (Raimondo et al., 2005).

Management	Management plan/s	Devil's claw has not been considered for the development of a devil's claw market is fairly limited and has been declining. For developing a BDM.
	Studies on harvesting pressure (legal/ illegal)	This was assessed by Raimondo et al. (2005). There is localised over-harvesting was assessed to be low.
	Studies to determine sustainable harvest levels/ harvest guidelines?	NWDACE Devil's Claw Harvesting Project has developed guideli done according to a quadrant rotational harvesting system, re- minimum of three years. Only the secondary tubers may be har remain in the ground as specified. http://www.harpago.co.za/P Devil's Claw Harvesting Project is no longer operational.
	Resource monitoring	NWDACE should expand its training and monitoring programme with sustainable harvest practices (Raimondo et al., 2005). It is recommended that the current status of this programme b monitoring.
Conservation	Threats /drivers of change	Harvesting is not a serious threat to the national population, bu taken place in certain localities according to Raimondo et al. (20 The species is tolerant of habitat degradation and grazing press where it occurs.
	Status (red listed?)	Protected (NEMBA). Not CITES listed. Listed as 'least concern' ir South Africa should consider a CITES Appendix III listing (Raimo The CITES plant committee convened to consider this and Hood
Information sources	Key literature sources	See below.
	Ecological experts	See reference list.
Institutional aspects	Key actors and mandates (Government, industry, NGO)	North West Department of Agriculture Conservation and Enviro Traffic – CITES status, trade monitoring SANBI
	Projects /networks	North West Department of Agriculture Conservation and Enviro Harvesting Project Devil's claw working groups- regional, national and provincial. N these groups is readily available.

Table 5.5.2: Devil's claw review of resource assessments

Location	Part used	Scale of assessment	Aims & method	Results/findings	Reference
Whole range in South Africa	Tubers	National	The range mapped from herbaria records and user information. 46 x 1 km² plots were sampled throughout the range. To determine abundance, the number of plants were counted within 24 randomly located transects, each 100m x 2m.	The findings are combined with 2005 RA below.	Hachfeld (2003)

South Africa	Tubers	National	The same methods as the above RA was used, and a further 39 x 1 km² plots were sampled. GPS co-ordinates for all transects were recorded so they can form a baseline for monitoring. The plots sampled in both studies comprise a total of 89 km^2. Information was also gathered on: • Estimates of total harvest for commercial purposes • Location of commercial harvesting • Contribution to livelihoods • Measures of post-harvest recovery and survival rates • Assessment of the sustainability of current harvest rates and harvesting methods	The species distribution in South Africa is mapped. The total population could not be estimated owing to patchy distribution. Areas of dense concentration were identified to be in communal land in the North West province and eastern border of the Northern Cape. Populations are too small and dispersed to support commercial harvesting in other parts of its range (Raimondo et al., 2005). The species as a whole is assessed to be not threatened by harvesting in South Africa, considering the findings that: • A small proportion of the population in SA is harvested. • An average of 70% of plants harvested were not killed. • The species has a highly persistent seed bank • Some localised impact on populations was detected.	Raimondo et al. (2005)

5.6 Honeybush

Table 5.6.1: Honeybush species profile

Data categories	Data fields	*Cyclopia intermedia*	*Cyclopia sub*
Species life history	Life form	Shrub	Shrub
	Reproductive type	Re-sprouter	Re-seeder
	Age at first fruiting	Harvestable at about five years.	Harvestable

	Yield of harvested part per plant (and per ha)	Average yield: 400g Range: 100g to 1500g Density 200-4300/ha	Average yiel Range: 500g Density: 100
	Propagation	From soil seed store, post fire when conditions are right. Very limited seedling recruitment.	Seeds germi
	Domestication and cultivation	Very limited cultivation.	Most widely
	Pattern of distribution	Widely distributed patches across 11496 km^2 on southerly facing slopes at elevations from 350m to 1800m. 4480km^2 in protected areas (39%).	Patchy and l 4541km^2, so lines, elevati 1384km^2 in p
	Ecological role	Pioneer species, resprouts after fire.	Pioneer spec
Use	Part used	Whole plant.	Whole plant
	Industry history and structure	85% of annual wild crop. 2019: 75% of total crop was wild-harvested. 2016: 85% of total crop was wild-harvested. Mainstay of the industry. There are only six processors (plus two small ones). Almost all the harvest goes through these processors. There is increased harvesting since the late 1990s, with the highest yields in about 2010/2011 (600 tons/year) and an average yield of 350 tons in 2006 to 2017. The yield is declining currently (due to decline in demand).	10% of annu
	Harvesting techniques and frequency	The whole plant is cut with a sickle, or secateurs, at return interval of every 4 years, when about 90% of the population is harvested. Alternatively, 50% of a population is cut every two years (still four-year age for plant (see 2018 harvesting guidelines for details).	A maximum secateurs, ev and enough continued gr for details).
	Usage intensity across species range (areas of high medium and no use, % of range utilised)	The plant is wild harvested, with high intensity use in an area of 6306km^2 in the Eastern Cape and Western Cape's Langkloof and Eland's Valley (about 50% of range). In the western part of distribution, the populations inaccessible and sparse.	The plant is and Western Tsitsikamma intensity use
Management	Management plan/s	Eastern Cape: Farmers are required to submit a harvest management plan with a permit application for wild harvest. A BMP (DEFF) is in progress, due to be completed end 2020.	Eastern Cape harvest man application f BMP (DEFF) end 2020.
	Studies on harvesting pressure (legal and illegal)	No actual reports on this. There is a map of 'threat sites' for the DEADP project (McGregor, 2017).	No actual re sites' for the
	Studies to determine sustainable harvest levels/ harvest guidelines	DEADP reports (McGregor, 2017)	DEADP repo Van der Wal

Conservation	Threats /drivers of change	Increased fire frequency, illegal harvesting, over-harvesting, alien invasive plants, land transformation. Climate change has less of an impact because it is a mountain species. McGregor, 2017: 23-26.3% range loss under min to max RCP.	Increased fir harvesting, a transformati affected by c distribution i rainfall is rel
	Trends over last ten years	Declining.	Declining.
	Status (red listed?)	Listed as 'least concern'.	Listed as 'lea
Information sources	Key literature sources	See below.	
	Ecological experts	Dr. A Schutte Vlok, Prof. E. Joubert	Dr. A Schutte
Institutional aspects	Key actors and mandates (Government, industry, NGO)	Honeybush Community of Practice South African Honeybush Tea Association ARC Living Lands Processors: Melmont, Cape Honeybush, Honeybush Natural Products, The Heights, Honeyblossom Tea Traders, Agulhas Honeybush Tea EC DEDEAT (permits) Cape Nature (permits)	Honeybush C South Africa ARC Living Lands Processors: I Honeybush N Honeyblosso EC DEDEAT (Cape Nature
	Projects /networks		
	Certification		

Table 5.6.2: Honeybush review of resource assessments

Location	Part used	Scale of assessment	Aims & method	Results/findings	Reference
Eastern Cape and Western Cape, fynbos biome	Whole plant		PhD thesis: *Aspects of the sustainability of the honeybush industry* The aim was to determine the nature and extent of the wild honeybush resource (*C. intermedia*). The methods used included regional scale mapping based on existing literature, locality records (SANBI, PRECIS etc), GIS based multiple criteria analysis from secondary data (environmental variables).	(A is an actual measured value, P is potential – modelled or extrapolated). Focussed on *C. intermedia* (A)Average yield per plant: 400g, Range: 100 to 1500g (A)Density: 200 – 3500 plants per hectare (P)Average yield per ha: (P) Total distribution range: 11 496km^2 (P)Total likely distribution based on more detailed environmental variables: 5 111 km^2 (P)Total in protected areas: 2 263 km^2	McGregor (2021) McGregor (2017)

			'Probability of distribution' modelling was done with MaxEnt. Local scale mapping was done by sourcing data from management plans with maps of populations (EC DEDEAT permits); expert mapping with landowners, processors, harvesters, botanists, agricultural extension officers; mapping at workshops with stakeholders; and field mapping. Population surveys were done at 30 sites: 22 harvested sites and eight sites in protected areas to establish typical population structure, allometry, and abundance. An analysis of yield data was done using historic data from processors, landowners, and harvesters. Harvest surveys at 12 sites were done to determine the average yield per plant. Post-harvest surveys were done at four sites.	(A)Total area in harvest zone (the area where harvesting currently takes place): 659 km^2 (A) Total area currently harvested: 70km^2 (likely represents about 75% of actual area under harvest) (A)Total annual tonnage wet tea: 800-1000kg (A)Total processed annual average (past 8 years): 300 tons (50% of wet weight, 85% of which is *C. intermedia*)	
Eastern Cape and Western Cape, fynbos biome	50% of the whole plant		MSc thesis: *An assessment of the wild Cyclopia subternata (Vleitee) resource* The aim was to determine the nature and extent of the wild honeybush resource (*C. subternata*).	Total distribution range: 4 541,9 km^2 Total likely distribution based on more detailed environmental variables: 1 513.97 km^2 Best practice harvesting requires knowledge and	

			Mapping was done with GIS based MCS, modelling with MaxEnt, expert mapping. Workshop sessions were held with stakeholders to gather information on best practice for harvesting as well as through interviews and questionnaires. Field surveys of populations were done. Harvest surveys and interviews with harvesters were done.	experience of the plant and its environment. Only 50% of the plant can be harvested every two years for sustainable harvesting. (Other details are contained in the conclusion on 'best practice'). '	

Other Honeybush species status and cultivation:

- *Cyclopia genistoides* (kustee) RA done in 2011 - Near threatened status (cultivated, not wild harvested)
- *Cyclopia intermedia* (bergtee) RA done in 2016 - Least concern status (cultivated, not wild harvested)
- *Cyclopia subternata* (vleitee) RA done in 2016 - Least concern status (wild harvested, most cultivated)
- *Cyclopia sessiliflora* (Heidelberg-tee) RA done in 2011 - Near threatened status (wild harvested)
- *Cyclopia longifolia* (Van Stadens tea) RA done in 2011 - Critically endangered B1ab(iii) status (cultivated only)
- *Cyclopia maculata* (Genadendal Tea) RA done in 2011 - Near threatened B1ab(iii) status (wild harvested and cultivated)
- *Cyclopia plicata*, RA done in 2011 - Endangered B1ab(iii,v)+2ab(iii,v) status (used to be wild harvested, now nearly extinct)

5.7 Kalahari melon *(Citrillus lanatus*)

Table 5.7.1: Kalahari Melon species profile

Data categories	Data fields	Information summary
Species life history	Life form	Creeping annual herb.
	Reproductive type	Annual, reproduces from seed.
	Age at first fruiting	Yearly fruits.
	Yield of harvested part per plant (and per ha)	Up to 40 melons have been recorded on one wild plant; their av 2011).
	Propagation	From seed.

	Domestication and cultivation	The plant is cultivated in a semi-wild state throughout South Afri including Mediterranean Africa, the Middle East, West Asia, Chin 1996; Vermaak et al., 2011; Welman, 2011). Populations exist ov with multiple landraces subject to selection over hundreds of yea 2003).
	Pattern of distribution	A Kalahari Desert species widely cultivated.
	Ecological role	Weedy pioneer species growing in dry riverbeds and sandy riveri
Use	Part used	Oil obtained from the seeds has commercial value. Fruit flesh, rind and seeds are consumed by local communities.
	Use	Oil from seeds is used in skin moisturiser and other cosmetic pro
	Usage intensity across species range	Widely used for subsistence purposes. Oil is extracted from seed pharmaceutical industry.
	Harvesting techniques and frequency	Melons are harvested when ripe and the seed extracted from th
Management	Management plan/s	No
	Studies on harvesting pressure (legal and illegal)	Not applicable, the plant is easily propagated from seed.
	Studies to determine sustainable harvest levels/ harvest guidelines?	Not applicable, the plant is easily propagated from seed.
	Resource Monitoring	None
Conservation	Threats /drivers of change	Possible genetic contamination from cultivated strains.
	Trends over last ten years	N/a
	Status (red listed?)	*Citrullus lanatus* is not threatened and its status is described as ` (2009). This means that the species is not at risk of extinction or
Information sources	Key literature sources	See below.
	Ecological experts	
Institutional aspects	Key actors and mandates (Government, industry, NGO)	
	Projects /networks	
	Certification	

Table 5.7.2: Kalahari Melon review of resource assessments

None found.

5.8 Marula

Table 5.8.1: Marula species profile

Data categories	Data fields	Information summary

Species life history	Life form	Deciduous, single-stemmed tree growing to 18m. Can live for up t
	Reproductive type	Insect-pollinated, animal seed dispersal. Dioecious: separate male producing fruit.
	Age at first fruiting	5-7 years (trees from seed); 3-5 years (trees from grafts).
	Yield of harvested part per plant (and per ha)	A single tree can produce up to 500kg of fruit annually (Nerd & Mi 2000). In Sudan, studies found *S. birrea birrea* produced 31350 fru hectare, or 14.7 tons per hectare per year (Daldoum et al., 2012).
	Propagation	Propagation is done from seeds, grafting, cuttings. Seeds should b propagated on damp peat moss. The seed plug should be removed poor root system and are not recommended. Grafting is recomme must be grown from seeds for grafts. Seedlings from nurseries hav
	Domestication and cultivation	The World Agroforestry Centre (ICRAF) began a participatory dom encouraging subsistence farmers to actively domesticate marula. using grafting. Marula trees have been introduced for cultivation i States of America (Muok et al., 2011). DAFF (2010) lists comprehe Cultivated trees show higher fruit yield, and can be selected for fru is mainly of female plants. There are two main traders of commer Distell Pty Ltd. in Stellenbosch, South Africa, which bottles Amarul national Mine Workers Development, a DFID-funded project, proc collaborative project (CRIAA SA-DC) between farmers, a cooperati Project, a local NGO (Wynberg et al., 2002). Leakey (2005) provide selection of trees for cultivation.
	Pattern of distribution	The plant occurs from Ethiopia to South Africa, in 29 African count South Africa, Swaziland, Botswana, and Namibia. In South Africa, i Cape, Limpopo and Mpumalanga, but is dominant in the Ba Phalal It is found from sea level to 1600m, in savanna or forest margins, bushland. It prefers sandy soil and rocky hillsides. The tree is frost rainfall regions from 250-1000mm per year. Three subspecies: - *S. birrea subsp. caffra*: Kenya, Tanzania, Angola, Malawi, Mozaml Namibia, South Africa, Swaziland, Madagascar. - *S. birrea subsp. multifoliolata*: Tanzania and Kenya. - *S. birrea subsp. birrea*: tropical areas of West, north-east and Eas Tanzania and Kenya are recognized as centres of biodiversity for t
	Ecological role	Marula is considered a keystone species in that its large size provi a number of sub-canopy plants can thrive. The canopy itself provi and vertebrates, and several moth species breed on marula trees. by a number of species (Shackleton et al., 2002b).
Use	Part used	Fruit, leaves, bark, seeds, seed shells, gum, wood, pulp, kernel, nu
	Harvesting techniques and frequency	Flowering occurs from September to November and fruiting from occurs from January to April. Ripe fruit is collected from the groun Annual harvesting is allowed from five years old.
	Usage intensity across species range (areas of high medium and no use, % of range utilised)	Trees occur in national parks and in agroforestry systems where th Use near to villages and in agroforestry systems is higher than in n *S. birrea* has had cultivation success across its range, as well as in America. Cultivated trees show higher fruit yield (DAFF, 2011).

		The highest area of production is in the Ba Phalaborwa Valley in Li restricted but does occur. Knowing the area under marula cultivation, as well as the area wit systems, arable land and conservation protection will give a better the species range.
Management	Harvesting guidelines available	Shackleton et al. (2002b) indicates that there are local rules (not le South Africa and Namibia. Murye (2017) found the current level o suggested more official monitoring and control, with the current l
	Have studies been done on harvesting pressure (legal and illegal)?	Murye and Pelser (2018) found that if harvesting levels continue a become unavailable in 5-10 years. The authors suggest replacing c producing, having dedicated marula fields protected from animals sustainable harvesting, and revisiting rural development policies. Shackleton et al. (2002b) showed a perception of scarcity of maru of dwindling resources in South Africa. Murye (2017) found that increased harvesting of marula fruits and trees and the sustainability of marula tree species in Swaziland. Maroyi (2001) found that 95.7% of a local population in south-cen populations are decreasing.
	Have studies been done on determination of sustainable harvest level models?	Emanuel et al. (2005) determined that 92% of fruit could be harve the population.
Conservation	Threats /drivers of change	Agricultural expansion leading to deforestation, soil erosion, land overgrazing (Muok et al., 2011). Exploitation of natural stands for bark and wood harvesting (Muok Skewed sex ratio in favour of females due to selective propagation al., 2011; Murye 2017; Nghitoolwa et al., 2003; Shackleton et al., 2 Gouwakinnou et al., 2011a). Neglect in farmlands due to sparse distribution, resulting in trees l transplanted out from under parent tree canopies, and seedlings r pressure (Muok et al., 2011). Elephants debarking and pushing adult trees over in Kruger Nation (Viljoen 1988; Coetzee et al., 1979; Jacobs and Biggs, 2002a and 20 2019).
	Trends over last ten years	Decreasing according to local reports. Poor or no recruitment in p livestock.
	Status (red listed?)	Listed as 'least concern' (2008). Listed as a protected tree in South
Information sources	Key literature sources	See reference list.

Table 5.8.2: Marula review of resource assessments

Location	Part used	Scale of assessment	Aims & method	Results/findings	Reference
Ophande community on the Makhatini	Fruit and trees	Local community	The aim was to characterise the available marula resources through	There are few to no trees to replace the current standing crop of fruiting trees and no re-planting	T. Mchardy (2002)

flats, Maputaland			the density of standing crop of trees in different land-use categories (homesteads, arable fields, grazing lands) and yield per fruit, per tree and per hectare. Age size classes in each land use category. Method: absolute counts and dbh measurements in plots (not specified).	of marulas (household interviews). Homesteads appear to be sited near a fruiting marula tree and appear to have larger fruits and higher yields in number of fruits, than other locations.	Institute of Natural Resources
South Africa	Fruit and trees	National (climatic data, at a resolution of 1 x 1 km)	The aim was to determine the potential distribution of marula in South Africa mapped using nine bioclimatic variables as input into a GIS. By mapping potential distribution, it creates a base layer from where questions can be asked surrounding land tenure in distribution areas, as well as other socio-economic questions. Methods used included: Bioclimatic variables (envelopes) used mean min temperature of	There was a higher accuracy of predicating the potential occurrence of marula than previous models for the species as used in TSSG model (Van Maltiz ,1995).	Combrinck & Muller (2002) CSIR

			the coldest month, mean max temperature of the hottest month; mean annual max and min temperature; growth days; growth period mean temperature, non-growth temperature; mean annual rainfall and temperature.		
South Africa: Limpopo	Whole tree	Reserve: Nylsvley Nature Reserve	Aim: To determine the population biology of *S. birrea caffra* in Nylsvley Nature Reserve, Limpopo, South Africa. Data was collected in 2015 and 2016 using a random sampling method. Based on measured height, trees were grouped into seedlings (<1m), juveniles (1-3m) and adults (>3m). Canopy cover was measured in metres, and health was assessed on a scale of 0-4, as was disturbance. All kernels at tree bases were collected, and photographs were taken of fruit. Seed dispersal was estimated	85 trees were located. The population mainly comprised of seedlings, with few juvenile and adult trees. 53% of the canopy cover comprised trees of <4m, and no seedlings were found under the parent plants. Crowns were largely undamaged, or with only slight damage (7%). Few adult trees bore fruit, and few seeds were found evidence of as seed predation was rife, as was anecdotal evidence of fruit consumption by mammals and humans. Such predators were found to play a large role in tree distribution.	Tshimomola (2017)

			using the position of seedlings under parent trees.		
South Africa: Limpopo	Whole tree, fruits, kernels, bark, leaves	Local: Masea village in Mutale Local Municipality within the Vhembe District Municipality	Aim: To investigate indigenous knowledge, uses and management *S. birrea* in Matshena village, Vhembe District Municipality. Thirty interviews with locals were conducted, with interviewees selected using a convenient sampling method, to ascertain the uses, parts used and management of *S. birrea* using a semi-structured, open-ended questionnaire. 100m transects 10m wide were used, in the communal fields utilised by the local village for marula collection. Tree morphology was assessed, including basal stem circumference, height and crown health. Stem diameter and height were used to assess population structure.	Fruits (35%), kernels (28%), and bark (24%) were the main plant parts utilised. Fruits were consumed fresh, as a juice, or cooked into a jelly or alcoholic beverage. Kernels were consumed fresh or cooked. Bark was used for traditional medicine. 130 trees were sampled. The majority of trees were juveniles with a stem circumference of 51-150cm. No individuals with a stem circumference of less than 50cm were found, nor were any individuals <3m in height, indicating regeneration problems within the population. This was thought to be due to fruit predation by goats and human consumption of fruits and kernels. 79% of trees had a healthy crown.	Mabala (2017)
South Africa: Limpopo	Whole tree	Local: Ga-Makhushane and	Aim: To compare the distribution patterns and population	Both villages view *S. birrea* as an important resource, with 73% and 70% of informants using	Mocheki et al. (2018)

		Tshivhongweni villages	statuses of *S. birrea* in two villages in the Limpopo Province. Study areas were selected for abundance of *S. birrea.* Thirty-five interviews were conducted in each village to determine Nearest-neighbour plant sampling within a population was used by measuring the distance between *S. birrea* individuals within a village, to determine population structure. For 50 trees in each population, basal stem circumference, height and canopy structure were assessed.	it for food, 14% and 25% using it for medicine and in the second village 4% as a shade source and 1% as a windbreaker. Fruits were utilised the most in both villages, followed by bark. 140 individual trees were found between the two villages. Trees were distributed regularly, with differences in the dispersion and size (height, circumference, and canopy cover) of trees between the two villages ($p<0.05$). Population differences were ascribed to local climatic conditions as well as patterns of use.	
South Africa	Whole tree	Reserve: Kruger National Park	Aim: Conduct a preliminary survey on changes in the density of large trees in two areas of Kruger National Park between 1944 and 1981. Aerial photographs from 1944 and 1974 (both 1:30 000) in Satara and 1977 (1:30 000) and 1940 (1:20 000) in	In Satara, the number of large trees per hectare was 12 in 1945, 9 in 1965, 2 in 1974 and 0.5 in 1981. The total decrease over this period was 93.4%. In Lower Sabie, this was 5.5 in 1940, 5 in 1965, 3 in 1977 and 2.5 in 1981. The total decrease over this period was 49.6%. The largest decrease occurred between 1965 and the mid-1970s for	Viljoen (1988)

			Lower Sabie and 1965 (1:60 000) in both sites, were used. For each area, 10 500 x 500m plots were chosen on the oldest photographs, and all trees with canopies larger than 6m were counted on all photographs. Aerial photographs at a scale of 1:4500 were then taken in 1981, and the number of trees with canopies larger than 6m again counted in 10 random plots of 150 x 150m. The number of trees per hectare was determined and compared. The dominant trees in the area were *Acacia nigrescens, Sclerocarya birrea* and *Combretum imberbe.*	both areas, but particularly for Satara. These decreases are attributed to elephants recolonising the park in the 1960s, a long drought in the 1960s, and planned rotational burning that began in 1954.	
Zimbabwe	Bark, whole tree, fruit	Local: Ward 3, Mwenezi	Aims: Determine the abundance and distribution of *S. birrea,* as well as the population dynamics, determine the relationship between debarking and size, and	173 trees were found: 7/ha on average, varying from 2 to 27/ha. Large trees were dominant ($p<0.001$). Debarking varied based on size ($p<0.05$) with trees with a diameter of 40.1-60cm being most affected. This size group also fruited significantly more than	Munondo (2005)

			determine sustainability of current population use. 1:12 500 air photos (2000) were scanned, and geo-referenced. Focal trees were mapped, sample sites were located at varying distances from the marula oil processing centre. 11 transects were mapped from focal trees within these sites, with variable length (after 10 large trees were encountered) and 20m width. Tree measurements were used to classify size class, and canopy size was assessed. Trees were categorised as fruiting or non-fruiting, based on fruit evidence. Presence or absence of debarking was recorded.	other size classes ($p<0.05$). A gradual decrease in number of trees is predicted based on the population structure.	
Eswatini	Trees, bark, fruit, leaves, seeds, wood, roots	Local: Mpolonjeni Constituency (Inkhundla) in the Lubombo Region	Aims: Determine the role of marula in poverty alleviation among the rural population in Eswatini and to identify policy interventions for conservation of the marula tree	All four chiefdoms were comprised of lowveld bushveld savannah. 17 species of tree, six species of grass and four species of invasive plants were identified. *S. birrea* was scarcely distributed, with 344 trees assessed. There was	Murye (2017)

			for local use. A socio-economic survey was done, consisting of 411 participants from four chiefdoms within Eswatini. A multi-stage, random sampling procedure was used to select adults within households to participate in a structured questionnaire. 20 key informants were also selected from stakeholder companies and organisations for in-depth interviews. All marula trees in the area were assessed. A ground survey analysed woody species composition, density, age structure and size structure in arable land, grazing areas and the Mkhaya nature reserve. Five plots of 200 x 200m were assessed for each land use type. This was done using a Point Centre Quarter (PCQ) method, with sampling done along transects in each	a male:female ratio of 1:3.3. In the nature reserve, seedlings increased from 143 to 206 between 2014 and 2015. In the grazing area, this was stable at 59 and 58 trees. In the fields, there was a decrease in seedlings from 24 in 2014 to 17 in 2015, indicating regeneration of marula trees in grazing and arable fields is at risk. This is thought to be due to ploughing for planting and predation by grazing livestock, as well as a population skewed towards large, mature individuals. There were high levels of regeneration observed in the nature reserve. 53.3% of households supplement their income by harvesting and selling marula, and 68.5% of this number consider it to be an important part of their income. Most households use marula to brew an alcoholic beverage (76.4%), for food (67.5%) or to sell the kernels (51.9%). Most marula harvesting occurred around the homesteads, in the arable fields or grazing areas, but some unlawful harvesting from the nature reserve took place. Harvesting was most successful around the arable fields, measured as 63.2% collecting “more than two 20l buckets per day”, versus 30.4% around homesteads and 40.5% in	

			plot. At 10m intervals along the transect, quadrats of 5 x 5m around the point were assessed. All marula trees close to the sampling point were assessed, and distance to the central point measured. Tree diameter above the first basal swell was used to class trees into size categories, and all trees under 10cm diameter were classed as seedlings.	grazing areas. 53.8% of respondents thought that marula stocks are diminishing.	
Namibia	Whole tree	Local: Onambome and Oshiteyatemo villages	Aim: To collect baseline population structure and gender ratio information to inform management strategies. 286 ha of wooded farmland around two villages was surveyed for *S. birrea.* Twenty fields were surveyed in each village. In each field, trees with a circumference of >3cm were counted, diameter at breast height was measured and size class was assigned. Field	Individuals with a diameter at breast height of more than 50cm accounted for 30-50% of trees. The two villages differed in population structure, with more seedlings and juvenile trees found at Onambome, and more mature trees found at Oshiteyatemo. 649 trees were counted, with a bias towards females in the larger size classes. Marula trees were found to be scarcely distributed (1.5 individuals per hectare) in wooded farmland.	Nghitoolwa et al. (2003)

			size was ascertained, and comparable numbers of fields with low (1-2), medium (3-4) and high (>4) numbers of trees were assessed in each village. Fieldwork was conducted in July and August, and so consultation with field owners was used to determine gender, confirmed by the presence of endocarps beneath the tree.		
Zimbabwe	Fruit, whole tree, kernels	Local: Mukwakwe area	Aim: Determine the availability of *S. birrea* for harvesting of nut oils, using abundance, population structure and regeneration capacity. Thirty individuals from four villages were surveyed using structured and semi-structured interviews to determine perceptions of natural resource issues. Farming and natural land were sampled for marula trees along random transects within	All households harvested marula for their own use. 43% of households sold marula products. The average household harvested 160 ± 18 kg of marula fruits in 2004, with a range of 50-800 kg. This did not increase with household size. An average of 8.03 ± 3.19 *S. birrea* trees were found per hectare, with three times more on the natural land than the farmland (19.63 ± 11.82 versus 6.40± 5.29, p = 0.001). The population density and numbers were deemed to be high, with a relative density of 21.67%. There was a large proportion of seedlings and saplings, with an inverse J- shaped curve to numbers within different size classes,	Ngorima (2006)

			the four villages. Along the transects, point centre quarter (PCQ) method was used at 100m intervals to assess composition, density, and size structure. The distance from the central point to marula trees was measured, and tree diameters were measured and used to assign size profiles. Additional woody species were sampled: the closest species >1.5m in height to the central point was identified and measured.	indicating good regeneration.	
Zimbabwe	Whole tree	Local: Gonarezhou National Park, Chibwedziva Communal Area and Chizvirizvi Resettlement Area	Aim: To provide a baseline assessment of the population density and structure in Gonarezhou National Park and surrounds. Five belt transects of 100m width and variable length (15 trees) were conducted in the national park, communal area and resettlement area. Sampling was done in November. For each tree, height, girth, and	310 plants were recorded. 76% were >3m, while 17% were saplings. Seven dead trees were recorded in total: three in the national park, one in the communal area and three in the resettlement area. Tree height and density were highest in the national park, but sapling density was not. Small trees (diameter <0.2m – 0.6m) were most prevalent across all study sites, with a sharp decline in numbers >0.6m diameter, indicating high regeneration but low recruitment into adult trees.	Satuku et al. (2019)

			whether the tree was dead or alive were recorded. Height was used to assign size classes (tree >3m, shrub 1.5-3m and sapling <1.5m). Within each transect, saplings were counted in two plots of 20 x 30m.		
South Africa	Whole tree, fruit, wood, leaves, kernels	Local: Four villages in Bushbuckridge	Aim: To quantify the local use, abundance and productivity of *S. birrea*. Structured interviews were conducted in 36 homesteads in each of the four villages to determine marula processing, use, planting and care. Two workshops were held (27 and 35 participants) to identify issues relating to tenure, access and control of marula trees. Density of all trees was measured in homestead plots (99 plots), farmed field plots (30 plots), on transects of four 1 ha plots 300 - 500m apart within communal grazing lands (16 transects), and in randomly located	Tree density was highest in the protected areas and lowest in arable fields: 10.8 trees/ha in homesteads, 5.7 trees/ha in fields, 61.3 trees/ha in communal grazing lands and 102.1 trees/ha in the protected areas. Female tree density was 40-50% higher in the homesteads than in the grazing lands, fields or protected areas. Fruiting was significantly higher in the villages than in the protected areas (> 17 000 per tree versus <3 500 per tree, $p < 0.005$). Trees in the protected areas were significantly smaller than those within the villages (mean circumference 141.7 ± 7.2cm versus 211.1 ± 5.7, $p < 0.001$; mean height 7.8 ± 0.3 m versus 11.1 ± 0.3 m, $p < 0.001$). Fruit yield was significantly lower in the protected areas than in the villages per unit basal area ($t = 9.8$; $p < 0.001$) and canopy volume ($t = 6.4$; $p < 0.001$). There were more larger trees in the communal lands than in the protected areas (p <	Shackleton et al. (2003)

			0.2ha plots in two local protected areas (50 plots). Height and basal stem circumference were measured at each tree. Fruit yield was assessed by marking a sample of trees and counting all fallen fruit at these trees throughout the fruiting season.	0.001). Fruit from the villages was approximately 20% larger than from the protected area trees (24.9 ± 0.19 g versus 20.9 ± 0.18 g, $p < 0.001$). There was also a relationship between stem circumference and fruit yield: Village trees: Log(No. offruit) = 0.0039 (circum.)+ 3.582 ($r2 = 0.15$; $n=86$; $p < 0.005$) Protected areas: Log(No. offruit) = 0.0051 (circum.)+ 2.359 ($r2 = 0.16$; $n=62$; $p < 0.001$) There were more female trees in the homesteads as a result of active planting and care. Most respondents felt there was sufficient fruit to meet demand.	
Cameroon	Whole tree	Local: Sahelian zone	Aim: To determine the main uses of *S. birrea,* and understand traditional management, population dynamics and influence of land-use type on distribution. 250 interviews were conducted with locals to determine the habitat and conservation of the species, its	70% of interviewees use marula for handcraft, food and firewood. Farmers expressed concern about resource overexploitation, saying that fewer trees are present than in the past. Despite this, 75% of interviewees indicated that they don't have a plan for harvesting management. Tree density was on average 11.71 per hectare on farmland and 115.67 per hectare in the protected area. 37.4% of individuals had a	Yougouda (2018)

			uses and harvest patterns. 45 plots on farmland (the size of the farm) and 25 plots in the protected area (0.2ha each) were sampled. All individual trees were counted and marked. Sapling and seedling presence was also recorded. Height and circumference were assessed and used to divide trees into size classes.	diameter at breast height of 5-15cm. 45% of plots in the protected area contained juvenile trees, versus 15% in the farmland. Seedling density did not differ between the land use types, but sapling density was higher in the protected area (p = 0.0000). There were few large adult trees, indicating a skewed population structure.	
South Africa	Whole tree	Reserve: Kruger National Park	Aim: Determine the different kinds of elephant-damage on *S. birrea.* Roads through all major stands of marula trees were surveyed, with separate sections of road acting as separate transects with an average length of 8.9km. All trees taller than 5.5m within 100m from the road were included. The level of damage was categorised, including the number of scars and type of damage.	5953 trees were observed, with an average of 2.3 trees/hectare. Severity of elephant damage to trees was positively correlated with distance from the road.	Coetzee et al. (1979)
South Africa	Whole tree	Reserve: Kruger National Park	Aim: Determine the population structure of *S.*	The structure of sub-canopy individuals was significantly larger inside	Jacobs and Biggs (2002a)

			birrea including regeneration and recruitment of seedlings and compare these within different landscapes in Kruger National Park. 20 road transects (2km long and 100m wide) were conducted in four major landscapes in the Kruger National Park, as well as 16 seedling transects (100m long and 5m wide) per road transect (totalling 320). Every tree was recorded, and its size assessed, and size classes assigned. A road transect of 1.5 km was surveyed inside the roan enclosure, with adult trees surveyed in the same way and seedlings surveyed in 12 transects. Three belt transects and one road transect along the fire breaks outside the roan enclosure were also conducted. The elephant and game censuses were used to calculate densities of elephants and impala.	the roan enclosure than immediately outside of it. The population structure and number of mature trees differed significantly between the different landscapes. The population in the *Colophospermum* mopane shrubveld was found to be virtually extinct. The *Colophospermum mopane/Acacia nigrescens* savanna population lacked immature trees. The populations in the remaining two landscapes appear healthy, but many are suffering extreme damage from elephants. High regeneration rates were found in all locations. Density of marula trees was significantly higher in the roan enclosure than in all other landscapes. Less diverse landscapes seem to contribute to greater herbivory pressure on marula.	

South Africa	Whole tree	Reserve: Kruger National Park	Aim: To generate a data set to assess the role of elephants in marula population structure, in order to inform management strategy. Twenty transects were conducted along roads or fire breaks. Transects were 2km long and 100m wide. All live and dead marula trees were recorded, and damage to living trees was assessed.	Approximately 7% of the sampled population was dead, while 55% were damaged, and 15% of all trees were severely damaged. Damage levels did differ with landscape type. Shorter trees (2-8m) were disproportionately impacted by elephants.	Jacobs and Biggs (2002b)
South Africa	Whole tree	Local: Wits Rural Facility, Kruger National Park, and Jejane Private Nature Reserve	Aim: Determine how marula populations can sustain themselves in disturbed environments and why marula populations are so variable and unstable. Part 1: Previous studies' data sets, as well as 40m wide transects in Wits Rural Facility, Kruger National Park, and Jejane Private Nature Reserve were studied, amassing 22 populations in total. Trees were counted and measured. A total of 1903.3ha was	Part 1: Population densities varied from 0-88.88 trees/ha. Adult tree densities were much lower than juvenile: 4.15/ha vs 15.93. Five populations showed recruitment failure, one population was juvenile dominated, four had stable age structures and the remainder had missing size classes. Part 2: 495 trees were assessed. Stems grew and shrank in the growing and dormant seasons. 1% of trees died during the study period, but all these had shrunk in stem diameter by >8% in the previous year. Part 3: Seedlings grew up to 11mm in diameter and 22cm in height annually, with relative growth rates	Helm (2011)

			surveyed. Tree height and circumference was used to determine size class. Growth rates of saplings was measured for three years. Part 2: Trees were selected in N'washitsumbe enclosure, Hlangwine enclosure and Wits Rural Facility by walking four wandering transects at each site until 40 individuals in each of three size classes (1-3m, 3-5m and 5-8m) were found. Height, diameter above basal swelling and diameter at breast height were measured, as was evidence of herbivory, in 6-month intervals between May 2008 and May 2010. Part 3: Growth trials were conducted between 2007 and 2010 to examine growth rates and biomass allocation in different soil types and in seeds from different locations. Fruit	between 1.9 and 4.8%, positively correlated to rainfall and plant size. Growth rates were highest right after germination (20%). Seeds from higher rainfall regions grew faster than those from lower rainfall regions. Part 4: Sites were male-biased, and disturbance influenced the size at which fruit was produced. 32.4% of seeds germinated out of 60.3% viable seeds. 3.5% of the seeds/tree germinated into seedlings. 2% of seeds survived for more than one year, with high levels of seed predation.	

			was collected from various locations, and seeds extracted and planted. Each week seedling stem height, stem diameter and number of leaves were measured. Part 4: Fruit production and seed survival were assessed at five sites. Transects of 300-1000m and 40m wide were assessed for individuals ≥1 m in height until 200 individuals were sampled. Within transects, individuals <1m in height were assessed in sub-transects of 2m wide. Tree height, basal diameter and canopy diameter were measured. The number of fruit in the canopy and on the ground was counted, and 20 endocarps per site were assessed for seed viability. Seed banks of 10 females at each site were also assessed.		
South Africa	Whole tree	Reserve: Kruger National Park	Aim: To determine if fire or elephant herbivory resulted in	730 trees were assessed. 12% were dead and 49% had evidence of bark stripping.	Helm et al. (2011)

			greater mortality in *S. birrea,* if these two interact, and at what stem diameter marula trees are resistant to fire. 23 transects were assessed, covering 92 hectares. For each tree, basal stem diameter, maximum percentage of bark removed around the circumference, total percentage of bark area removed up to 3m, the height of the lowest point of removal, percentage of bark recovery, presence or absence of exposed sapwood charring, presence or absence of wood boring insect and the agent of bark removal (elephant or porcupine) was recorded. Fire simulation experiments were done while the trees were dormant on 40 trees, with 20 kept as controls. Tree height, basal diameter and percentage	28% of the 40 trees exposed to fire had died six months later. Marula trees with a basal stem circumference of >5.5cm were resistant to fire. Bark stripping had a significant effect on canopy dieback. High adult mortality was related to herbivory.	

			canopy dieback were measured before and after burning. Bark removal and fire simulation experiments were conducted by removing 0, 30, 60 and 100% of the circumference of the bark. Trees were resurveyed 16 months later to determine survival and bark regrowth.		
South Africa	Whole tree	Reserve: Jejane Private Nature Reserve	Aims: To determine reasons for the decline in adult marula trees, evaluate elephant impact on marula trees across sexes and size classes. 202 marula trees surveyed in 2009 and 2016, were resurveyed in 2018. The trees were located in eight transects within Jejane Private Nature Reserve. Differences in mortality levels between sexes were analysed with a Chi-square test, and differences in survival probability were analysed with a log rank test.	124/202 trees were still alive. Elephant presence, tree height and termite presence best explained mortality. Small, female tree mortality was highest, and female trees were found to have a lower survival probability than male trees.	Cook and Henley (2019)

Zambia	Whole tree	Local: Luangwa Valley	Aim: To demine the relationship between elephant herbivory and *S. birrea* germination and distribution. Three seed treatments in elephant dung boluses were examined: on a wooden platform away from termites, on the ground and removed from the bolus. The number of seedlings and their stem height and diameter was assessed 12 months later. 11 trees in a study area of 111 were visited 1-5 times per month to record fruit numbers in the ground and canopy, as well as fruit drop rates over 3-5-hour periods. Individual trees were mapped on 1:40 000 aerial photographs. Trees were visited and height and diameter measured. Seedlings were assessed in three plots where adult trees were common.	The seeds on the wooden platform resulted in 13 shoots, while the seeds on the ground resulted in 27. 226,000 fruits were recorded from 111 trees in April. Fruit fall rates varied between 0, 32, 30, and 74 fruits per hour. 222 adult trees were found, or 14.8 trees per hectare. There was a distinct absence of seedlings or younger trees. An average of 8000 fruits were produced per tree per year.	Lewis (1987)

South Africa	Whole tree	Local: three private game reserves near to Kruger National Park	Aim: Determine the abundance and population structure of marula trees, and the severity of damage by elephants at three game reserves. Thirty 1000 x 5 m transects were surveyed in each of the three reserves. Blocks of vegetation created by roads and cutlines were numbered, and 15 random numbers chosen to represent plots. Equitable numbers in the northern, southern, western, and eastern sections were chosen. Within plots, one transect was assessed inside the block (>10m from the edge) and one at the edge. The diameter of each *S. birrea* tree above the first basal swelling was measured, and fruit, bark stripping and branch breakage was noted.	615 marula trees were found in 90 transects. Marula tree density varied from 5.03 – 7.83 trees per transect. Trees were more common in the interior of plots (mean 8.1 trees per transect vs 5.6 at the edge). Large trees dominated the transects. 36% of the trees were fruiting. 62% of trees had elephant damage. Fewer immature trees were present, but the population was deemed sustainable.	Gadd (2002)
South Africa	Whole tree	Reserve: Nylsvley Nature Reserve	Aim: Analyse six major tree species of the African savanna,	No immature trees were found, with the few seedlings found dying between studies. The	Walker et al. (1986)

			to determine population dynamics. Colour aerial photographs were used to identify individuals. The trees were visited, and their circumference measured to assign size classes. The area near to an adult individual was searched for seedlings and saplings.	population structure is unstable, with regeneration unlikely.	
South Africa, Namibia	Fruit, kernels, whole tree	Local: Makhatini and Bushbuckridge in South Africa, and the former Ovamboland in North-central Namibia	Aim: Compare the role of marula in local livelihood systems, local culture, household commercialisation and the impacts of trade natural capital in three regions of Southern Africa. 60 to 142 household interviews were conducted at each site to determine *S. birrea* resource use and availability.	In Namibia, there was an average of 7.1 marula trees per field. In South Africa, 1200-1500kg of fruit were collected per year per field. There was an average of 2.7 marula trees per field, with 41-78.9% of respondents saying they had at least one marula tree on their property, and 10.8 trees per hectare in communal areas. Gender ratios were skewed towards females.	Shackleton et al. (2002a)
Zimbabwe	Whole tree	Local: Zambezi catchment	Aim: To classify the vegetation of the Zambezi catchment. Aerial photographs (1: 65 000 and 1: 80 000) were used to describe sampling	Marula was found to be widespread at medium altitudes and occurred in 13 designated vegetation types.	Timberlake et al. (1993)

			sites. At each of 1388 sites of 0.5-1hectare, plotless samples were used to identify all woody plant species in three size classes: less than 0.5m, 0.5-3m and larger than 3m.		
Sudan	Fruit, whole tree, seedlings	Local: Two sites in Rashad District in the Nuba Mountains	Aims: Inventory *S. birrea* stands, assess fruit production and natural regeneration. Data was collected from samples demarcated along transects in two sites in May 2005. In each site, four transects from the top to the bottom of the hills were established in northerly, southerly, westerly, and easterly directions. The hills were divided into top, middle and bottom strata, creating 24 circulars, 0.1-hectare sample plots in the two sites. All adult trees and seedlings within the plots were counted and sexed, as well as fruit estimated.	*S. birrea* constituted half of the tree density of the area, or 60 trees per hectare. There was a 1:1 ratio of male and female trees. Average fruit production over three months was 31350 fruits per tree, or 940500 fruits per hectare: 14.7 tons per hectare per year. 210 seedlings were found per hectare, and the seedling survival rate was 10%.	Daldoum et al. (2012)

			Fallen fruit was collected from three trees at each plot twice daily for three months until no more fruit was produced. A thorn fence was used to exclude animals. Average total number of fruits per tree was calculated. The number of germinated seeds at each plot was counted at first sampling, seedlings were marked with wooden pegs and mortality was calculated every three months for a year.		
Benin	Whole tree	Reserve: W National Park of Benin	Aim: To determine the impact of land use type on the conservation status of *Sclerocarya birrea subsp. birrea*. Two to three farms in each of 18 villages in the reserve were examined, giving a total of 40 plots. In the reserve, 34 0.2ha plots were chosen at random. In each plot, vegetation type and *S. birrea* individuals (mature and saplings) were	There was an average of 27.6 adult trees found per hectare in the protected area, and 3.4 adult trees per hectare on the farms. Seedling levels were equitable between the reserve and the farms, but seed germination was higher on the farms. Very few saplings and small adults were found on the farms.	Gouwakinnou et al. (2009)

			assessed, and seedlings under adult trees were also assessed. A coefficient of skewness was used to assess intra-population trends.		
Benin	Whole tree	Local: Karimama District (KD), Tanguieta District	Aim: To assess the population structure in terms of sex, in local perception and in the field. Structured interviews were done with 60 locals across the range of *S. birrea* and across different climatic regions, to determine understanding of sex differentiation in the trees. If there was understanding, characteristics used to determine tree sex were recorded. Three transects of 2-3km in length were traversed and each adult individual along each transect was counted and sexed. Two transects were laid in agroforestry systems in the two climatic regions, and one in a protected	55% of locals were aware of two sexes of *S. birrea*, with those over 40 showing the greatest awareness. 676 individual trees were found. Of these, 48% were male and 52% female. Four male individuals with hermaphroditic flowers were found, indicating that these could bear fruit.	Gouwakinnou et al. (2011a)

			area. The study was undertaken from late February to early May, to allow flower presence to guide sexing.		
Benin	Fruit, whole tree	Local: two climatic zones in Benin	Aims: Assess variability in fruit production along climatic gradients, correlate these among phenotypic types and derive applications for domestication. Fruit was collected from 27 fields in a dry tropical climate (late April), and from 15 fields in a subtropical humid climate (early May). 10-24 fallen fruits were collected from one tree per field, from the four quarters of the crown projection (Leakey et al., 2000) and diameter at breast height (dbh) was recorded for each tree.	Tree size did not have a significant effect on fruit weight. There was significant variation in traits between trees, and fruits from the same tree. Mean fruit mass was 19.90g ± 0.37 for the dry zone, and 17.02g ± 0.24 for the humid zone. The high coefficient of variation in traits shows good potential for domestication.	Gouwakinnou et al. (2011b)
Namibia	Fruit, whole tree	Local: North-central Namibia	Aim: To measure marula stem densities and marula fruit yields in North-central Namibian homesteads, fields, communal lands, and protected areas.	The total fruit yield per tree was 596 kilograms (std. dev. 465kg). The average fruit mass was 30 g. The average canopy size (w x h) was 45 square metres. The average trunk diameter was 67 cm. The average tree height was 10.2m, and	Botelle et al. (2002)

			104 trees from 20 farm plots in eight sample sites across three regions of Namibia were assessed. Fruit yield, trunk size, canopy area, age and height were determined. Specifics are not given on how these were determined.	average tree age was 53 years.	
South Africa	Fruit, whole tree	Local: Bushbuckridge in Limpopo province	Aim: Provide a population matrix model to determine sustainable harvesting levels of *S. birrea.* Interviews were conducted with 36 households in the region to determine commercialisation of marula. 5218 trees in across different land uses around four villages were measured for height, basal circumference, and presence of fruit. Ninety-nine homesteads and 30 arable fields were used as plots within which all trees were sampled. Communal grazing lands in each direction from the village were sampled with four	Between 1995 and 2001 the percentage of households trading marula products increased from 4.8 to 53.2%. The survival rate for seedlings was 0.4, for juveniles 0.94, and for adults 0.99. An average of 3101 fruits per tree were collected. Predicted sustainable harvest levels were 92%.	Emanuel et al. (2005)

			transects, each comprised of four 1-hectare plots 300-500m apart. Fruit was collected and counted at 10-day intervals.		

5.9 *Pelargonium sidoides*

Table 5.9.1: *Pelargonium sidoides* species profile

Data categories	Data fields	Information summary
Species life history	Life form	Evergreen perennial with underground lignotubers that allow the plant to resprout after dieback from frost or fire.
	Reproductive type	Seed and regrowth from underground tubers.
	Age at first fruiting	N/a as tuber is harvested.
	Yield of harvested part per plant (and per ha)	N/D. Guidelines advise harvesting of the main tuber, leaving the rest of the roots and tubers in the ground to regrow. Thereafter the site should not be re-harvested for 10 years or more.
	Propagation	Root cuttings and seed (Government

		Gazette, 2013).
	Domestication and cultivation	Trials have been established around the country: Eastern Cape: Department of Economic Development and Environmental Affairs (DEDEA), the Eastern Cape Development Corporation, Amathole Municipal District, and Parceval Pharmaceuticals (Pty) Ltd. The lmingcangathelo Pelargonium Project (IPP) involves 40 members of the local community. CSIR has identified a 15ha cultivation site owned by the Senqu municipality in the Eastern Cape (Zakhele Village, Rhodes) approximately 30 000 plants and 350 000 seedlings were planted.

	Pattern of distribution	The plant is widely distributed in five South African provinces and Lesotho covering c. 600 000km². It is tolerant of a wide range of environmental conditions and can be found in grasslands as well as in association with shrubs and trees. It is found from near sea level to 2700m. It dies back after frost or fire and re-sprouts from tubers.
	Ecological role/ impact of overharvesting	There are isolated reports of poor harvesting techniques causing erosion.
Use	Part used	Lignotuber (underground stem and root system)
	Use	Medicinal: for the treatment of respiratory tract infections, strengthening the immune system, common colds and bronchitis.

	Usage intensity across species range	Wild harvesting appears to be limited to the Free State, Eastern Cape and Lesotho. A large part of its range is currently not affected by harvesting, mainly because plant densities are low (De Castro et al., 2010). However, sales of phyto medicines based on extract of *P.sidiodes* in Germany have been growing exponentially since 2000 raising concerns about the impact of wild-harvesting in South Africa and Lesotho (ACB, ND).
	Harvesting techniques and frequency	Lignotubers are dug out, leaving some pieces to regrow. Under the harsh in situ conditions of wild plants, new lignotuber formation from previously harvested re-

		sprouting plants has been estimated to only reach harvestable size after four to seven or more years (Newton, 2004; Newton et al., 2008; De Castro et al., 2010). Motjotji (2011) recommends 10 to15 years before re-harvesting depending on environmental conditions. Annex II of BMP provides harvesting guidelines.
Management	Management plan/s	National: BMP-S published (Government Gazette, 2013), now due for revision. Management unit level: Basic requirements are set out in the BMP-S Harvesting Guidelines are a requirement for obtaining a harvesting permit.

	Studies on harvesting pressure (legal and illegal)	Wild harvesting appears to be limited to the Free State, Eastern Cape and Lesotho. A large part of its range is currently not affected by harvest. (De Castro et al., 2010). Too frequent return harvests have been observed in a small proportion (<5%) of areas harvested to date (De Castro et al., 2010).
	Studies to determine sustainable harvest levels/ harvest guidelines	Motjotji (2011) recommends 10 to15 years before re-harvesting depending on environmental conditions. This is longer than the previously suggested four to seven or more years (Newton 2004; Newton et al., 2008; De Castro et al., 2010). Newton et al. (2008) suggest that local wild populations may be lost

		entirely if too frequent harvesting occurs, especially in periods of drought. Minimising tuber damage, implementing minimum return harvest intervals and establishing harvest quotas or implementing other appropriate management interventions are high priorities if the harvesting of *P. sidoides* in the wild is to be sustainable. Harvest guidelines were developed for the BMP.
	Resource monitoring	No formal monitoring is currently being carried out other than by industry, and this is not in the public domain.
Conservation	Threats /drivers of change	Gauteng and Free State provinces: Urban development and agriculture

		has occurred in most of the historic sites. Eastern Cape, north-eastern Free State and Lesotho: The main threat is habitat degradation as a result of overgrazing, bush encroachment, and erosion where the plant occurs in communal grazing lands. Harvesting only impacts a small proportion of the total population. Even in regions where harvesting is most active, e.g. in the Eastern Cape, harvesting was recorded from only 6% of sites (De Castro et al., 2010). Population declines caused by too regular return harvests have been observed in certain localised areas in the Eastern Cape (ACB, 2011).

	Trends over last ten years	As above.
	Status (red listed?)	*P. sidoides* is not listed on the International IUCN Red List of Threatened Species as a global assessment has not yet been carried out. South Africa's Red List (Raimondo et al., 2009), representing a comprehensive assessment of all South Africa's indigenous plant taxa, uses the IUCN 3.1. criteria and categories but also includes additional non-IUCN categories required for conservation work in the South African context. *P. sidoides* is classified under one of these South African specific categories, as 'of least concern: declining'. This indicates that currently this species

		does not qualify under IUCN categories of threat (critically endangered, endangered or vulnerable), but it is experiencing loss of individuals due to various influences including habitat loss, habitat degradation from overgrazing by livestock and limited localised loss due to over-harvesting (Government Gazette, 2013). Its status not determined in Lesotho. There is a need for a global assessment using the IUCN 3.1. criteria to be conducted by Lesotho and South Africa (Government Gazette, 2013). Currently *P. sidoides* is not included in any of the

		CITES appendices. The plant is a NEMBA protected species.
Information sources	Key literature sources	The information here is based mainly from the Biodiversity Management Plan (Government Gazette, 2013). See below.
	Ecological experts	Newton De Castro Prof. Tony Dold Dr Motjotji Ulrich Feiter
Institutional aspects	Key actors and mandates (Government, industry, NGO)	SANBI threatened species programme Pelargonium working group Department of Environment Forestry and Fisheries (DEFF) Industry: Ulrich Feiter /Parceval who sells to German pharmaceutical Schwabe NGOs: TRAFFIC, Biowatch, African Centre for Biosafety
	Projects /networks	SANBI threatened species

		programme works with TRAFFIC east/southern Africa. GEF 6 Project.
	Certification	

Table 5.9.2: *Pelargonium sidoides* review of resource assessments

Location & Date	Scale of assessment	Aims & method	Results/findings	Reference
SA and Lesotho (2010)	Entire range	Mapping of distribution was based on historical distribution records from the PRECIS database, National Herbarium (PRE). 103 sites were sampled in suitable habitat across the species range to estimate the number of plants per 100ha plot. Density counts were carried out within five 50m by 2m (100 m^2) transects. Extrapolation of data from transects was used to estimate population size in 100ha taking into account potentially suitable *P. sidoides* habitat occurring within the selected 100ha block using field observations and Google imagery.	The plant was widespread and abundant to extremely abundant in the north eastern and south eastern Free State and Lesotho. It was abundant in the Eastern Cape from Grahamstown to King William's Town. It was sparsely distributed, and represented by isolated and mostly small sub-populations in Gauteng, Mpumalanga and the Western Cape. Harvesting takes place in a very small proportion of the area of occurrence. There is limited localised decline due to incorrect harvesting practises but otherwise post-harvest recovery is good with more than 80% recovery in sample plots. Land conversion and rangeland degradation due to poor management and overgrazing are a much greater threat than harvesting.	De Castro et al. (2010)
		Other local level assessments	Severe harvesting impact was reported in some areas (ACB, 2011).	

Lesotho (2008)	National		There was limited localised decline due to incorrect harvesting practises. Rangeland degradation due to overgrazing is also a threat.	Newton et al. (2008)

ACB raised concerns about insufficient knowledge on the resource base and the impact of harvesting. They were not able to access De Castro 2010 but are concerned about the summary in the BMP stating that harvesting impact is minimal. The baseline data collected by the 2010 study must be assessed for its completeness and where necessary, gaps in knowledge must be filled. We agree that comprehensive baseline data must be analysed and believe these to be prerequisites for any future conservation management plan for the species.

5.10 Rooibos

Table 5.10.1: Rooibos species profile

Data categories	Data fields	Information summary
Species life history	Life form	Perennial shrub with single branching stem.
	Reproductive type	Re-sprouters and re-seeders.
	Age at first fruiting	
	Yield of harvested part per plant (and per ha)	
	Propagation	Seeds and shoot cuttings.
	Domestication and cultivation	The plant is widely propagated and cultivated in the Northern Ce (Western and Northern Cape).
	Pattern of distribution	The plant is found in winter rainfall, mountainous sandstone are value.
	Ecological role	Rooibos plays a key role in post fire recovery of the fynbos. One after fire, rooibos seedling roots are able to fix nitrogen and mak emerging seedlings (Malgas and Oettle, 2007).
Use	Part used	Leaves and stems.
	Use	Tea, medicinal and cosmetic products.
	Usage intensity across species range	Wild harvesting takes place in the mountains of the northern Ce Bokkeveld
	Harvesting techniques and frequency	50-70% of the upper bush is harvested annually or bi-annually in stems less than 2mm (Malgas and Oettle, 2007; R. Louw, 2006).
Management	Management plan/s	Sustainable management guidelines for wild rooibos harvesting
	Studies on harvesting pressure (legal and illegal)	
	Studies to determine sustainable harvest	Louw (2006). Guidelines from knowledge of wild harvesters (Malgas and Oettle

	levels/ harvest guidelines	
	Resource Monitoring	No studies.
Conservation	Threats /drivers of change	Rooibos cultivation threatens wild populations (and other fynbo Other threats include impacts on the gene pool from cross-pollin with a narrow genetic base. Narrowing the gene pool could redu resilience to climate change. Additional threats include: • Ploughing of natural veld to establish rooibos plantations. • Inappropriate veld management and grazing systems – too mu destroy rooibos plants. • Inappropriate harvesting practices.
	Trends over last ten years	Trends have not been systematically monitored.
	Status (red listed?)	Listed as 'least concern'.
Information sources	Key literature sources	See below.
	Ecological Experts	Rupert Koopman
Institutional aspects	Key actors and mandates (Government, industry, NGO)	Rooibos Council Wuppertal Rooibos Association Heiveld Cooperative, Suid Bokkeveld Environmental Monitoring Group Cape Nature, DEFF
	Projects /networks	
	Certification	Right Rooibos Sustainability Standard

Table 5.10.2: Rooibos review of resource assessments

Location	Part used	Scale of assessment	Aims & method	Results/findings	Reference
Northern Cedarberg, & Suid Bokkeveld	Leaves	Species range	The aim was mapping the known and potential distribution of wild rooibos, using a climatic envelope approach. No resource assessment of wild rooibos seems to have been done.		Malgas et al. (2010)

6 Concluding remarks and recommendations

Resource assessments can take on different forms depending on the purpose of the survey. For example, if the objective is purely to understand the sustainability and recovery rates of specific harvesting regimes, it is not necessary to do a total stock assessment. A focused sampling of specific areas under variable harvesting pressures will be adequate. On the other hand, if the purpose of the survey is to understand direction changes in total stocks over time, then a more detailed and comprehensive survey will be required requiring detailed stratification of driving variables across the full distribution of the target species. Resource monitoring is a costly exercise. It is essential that the purpose and aims of the exercise, as well as understanding the needs of the end users of the data, are clearly articulated. The frequency, method of sampling, and location of monitoring plots will depend on the target species.

To understand the causes of change, a comprehensive assessment of the driving variables acting on both the stocks and flows of target species will be necessary. This requires an understanding of the structure and functioning of the host ecosystem and its resilience to change. This is a complex undertaking, particularly where there is no prior existing data. It is for this reason that it is recommended, where possible, that monitoring sites be located in existing data rich research areas, and where synergies with other long-term monitoring programmes (such as SAEON, or SANPARKS) can be realised.

Monitoring programmes need to be designed with statistically sound sampling and experimental protocols. It is recommended that monitoring be based on the use of strategically located super sites allowing for monitoring at multiple scales, and combining ground surveys, aerial photography, and remote sensing within a nested plot design using stratified random sampling.

There is need for the development of species-specific predictive models calibrated for specific areas for each target species, that can be used to facilitate estimations of densities, yields, and sustainable harvest levels.

A number of bio-traded species can be considered as key stone species based on their ecological importance. These species can potentially be used as ecological indicators of environmental and climatic changes. Several of the target bio-traded species are biome specific, and as such are suited to be ecological indicators of changes in these biomes. For example, marula and baobab are specific to the savanna biome, and honeybush and buchu to the fynbos biome. This consideration is important in that monitoring results will be of relevance beyond just the commercial interests of these species and can provide valuable information to feed into the long-term monitoring programmes of organisations such as SAEON and DEFF, who are mandated to monitor environmental change within each biome.

There are a number of overlapping organisational mandates indicating a joint responsibility for monitoring of bio-traded plants. These include SANBI, DEFF, SAEON and industry. There is need for collaborated and coordinated efforts between these organisations.

The monitoring of bio-traded plants provides research opportunity for government, academia, and industry to explore technological advances in the field of remote sensing, modelling, and the use of tools such as LiDAR, high resolution multispectral imagery, AI machine learning etc.

With the increased trend for the cultivation of a number of bio-traded plants (such a buchu, honeybush, rooibos, devil's claw, Kalahari melon), there is likely to be increased active or passive genetic selection for desirable traits. These traits may not necessary be beneficial for the survival of the species in the wild. This risk of genetic contamination and genetic erosion of wild stocks from semi-domesticated cultivars is very real and requires ongoing monitoring.

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