Current perspectives on the economic botany of the genus
*Aloe* L. (Xanthorrhoeaceae)

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**Abstract**

*Aloe* L. (Xanthorrhoeaceae) is a genus of over 500 species found on the African continent, Arabian Peninsula, Madagascar and eastern Indian Ocean Islands. It is valued by people at many economic scales but verifiable data, with which to quantify the role of *Aloe* in local livelihoods and commercial trade, are scarce. For a speciose genus of appreciable ethnological value, few taxa have been known in formal and international trade. Leaf mesophyll and exudate from certain *Aloe* species support sizeable commercial industries that differ markedly in geographical focus, supply chain and taxa used. Leaf mesophyll is primarily sourced from plantations of the well-known *A. vera* in Mexico, the United States and parts of South America, and is generally used in products made in the same region. By contrast, leaf exudate is principally wild-harvested from *A. ferox* in South Africa and *A. secundiflora* in Kenya for export to Europe and Asia. To a much lesser extent, *Aloe* spp. are used commercially in foods and to produce honey. It is unclear to what degree *Aloe* spp. are traded as medicinal plants for traditional use throughout their range. Their popularity in horticulture as decorative and/or collectable ornamentals sustains a considerable international trade. Besides habitat loss, wild populations of many species of *Aloe* are threatened by exploitation for the succulent plant trade and a few species by over-utilisation for natural products, making rare, endemic and utility taxa an obvious priority for conservation. With the exception of *Aloe vera*, all species of *Aloe* are protected by the Convention on International Trade in Endangered Species (CITES). There is, nevertheless, considerable potential for commercially-valuable species of *Aloe* to be employed for rural development and poverty alleviation. The success of the expanded *Aloe*-based industries will depend on sustainable harvesting and other practices compliant with the Convention on Biological Diversity.

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1. **Introduction**

The leaf-succulent genus *Aloe* L. (Xanthorrhoeaceae) is a familiar floristic element throughout its distribution in Africa, the Arabian Peninsula, Madagascar and the eastern Indian Ocean Islands (Reynolds, 1950) and, as such, inherently contributes to regional biocultural diversity (Cocks, 2006). *Aloe* comprises over 500 species, ranging from diminutive shrubs to large tree-like forms, with new taxa still being described regularly. Like other “big” genera of more than 500 species (Frodin, 2004), fully comprehensive studies of the taxonomy and biology of *Aloe* are difficult and research to date has largely focused on geographical or taxonomic subsets. The genus is represented in several biodiversity hotspots, including the Horn of Africa, Madagascar and Indian Ocean Islands, Maputaland-Pondoland-Albany, Cape Floristic Region and Succulent Karoo (Mittermeier et al., 2004; Myers et al., 2000) and includes many taxa that are naturally rare and geographically restricted (Oldfield, 2004). Besides habitat loss and other threats to biodiversity in general, specific concerns have been raised for certain *Aloe* species due to exploitation for the ornamental plant trade and natural products industry. *Aloe* presents a textbook conservation challenge, requiring the protection of taxa that are rare, endemic and/or exploited, and

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management to ensure their availability as natural resources important in livelihood security.

Numerical values of “worth” can be persuasive in the argument for species-level conservation. Quantifying the biocultural value of individual taxa, however, is difficult, since folk uses and cultural significance rarely attract a monetary value, although the benefits to wellbeing and livelihood security may be obvious. On the other hand, quantitative data, describing the volume and market value of plants and plant-derived products passing through trade channels, are useful for understanding the economic value of plants, if not their cultural significance. A variety of indicators attest to the cultural and economic value of Aloe, such as the numerous vernacular names and uses recorded for the genus (Grace et al., 2008, 2009, 2011). A recent search for “aloe” on Google.com returned no fewer than 30.8 million results, compared with 206 000 for neighbouring genus Gasteria (search term “gasteria”) and 88 600 for Xanthorrhoea (“xanthorrhoea”), both of which are also popular horticultural subjects. The contemporary value of Aloe has been preceded by many centuries of people–plant relationships. It is one of the few identifiable plant taxa depicted in the rock art of the southern African San people (Reynolds, 1950) and at least one species, A. vera (L.) Burm.f., has been traded between the Arabian Peninsula and Mediterranean for at least two thousand years (Morton, 1961). The ethnobotany of Aloe is described in a considerable body of literature, analysis of which suggests most species are valued in some way and used on a local scale (Grace et al., 2008, 2009).

For a speciose genus of appreciable ethnological value, surprisingly few species of Aloe have been known in formal trade. The market profiles of species such as A. ferox Mill. and A. vera appear to be expanding, yet the trade in aloe-derived products remains poorly understood and relevant information unavailable. This paper reviews the economic botany of the genus Aloe and its role in livelihood security. In keeping with the theme of this issue, the discussion is focused on South Africa, one of the centres of diversity in the genus with over 120 species (Glen and Hardy, 2000). Information from the literature is combined with anecdotal evidence of the contemporary economic uses and trade in Aloe spp., highlighting their importance across a range of socioeconomic scales. Conservation concerns and the potential for aloe to support sustainable industries compliant with the Convention on Biological Diversity, are considered.

2. Aloe in trade

2.1. Natural products

The commercial trade in Aloe-derived natural products is based mainly on two materials obtained from the leaves of certain Aloe species: leaf exudate, used in laxatives, and leaf mesophyll, used in products applied topically for skin ailments or taken internally for digestive complaints and general wellbeing. The remarkable history of aloes in commerce has been documented in a substantial and varied body of literature (see, for example, Morton, 1961) and warrants only a brief account here. The formal trade in leaf exudate of at least one species, A. vera, has been recorded since the fourth century BCE (Morton, 1961), and resulted in the species’ movement along trade routes from the Arabian Peninsula to the Mediterranean, Indian subcontinent, Americas and Caribbean, where it has become naturalised. Dried leaf exudate preparations from a small number of other species have been known in formal trade since the late sixteenth century. These include A. perryi Baker on Socotra, A. arborescens Mill. and A. ferox in South Africa, and records of uncertain validity for A. africana Mill. and A. marlothii A.Berger, also in South Africa (Reynolds, 1950; Hodge, 1953; Bruce, 1975; Smith et al., 2008). Explanations for the few Aloe spp. entering international trade may lie in the selection of taxa with desirable medicinal properties as much as abundant supply and the proximity of plant populations to transport hubs and ports. The leaf mesophyll and exudate of Aloe spp. probably share an equally long use history, yet the mesophyll has been known only in contemporary trade. This may have begun in the 1920s with a single producer in the United States distributing fresh leaf mesophyll from farmed A. vera by mail (Morton, 1961). Commercial interest in the leaf mesophyll emerged in the 1930s in the United States (Grindlay and Reynolds, 1986) and expanded as technologies were developed to process and prolong the shelf-life of the tissue. Today, the use of leaf exudate is waning in the United States and Europe due to concerns for safety (Jellin and Gregory, 2009). In contrast, there appears to be an increasing demand for the leaf mesophyll as an ingredient in a broad range of manufactured products such as patent remedies, foods and food supplements, toiletries, beauty products and household commodities.

The industries based on Aloe leaf exudate and mesophyll differ markedly in geographical focus, supply chain and species used. Leaf exudate is principally wild-harvested from populations of A. ferox on communal or privately-owned land in South Africa and, in East Africa, wild-harvested or cultivated A. marsabtensis Verdoom & Christian, A. ngongensis Christian, A. rabaiensis Rendle, A. secundiflora Engl. and A. scarifolia Newton & Lavranos (sometimes confused with A. turkanensis Christian (Newton, 1994)). The main importers of leaf exudate are countries in Europe and Asia (Melin, 2009; Newton, 1994; Newton and Vaughan, 1996; Oldfield, 2004). In contrast, leaf mesophyll is primarily sourced from plantations of A. vera located in Mexico, the United States and several South American countries, and is generally traded in semi-processed forms within the same region (International Aloe Science Council, 2011). Aloe arborescens Mill. is cultivated on a lesser scale in Asia, South America and Italy for both leaf exudate and mesophyll (Bosch, 2006a). This species is also wild-harvested in South Africa for export, notably to Japan, where the species is a popular medicinal plant (Newton and Chan, 1998; Smith et al., 2008). Leaf mesophyll from predominantly wild-harvested A. ferox in South Africa (Newton and Vaughan, 1996), A. macroclada Baker in Madagascar (S. Rakotoarisa, pers. comm.) and several species in Tanzania (Sachedina and Bodeker, 1999) are used in expanding local industries that seem to mirror the use of A. vera in cosmetics, toiletries and non-scheduled remedies. It is conceivable that other species of Aloe enter the trade on a limited scale from time to time. Phytochemical characterisation of the leaf mesophyll of A.
davyana Schönland (= A. greatheadii var. davyana (Schönland) Glen & D.S.Hardy) (Botes et al., 2008b) suggests this species may be targeted for commercial development in South Africa. Although the genus has been the subject of numerous phytochemical studies (Reynolds, 1985, 2004; Dagne et al., 2000), differences between the species in commercial trade are not clearly documented and a comparative study of these would be useful to highlight potential in the trade.

Besides the use of synonyms in the literature, notably A. barbadensis Mill. for A. vera, a multitude of descriptive terms and names are applied to Aloe-derived products. Alternative terms commonly used for the leaf exudate include sap, juice or latex. The exudate arises from enlarged inner bundle sheath parenchyma cells and is released as a wounding response (Beaumont et al., 1985; Liao et al., 2006). The dried product prepared from boiled leaf exudate, sometimes incorrectly termed resin or extract, is variously known as drug-, bitter-, crystalline- or powdered aloes, aloe lump or -brick. Trade names for leaf exudate preparations were historically intended to indicate the provenance (and, therefore, superior quality) of the product, such as “Cape aloes” prepared from A. ferox. The convention was frequently misapplied and resulted in much confusion (see Hodge (1953) and Robertson (1979)). Nevertheless, the practice has persisted; for example, “Mossel Bay prime aloe” exported from South Africa does not necessarily contain leaf exudate collected from plants at Mossel Bay (Newton and Vaughan, 1996). Terminology referring to the leaf mesophyll, commonly known as aloe gel, fillet or pulp, is less complex, reflecting the relatively recent and largely industrial market for it. Processed derivatives of the leaf mesophyll are sold under names such as gel fillet, concentrated- and crude gel, decolourised- and/or pasteurised gel, freeze- or spray-dried powdered gel (Waller et al., 2004). Similar products are made using whole leaves. Although it shares some of the characteristics of mucilage, such as high polysaccharide content, the leaf mesophyll is a tissue rather than secretory product (Beaumont et al., 1985).

The global market for A. vera, the major source of leaf mesophyll, was reportedly worth US$125 million in 2004 (R878 million, using exchange rates at the time of writing of R7 to the dollar) with a projected growth margin of 35% per annum (Bosch, 2006c) and, hence, US$300 million (R2, 1 billion) today. Statistics given by the International Aloe Science Council (2011) indicate that some 24,000 ha of A. vera are cultivated globally, with 300 ha in Africa which may include plantations in Nigeria supplying local markets (Bosch, 2006c). Despite the industrial interest in A. vera as a source of natural products—described by Grindlay and Reynolds (1986) as the “Aloe vera phenomenon”—authoritative data in the literature describing the production volumes, trade figures and socio-economic benefits of the industry are scarce.

The significant economic impacts of wild-harvested Aloe, specifically in Kenya and South Africa, are clearer. The Aloe exudate industry in Kenya is centred in Rift Valley Province and based upon five or more species used somewhat interchangeably (Oldfield, 2005). During the 1990s, exports of wild-harvested exudate from Kenya sometimes exceeded 80 tonnes per annum, the principal importers being China and Thailand (Oldfield, 2004). At that time, collectors in some rural villages were reportedly paid KSh 20 (about R5.50 or US$0.8) per litre of exudate which may have taken several days to gather (L. Newton, pers. comm.). In South Africa, the rural industry supported by wild-harvested A. ferox was estimated to be worth R4 million (US$569,000) per annum in the late 1990s (Newton and Vaughan, 1996), projected to R15 million (>US$2 million) per annum a decade later (Shackleton and Gambiza, 2007). Estimates of the larger industry-taking into account the retail chain-have varied widely from R150 million per annum (US$20 million) to US$90 million per annum (>R600 million) (Shackleton and Gambiza, 2007). The industry yields some 400 tonnes of dried leaf exudate per annum, of which the bulk is exported (the major importers being Germany, Japan and Argentina), and the remainder used in non-scheduled medicines or placed in stored reserves (Newton and Vaughan, 1996). Production is necessarily confined to the species’ natural distribution in the Western and Eastern Cape Provinces; it was historically centred in small towns east of Cape Town and extended to the Karoo and Eastern Cape Province, where it has recently become the subject of rural development initiatives (Melin, 2009; Newton and Vaughan, 1996). However, opportunities are unclear for African producers (particularly of leaf mesophyll) to compete on global markets, which have been criticised for their impenetrability due to the influence of major producers in the United States (Sachedina and Bodeker, 1999).

The socio-economic benefits of the A. ferox industry in South Africa are spread widely (Newton and Vaughan, 1996), from the poorest people whose only source of income is derived from Aloe tapping, to itinerant agricultural workers and other part-time aloe tappers, their families and communities. In the Western Cape, the potential annual income for a full-time tapper was estimated to be R10,000 (US$1,400) in 1992 but, due to a complex debt cycle and lack of empowerment, this was seldom, if ever, realised (Newton and Vaughan, 1996). In towns central to the A. ferox industry, leaf exudate has been used as a currency for obtaining credit and offsetting debt in local stores, or to purchase food (Newton and Vaughan, 1996). Historical records show that the trade in leaf exudate from Aloe spp. is characteristically vulnerable to fluctuations in demand, driven by export markets and economic conditions, and in supply, influenced by factors such as drought and plant pests, despite the storability of dried exudate preparation (Newton and Vaughan, 1996; Robertson, 1979; Sachedina and Bodeker, 1999). Factories extracting leaf exudate and mesophyll from wild-harvested A. ferox, which employ a limited workforce of skilled and semi-skilled workers and operate year-round, have been seen to challenge the livelihood security of the majority of the workforce (Newton and Vaughan, 1996). On the other hand, a processing factory was central to the business model of an A. ferox cooperative established in the Eastern Cape in 2004 (Melin, 2009). The Aloe Tappers Association was established in South Africa in the 1980s (Newton and Vaughan, 1996) and the Kenya Aloe Working Group in the 1990s (L. Newton, pers. comm.) to promote fair conditions for workers and sustainable harvesting. Implementation of national legislature compliant with the Convention on Biological Diversity (CBD) (1992) is expected to serve the interests of Aloe harvesters and other stakeholders, notably by endorsing the rights to equitable benefits (see Section 3.
Sustainable use and conservation, below). Traditional medicinal uses of *A. ferox* in South Africa, transfer of knowledge to Europeans at the Cape of Good Hope, and the species’ introduction to European *materia medica* in the 18th century, have been documented in considerable detail (see Hodge, 1953 and references therein). Traditional exudate harvesting and preparation methods continue to be practised with few contemporary adjustments, and have been comprehensively recorded by, among others, Hodge (1953), Newton and Vaughan (1996), Sachedina and Bodeker (1999), Shackleton and Gambaiza (2007) and Melin (2009). The comprehensive literature would, therefore, be useful in identifying the holders of intellectual property relevant to the *A. ferox* industry.

*Aloe ferox* has not been recorded in the wild beyond the *Flora of Southern Africa* region, but is likely to have been introduced elsewhere (Bosch, 2006b). It is reportedly used as far afield as Kinshasa (Democratic Republic of Congo): topical preparations for haemorrhoids and skin complaints containing the leaves are prepared and dispensed by at least one health centre in the city (P. Latham, pers. comm.). *Aloe* spp. are traded in medicinal plant markets throughout Africa; whole plants of species such as *A. aristata* in South Africa and *A. sinkatana* in Sudan have been noted to attract particularly high prices (Marshall, 1998). Other species recorded in market surveys in South Africa include *Aloe ferox*, *A. maculata*, *A. marlothii*, *A. micrantha* and *A. tenuior* (Dold and Cocks, 2001; Williams et al., 2001). About 60 species of *Aloe* have been recorded in traditional medicine in southern Africa (Grace et al., 2008) and it is likely that some of these may be sold for medicine, albeit infrequently. The lack of references to local and small-scale trade in aloes, both historical and contemporary, agrees with the general trend towards opportunistic use of local species and poor market demands. A detailed study is necessary to more fully evaluate *Aloe* spp. in the medicinal plant trade and their contribution to livelihood security.

2.2. Horticulture

Aloes are both decorative and highly collectable. They have become common in the general horticultural trade servicing gardeners and landscapers, particularly in the regions where the genus occurs naturally, as well as the specialist ornamental plant trade. The horticultural challenges presented by the morphological and taxonomic diversity of the genus appeal to succulent plant enthusiasts. *Aloe* features prominently among the subjects of succulent plant collectors’ societies; indeed, a stylised short-stemmed *Aloe* (based on *A. peglerae* Schönland) appears in the logo of the Succulent Society of South Africa, and the Society’s journal is named for the genus. Although *A. vera* and perhaps a few other species were already in cultivation, lesser-known aloes from the African continent entered the ornamental plant trade when succulent plants became fashionable in Europe in the sixteenth century and seventeenth centuries (Pole-Evans, 1919; Reynolds, 1950). Today, the major importers of living specimens of *Aloe* spp. are Japan, the United States and United Kingdom (Newton and Chan, 1998). Artificially-bred *Aloe* hybrids considerably expand the diversity of collectable taxa (De Wet, 2004); *Aloe × Gasteria* and *Aloe × Haworthia* crosses are commonly known as gasteraloes and alworthias, respectively. A great diversity of cultivar names have been published, many of which have been registered with the South African Aloe Breeders Association (Newton, 2004).

Not surprisingly, the most sought-after aloes among succulent collectors include rare, morphologically distinctive and difficult to grow taxa, and desirability is reflected in the price of living plants in trade. Prized taxa include the rare Leesothen endemic *A. polyphylla* Schönland ex Pillans, tree aloes such as the Western Cape endemic *A. plicatlis* (L.) Mill., and the charming shrub *A. haemanthifolia* A.Berger & Marloth (J. Bertelsen, pers. comm.). The latter are favoured for their atypical distichous and bare-suicculent leaves with rounded apices. *Aloe haemanthifolia* is a particularly difficult subject in cultivation (Van Wyk and Smith, 2005), and plantlets (ca. > 10 cm in diameter) may retail for up to R650 (US$95). Newton and Chan (1998) recorded specimens sold for over R1 500 (>US$200) in the 1990s. *Aloe polyphylla*, one of the best-known aloes, is appreciated for its distinctive spiral phylotaxis and natural tolerance to frost and snow, which makes the species suitable for outdoor cultivation in the northern hemisphere (Reynolds, 1950). The difficulty of maintaining *A. polyphylla* in cultivation is evident in the difference in price between young plants (ca. 10 cm in diameter, up to US$21 or R140) and mature specimens (ca. 30 cm in diameter, US$100 or R680). The relatively low cost of immature plants of some *Aloe* spp. is, furthermore, a reflection of abundant supply yielded by micropropagation, even if the species is threatened with extinction in the wild, such as *A. boweia* Schult. & Schult.f. and *A. polyphylla* (Newton and Chan, 1998). Tissue culture protocols using a variety of explants have been published for *A. arborescens* (Kawai et al., 1993), *A. calcairaphila* Reynolds (Sarasen et al., 2006), *A. polyphylla* (Ramsay and Gratton, 2000; Abrie and Van Staden, 2001), *A. pretoriensis* Pole-Evans (Groenewald et al., 1975), and *A. vera* (e.g. Hashem and Kaviani, 2010, among others). The range of taxa available to purchase as plantlets would indicate, however, that in vitro multiplication techniques have been far more widely optimised for *Aloe*. Retail prices in the specialist succulent plant trade are frequently considerably higher than those of commercial nurseries and private vendors selling live *Aloe* plants in the markets and roadside nurseries of African towns and cities for decorative purposes. For instance, a single plantlet (ca. 5 cm in diameter) of the critically endangered tree aloe *A. pillansii* L.Guthrie, native to South Africa and Namibia, was recently sold for more than US$150 (> R1 000) at auction on eBay.com, yet plantlets of similar size retail for a tenth of the amount in nurseries in South Africa.

*Aloe* spp. are immensely popular subjects for landscaping, due to their characteristic architectural form and the diversity of birds and insects attracted to the flowers. Within their natural range, some large, single-stemmed species (e.g. *A. africana* Mill.) are suitable for street plantings, as they have rather shallow root systems and rarely drop leaves. The majority of *Aloe* spp. flower in winter, thus providing vibrant colour displays in gardens and parks, as well as in their natural habitat, during the dry season. An early example of spectacular massed plantings of aloes was “the largest collection of South African Aloes [sic] in existence” established at the Union Buildings in
1912 (Pole-Evans, 1919). However, the popularity of the genus as a garden subject has waned at times, and one of the great scholars of *Aloe*, G.W. Reynolds, was moved to endorse their use in rockery plantings (Reynolds, 1938). *Aloe* spp. are readily propagated and large numbers of plants can be amassed from minimal stock. Nevertheless, it is important to note that artificial plantings are prone to infection and infestation unless carefully maintained (Smith and Van Wyk, 2008). In South Africa, this has proved particularly problematic in the ex situ conservation of *Aloe* specimens transplanted to gardens and public spaces from areas earmarked for development.

Besides representation in impressive private growers’ collections, living collections of aloes are maintained in publicly-accessible botanic gardens around the world. Exspansive collections are held, for instance, at the Städtische Sukkulentensammlung Zürich (Municipal Succulent Plant Collection) in Switzerland, the Huntington Botanical Gardens in the United States, the Royal Botanic Gardens, Kew in the United Kingdom, and, in South Africa, the Karoo Desert National Botanic Garden. These collections serve the purposes of providing repositories of genetic diversity for ex situ conservation, and facilities for public engagement and education. Collections of living plants are useful for research, allowing intensive study of a diversity of plants. The excellent infrageneric classification of *Aloe* by A. Berger (1908), famously compiled without the author seeing a single plant in the field, was based on observations of specimens in the private collection of Sir Thomas Hanbury in Italy (Pole-Evans, 1919) as well as of herbarium material. G.W. Reynolds’ use of Berger’s (1908) classification as the basis for his treatments (Reynolds, 1950, 1966), which were based on extensive travels to collect and observe aloes in habitat, is a testament to its quality. More recently, phylogenetic studies of *Aloe* using DNA-based characters (Treuillein et al., 2003; O. M. Grace unpublished data) have indicated that elements in the existing classification are artificial. A future revision, taking molecular characters into account, will be necessary to accommodate the expanding species diversity and infragenic concepts in the genus.

### 2.3. Bee plants

Aloes are well-known bee plants in Africa. Species in flower during the dry season afford an important source of nectar for honey bees (*Apis mellifera*) and nectariferous birds (Bornman and Hardy, 1971; Botes et al., 2008a, 2008b; Symes et al., 2008). In South Africa, *A. davyana* is the most highly regarded: extensive flowering stands of the species on the outskirts of Pretoria are used seasonally by beekeepers, who move their hives to these so-called “aloe fields” in order to build up colonies, rear queens and increase colony numbers, as well as for winter honey production (Human and Nicholson, 2006). Honey produced by bees foraging on *A. davyana* is pale in colour and free from any after-taste, except for with a slight hint of smokiness (Glen and Hardy, 2000). It is not clear from the literature whether hives supported by *Aloe* spp. are kept only for subsistence, but it is likely that beekeepers may, at times, derive income from surplus honey and comb produced by their hives. On a commercial scale, at least one beekeeper in Kenya, near Nairobi, produces quality honey from a locally abundant species of *Aloe* (P. Latham, pers. comm.).

### 2.4. Food

The literature includes references to several species of edible aloes, their uses including snack foods, famine foods, as a cooked vegetable and as an ingredient in preserves. It should be noted that not all species of *Aloe* are edible: some contain toxic alkaloids (Dring et al., 1984) and certain species, including *A. vera*, may cause adverse reactions (Steenkamp and Stewart, 2007). The cultivated species *A. arborescens* and *A. vera* have been used on a large scale in foodstuffs, especially in dairy products such as yoghurt and ice cream, in Asia and the United States for some years. In South Africa, a perceptible increase in the variety of manufactured food products containing *A. ferox*, such as confectionary and fruit juice blends, apparently mirrors the global rise in popularity of *A. vera* leaf mesophyll in foods. The use of *A. ferox* leaves in commercially manufactured preserves and condiments follows a centuries-old tradition of use in the Western Cape (Watt and Breyer-Brandwijk, 1962).

### 3. Sustainable use and conservation

The ways in which aloes are used and valued have implications for their conservation and future utility. Specific threats affecting individual species are not well understood, but general trends are apparent across the genus. The threats and conservation status of *Aloe* spp. in South Africa are probably the most well studied (e.g. Smith et al., 2000; Van Jaarsveld and Smith, 1997). Full Red List assessments have been made of 43 species of *Aloe* (>7%) (IUCN, 2011), from which it is clear that the prevailing threat to the genus is habitat loss caused by anthropogenic factors, notably land use change (e.g. agriculture, mining, urban expansion), clearance of vegetation for energy needs, overgrazing/trampling by livestock, and soil erosion. Collecting for the ornamental plant trade affects many more species of *Aloe* than wild-harvesting for natural products or traditional uses. Rare, endemic and utility taxa are the target of such activities and are, therefore, priorities for conservation.

All species of *Aloe* are protected by the Convention on International Trade in Endangered Species (CITES), with the exception of *A. vera*. It was removed from the CITES Appendices in 1985, to reflect the species being widely cultivated (Oldfield, 1992 cited in Newton and Vaughan, 1996) despite possibly being extinct in the wild. The species originates from the Arabian Peninsula but there are no records of the species being seen in its natural habitat recently. Twenty-one species of *Aloe* threatened by extinction are listed on CITES Appendix I, prohibiting all international trade for commercial purposes (CITES, 2011). The remainder are listed on Appendix II, to control the trade in species of conservation concern and so-called “look-alike” taxa (CITES, 2011). This is typical of large, collectable and/or taxonomically complex groups; succulent examples include *Pachypodium* (Apocynaceae), *Euphorbia* (Euphorbiaceae) and, at the family level, Cactaceae. The case of *Aloe* was highlighted in a recent
evaluation of *A. arborescens*: although not currently threatened by the export of wild-harvested material from South Africa (described by Newton and Chan, 1998), the species’ removal from CITES Appendices would raise conservation issues for numerous species sometimes misidentified as *A. arborescens* (Smith et al., 2008). An evaluation of *A. ferox*, included in Appendix II, has been recommended in light of increasing exports of the leaf exudate (Melin, 2009). The level of national protection afforded to the genus varies widely, but permits are required for collecting, research and commercial harvesting in most countries where *Aloe* spp. occur. In South Africa, illegal trade in *Aloe* spp. is relatively well characterized but almost impossible to quantify, and necessitates closer trade controls (Newton and Chan, 1998).

Effective policy is crucial to support conservation and optimise the use of natural resources. In the case of *Aloe* spp., sustainable exploitation depends heavily upon the stakeholders in the horticultural and natural products industries. The expansion of markets for *Aloe* products has obvious and compelling socio-economic potential and may also benefit in situ conservation. One example of the positive effects of commercial exploitation is the Kenya Aloe Working Group, which aims to conserve natural populations of *Aloe* spp. by promoting the cultivation of species used for leaf exudate and mesophyll for livelihood security, in areas of low or erratic rainfall, where growing conventional food crops is uncertain (L. Newton, pers. comm.). It brings together stakeholders throughout the supply chain, and uses secure export markets as incentives for nurserymen, farmers, and manufacturers to use propagated *A. secundiflora* and *A. turkanensis* as a profitable alternative to illegally wild-harvested material. Farmers who can show that their plantations were established with *Aloe* seedlings from an approved nursery are able to register with the national CITES authority – the Kenya Wildlife Service – to legally export their products. The export of semi-processed materials and products, rather than raw materials, is encouraged to promote local employment opportunities and avoid re-importing the material in processed form at a later stage. For instance, in Coast Province, *A. rabaiensis* is used for making soap, skin cream and other products for local markets (L. Newton, pers. comm.). In South Africa, the *A. ferox* industry is among the local bioresource industries covered by recent legislative developments in bioprospecting, access and benefit-sharing regulations within the National Environmental Management Biodiversity Act (NEMBA). The new legal framework aligns national laws with international agreements such as the CBD and CITES (Crouch et al., 2008), with potentially positive outcomes for stakeholders at all levels in the *A. ferox* industry by, for instance, protecting the holders of traditional knowledge, the equitable distribution of benefits, sustainable resource management, and best practice in processing. Practical shortfalls in the implementation of the new legislature (see Crouch et al., 2008) have, however, affected at least one development initiative based on *A. ferox* in the Eastern Cape (Melin, 2009). An appraisal within the context of the new laws will be necessary to measure successes thus far, with particular attention to the differences between *A. ferox* wild-harvested from communal or privately-owned lands, and to identify changes still required of the industry. South Africa is among a small proportion of CBD member countries to have ratified the agreement in national law (Crouch et al., 2008) and developments in the *A. ferox* industry will undoubtedly be relevant to emerging *Aloe*-based industries elsewhere in the range of *Aloe* spp.

In Kenya, protocols for sustainable wild-harvesting on a commercial scale, known as Aloe Management Units, have been developed for *A. calidophila* Reynolds, *A. riva*e Baker, *A. scabridifolia* and *A. secundiflora* but have yet to be fully implemented (Wabuye and Kyalo, 2008). East African taxa identified as most suitable for the natural products industry and large-scale propagation include *A. macrosiphon* Baker and *A. ukambensis* Reynolds (Newton, 1994). Wild-harvesting of *Aloe* spp. is illegal and therefore not reflected in export statistics for Kenya, but is known to support a considerable trade in the leaf exudate; *A. secundiflora*, *A. scabridifolia* and possibly *A. turkanensis* (a possible misidentification of *A. scabridifolia* (Newton, 1994)) are of particular concern (Oldfield, 2004). Given the volume of plant material involved in the trade, there are legitimate concerns regarding the sustainability of harvesting rates and species-specific impacts. The leaves of six to ten *A. ferox* plants (with an average of 24 leaves each) are required to obtain one litre of leaf exudate (Melin, 2009), and up to two tons of fresh leaves are required to yield a kilogram of powdered *A. ferox* gel (Newton and Vaughan, 1996). Risks of misidentification or substitution of *A. ferox* with related species are low (Newton and Vaughan, 1996) but are greater in East Africa where several species are used, and the possibility of misidentification represents a significant threat to taxa with a restricted range (Oldfield, 2004). This would be of great concern should wild-harvested *A. davyana*, a representative of the taxonomically unresolved maculate species complex (Grace et al., 2009), become a source of commercial leaf mesophyll and/or exudate (Botes et al., 2008b). In general, traditional harvesting practices rarely result in plant death (Melin, 2009; Newton and Vaughan, 1996), and damage to plant populations is more likely to be the consequence of poor land management, fire and pests. However, higher harvesting rates have been observed in regions where the traditional method of leaf exudate collection is not customarily practised and where plants are wild-harvested from communal lands (Melin, 2009).

Specialist succulent collectors have an important role to play in the sustainable future of *Aloe* spp., not least in the ex situ conservation of species diversity and influence over market trends. Conservation is a key objective of succulent plant collectors’ societies, such as the International Organization for Succulent Plant Study, Cactus and Succulent Society of America, British Cactus and Succulent Society and, locally, the Succulent Society of South Africa. These interest groups promote ethical as much as legal plant collecting practices that are compliant with both the CBD and legal requirements. CITES exports from different African countries indicate that many of the living plants in trade must be propagated outside Africa, since the volume of living plant material exported falls far short of the volume of material advertised in trade (Newton and Vaughan, 1996; Newton and Chan, 1998) with little, if any,
returns to the source country. The scenario is not unique to Aloe (Crouch et al., 2008) yet influential parties are well placed to continue fostering demands for plant specimens sourced in ways that uphold the objectives of the CBD.

4. Conclusions

The economic scales at which Aloe is valued by people vary by orders of magnitude, from the rural poor whose sole livelihood is based on a single species of Aloe growing on communal lands, to agricultural economies based on several species of cultivated Aloe, and the extraordinary global production of A. vera. The literature is notably lacking in verifiable data regarding the production and trade in all species used commercially; these data are necessary for more quantitatively assessing the impact of Aloe spp. on livelihoods and concerns for their conservation. There is a need for detailed study of the informal trade in Aloe spp. as medicinal plants. The emergence of several national markets supported by local species, mirroring the use of A. vera, may significantly increase the biocultural value placed on species of Aloe throughout their distribution. In South Africa, the potential of the A. ferox industry to bring economic gains to very poor rural areas has been recognised, but success will depend on effective policy governing access to the resource, and careful management for sustainability as the industry expands. The increasing diversity of species in commercial trade warrants comparative studies of their natural product chemistry. Stakeholders in Aloe-based natural product industries and ornamental succulent plant trades have important roles to play in implementing changes that encompass CBD-compliance as well as national legal requirements. The diversity of the genus and the many ways in which Aloe is valued around the world highlight the need for effective conservation measures and policy approaches for Aloe spp. to be used sustainably.

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References


