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Invasive alien plants occurring in Lesotho: Their ethnobotany, potential risks, distribution and origin

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Background: Several recent studies have documented the ethnobotanical uses of plants used in Lesotho, in particular those used for medicinal purposes. However, these reports did not make a distinction between indigenous, naturalised or invasive alien plants. Furthermore, the existing records on the status of the occurrence of these plants in the country are not up to date.

Objectives: The aim of this article is to present information on the current knowledge regarding the status of invasive alien plant species in Lesotho and to discuss their ethnobotanical uses, distribution in the country, origin and safety. We further assess the existing legislation designed to regulate the spread of such plants and make a comparison with the invasiveness and regulation of such plants in the neighbouring South Africa.

Method: This article is based mainly on a literature survey of published information obtained from various databases, such as Google Scholar, Science Direct and Scopus, as well as from unpublished data such as technical reports, dissertations and theses.

Results: A total of 57 species, comprising one pteridophyte, one gymnosperm and 56 flowering plants (52 dicotyledons and 4 monocotyledons) are documented. Although these plants are invasive in nature, they are utilised for a variety of purposes including food, treatment of various medical conditions, cosmetics and functional uses. However, some of the species are reported to be poisonous to both animals and humans, with a majority of the plants causing skin irritation. Most of these species are widely distributed throughout the country and most of them originated from America, Europe and Asia. Although a number of reports on the occurrence of invasive alien plants have been generated, the information therein has not yet been published.

Conclusion: This study has identified knowledge gaps in terms of safety and distribution of the species, as well as shortfalls in the policies intended to regulate invasive alien species (IAS) in Lesotho. Further research in this regard is therefore recommended.

Keywords: biodiversity decline; control measures; encroachment; legislation; naturalised.

Introduction

The past ten years have seen an increase in the number of studies documenting the ethnobotanical and/or ethnomedicinal uses of plants in Lesotho, either in the form of literature reviews (e.g. Moteetee, Moffett & Seleteng-Kose 2019; Moteetee & Seleteng-Kose 2017; Moteetee & Van Wyk 2011) or in the form of ethnobotanical surveys based on questionnaires (e.g. Mugomeri, Chatanga & Chakane 2016a; Mugomeri et al. 2016b; Seleteng-Kose, Moteetee & Van Vuuren 2015). All of these studies concluded that numerous plants are used for several ethnobotanical purposes, including food, medicine and other functional uses such as furniture and building. However, these studies did not make any distinction between indigenous, naturalised or alien (and invasive) species. A few papers have documented the traditional uses, in particular medicinal uses, of invasive alien plants (IAPs) in other regions, for example in Limpopo province of South Africa (Maema, Potgieter & Mahlo 2016) and Bangladesh (Khan et al. 2011; Rahman & Roy 2014).

Pyšek et al. (2004:136) have proposed standardised terminology to be used in invasion biology and provide a definition of invasive plants as naturalised plants that 'produce reproductive offspring, often in large numbers, at considerable distances from the parent plants, and thus have a potential to spread over a large area'. The authors define 'alien plants' as those that have been deliberately or unintentionally introduced into an area because of human activity, or 'which have arrived there without the help of people from an area in which they are alien'. According to the Department of Environmental Affairs (2014), there is increased extinction of indigenous medicinal

plants as well as a decline in biodiversity; on the other hand, there have been increased incidences of invasive alien species (IAS). The increase of alien plants has resulted in serious economic impacts worldwide (Vilà et al. 2011). For example, according to Bromilow (2010), IAS cause a wide range of destructive consequences, which include a decline in species diversity, local and total extinction of indigenous species, ecological imbalance, increased fire hazard, decreased productivity of rangelands and reduction in land value. In addition, IAS are reported to cause reduction in conservation and tourism value, soil erosion and the consequent siltation of dams and rivers, depletion of water resources, changes in the natural soil composition and oxygen depletion in water (Bromilow 2010).

Lesotho, like many other countries, has witnessed an increase in the encroachment of invasive plants because of, among others, overgrazing, changing fire regimes, as well as climate change (Hae 2016). Climate change is especially critical because it 'facilitates the spread and establishment of many alien species and creates new opportunities for them to become invasive' (IUCN 2017). Despite their negative impacts, some IAPs were introduced with good intentions. For example, as Lesotho is one of the least forested countries in Africa (Chakela 1999), tree species such as *Acacia dealbata*, *Populus* x *canescens* (Aiton) Sm., as well as *Pinus* L. and *Eucalyptus* L'Hér species were introduced for soil conservation measures, provision of fuel wood and as valuable forms of biomass (NES 2000). However, the latter two are reported to use greater amounts of water than the natural vegetation. This has led to depletion of the underground water, hence posing a threat to the ecosystem functioning (NES 2002, 2005). In addition, aquatic plant invaders pose serious threats to waterbodies, for example common aquarium plants such as Parrot's Feather (*Myriophyllum aquaticum* (Vell.) Verdc. and the Red Water Fern (*Azolla filiculoides* (Lam.) that have invaded several dams in the country (NES 2000).

There are limited publications on the invasive alien plants of Lesotho; so far the only published information on the invasive alien plants of Lesotho has emanated from research conducted as part of regional studies, in particular South African projects, such as Kotze et al. (2010), focusing on the national invasive alien plant survey. Other publications include the pioneering work of roadside surveys of invasive plants in South Africa by Henderson (1989, 1991a, b, 1992, 1998a), as well as Bromilow (2010), Nel et al. (2004) and Rouget et al. (2004). Bromilow (2010) focused on problem plants and alien weeds of South Africa including Lesotho and Eswatini (previously Swaziland). A few specific studies on Lesotho IAS were undertaken by the National Environment Secretariat (NES 2005 2007). Other earlier technical reports by NES (2000, 2002) gave limited information on IAS. These reports have however not been published, are outdated and in some cases inaccurate. For example, according to NES (2002), some plant species such as *Acacia saligna* (Labill.) H.L.Wendl. and *Hakea sericea* Schrad. & J.C. Wendl. have dominated some areas to the extent that natural vegetation has been lost completely. However, based on previous publications (e.g. Jacot Guillarmod 1971; Kobisi 2005; Phillips 1917), there is no evidence that these two species ever occurred in Lesotho. This is possibly a case of mistaken identity; nonetheless, the situation is true for other species such as *Acacia dealbata* Link. (pers. obs.).

Henderson's studies culminated in the launch of the Southern African Plant Invaders Atlas (SAPIA) project, which included South Africa, Lesotho and Eswatini (Henderson 1998b). The objective of the project was to 'collate information on the distribution, abundance, and habitat types of invasive and naturalized alien plants' (Henderson 2007:215). Nel et al. (2004) proposed a classification of invasive alien plant species for South Africa, Lesotho and Eswatini into three categories: those already widespread, those that have recently started to invade and those that are not yet invasive. Rouget et al. (2004) evaluated the correlation between climate and distribution of 71 important IAPs, and an analysis of potential implications of these results for future spread of the invaders in different vegetation types of South Africa, Lesotho and Eswatini. In 2005, NES published the first assessment of the status of IAS in Lesotho (NES 2005), giving aspects of their origin, geographical spread, uses, impacts and control measures in the country, although the geographical spread of species was 'based on observation rather than survey and related mapping of IAS' (NES 2005). Even though not published, these technical reports serve as a good foundation for the development of research activities covering several aspects of biological invasions, including their taxonomy, ecology, ethnobotany and ethnopharmacology, etc.

This study is a review of the current knowledge regarding the status of the occurrence of invasive alien plants in Lesotho, as well as their ethnobotanical uses, distribution in the country, origin and safety. The study also reviews the present legislations and policies that deal specifically with the regulation of IAPs in that country.

Methodology

This study is based on extensive consultation of literature resources and it integrates data from these unpublished lists as well as published work on IAPs in Lesotho and the surrounding South Africa, which have similar vegetation. Regional publications used to search for Lesotho records include Henderson (1989, 1991a, b, 1992, 1998a, b, 2007). In addition, the publications on invasive alien plants for South Africa, Lesotho and Eswatini by Nel et al. (2004) as well as *Problem Plants and Alien Weeds of South Africa* by Bromilow (2010) were consulted. A search on the Plants of Southern Africa website (https://newposa.sanbi.org) was also undertaken. Technical reports of studies specific to IAS in Lesotho by the National Environment Secretariat were also utilised, namely NES (2005, 2007). Other earlier technical reports, which incorporated IAS in Lesotho, were also used, namely the Biological Diversity Report (NES 2000) and State of Environment Report (NES 2002). In addition, Google, Google Scholar, Science Direct, iSpot and iNaturalist (https://www.inaturalist.org/check_lists/9173-Lesotho-Check-List?iconic_taxon=47126)

were also used. Data were supplemented by examination of specimens located in the National University of Lesotho herbarium (ROML) as well as personal observations in the field (although not comprehensive), as shown in Table 1. As a result, a revised list was compiled updating the nomenclature using *The Plant List*, 2013, Version 1.1, Published on the Internet, from http://www.theplantlist.org/ and rectifying wrong records.

Ethical consideration

This article followed all ethical standards for research without direct contact with human or animal subjects.

Results and discussion

Species diversity

A list of invasive alien plant species occurring in Lesotho is presented in Table 1. Author citations are provided here and will not be repeated henceforth. A wide range of ethnobotanical uses of the IAPs is provided, ranging from food, fodder, through firewood, building material and timber production, to medicine and pesticides. In addition, information on their distribution and origin, as well as potential risks, is also given. In its report, NES (2005) documented a total of 31 invasive aliens comprising 15 trees and shrubs, 12 herbaceous and succulent weeds, 3 aquatic weeds and 1 grass species. A more comprehensive evaluation, produced 2 years later (NES 2007), listed a total of 54 invasive alien plant species (51 terrestrial and 3 aquatic) representing 25 families of angiosperms and 1 pteridophyte, with the largest number of species recorded in Asteraceae (7) followed by Cactaceae (5). That study also added information about species habitats, uses, distribution maps, pathways of introduction and invasive traits to the previous data. In the current study, a total of 58 species is recorded, comprising 1 pteridophyte, 1 gymnosperm and 56 flowering plants (52 dicotyledons and 4 monocotyledons). These numbers exclude 11 species (marked with † in Table 1) not listed by NES (2007) as invasive, but warrant further analyses to determine their status in the country (as discussed in subsequent sections). The largest number of species is recorded in the family Asteraceae (9), followed by Fabaceae (7) and Cactaceae (6). This is not surprising as Asteraceae is the largest flowering plant family, while Fabaceae is the third largest.

As Lesotho is completely surrounded by South Africa, we make a comparison with neighbouring areas of South Africa with regard to status, occurrence and distribution patterns of IAPs, particularly because 'invasiveness elsewhere is one of the most reliable indicators of invasion risk' (Early et al. 2016:5). To this end, it is important to note that nine species recorded by NES (2007) as IAS in Lesotho are not declared as such by the *National Environmental Management: Biodiversity Act* (No. 10 of 2004) (NEMBA) (https://invasives.org.za/legislation/what-does-the-law-say) in South Africa (highlighted in bold in Table 1). These are *Avena fatua*, *Cosmos bipinnatus, Erigeron bonariensis*, *E. canadensis*, *E. sumatrensis*, *Foeniculum vulgare, Glandularia aristigera*, *Polygonum aviculare* and *Populus nigra* var. *italica*. However, it is possible for a species to be invasive in one ecosystem but not in another. On the other hand, 11 other species (*Acacia baileyana*, *Agrimonia procera, Eucalyptus camaldulensis*, *Hypericum perforatum, Ligustrum japonicum, L. lucidum*, *Morus alba*, *Pennisetum villosum*, *Sorghum halepense*, *Verbena brasiliensis* and *V. rigida*) known to occur in Lesotho, and reported to be invasive in South Africa (https://invasives.org.za/resources/national-status-reports), are not recorded as invasive in Lesotho. However, it is important to note that South Africa is much larger and more diverse than Lesotho, with many different ecological conditions such as habitats, climate zones, soil types, etc., which may be suitable for the plants to become invasive. A search on the Plants of Southern Africa website (https://newposa.sanbi.org) for occurrence records of these plants in Lesotho returned the following results (number of specimens shown in brackets): *A. baileyana* (0), *Agrimonia procera* (1), *H. perforatum* (1), *L. japonicum* (0), *L. lucidum* (0), *M. alba* (0), *P. villosum* (1), *S. halepense* (3), *V. brasiliensis* (3) and *V. rigida* (3). A preliminary checklist of Lesotho plants (Kobisi 2005) listed all these species, with an exception of *L. japonicum*, as occurring in Lesotho. According to Henderson (2001), there were some records for *A. baileyana, H. perforatum*, the two species of *Ligustrum* and *M. alba*, while there were none for *P. villosum* and *S. halepense* occurring in Lesotho. Although Bromilow (2010) cautions that the distribution maps provided in his book are not a 'definitive indication of the actual distribution of a plant', his maps suggest that all these species (with the exception of *H. perforatum*) do occur in Lesotho. Of these species, the National University of Lesotho herbarium (ROML) has collections of only *S. halepense* and *V. brasiliensis*; however this should not be seen as an indication that the other species do not occur in the country, and it is possible that the country is under-reported. The existence of these species in Lesotho and their invasive status in South Africa may not necessarily suggest that they are invasive in Lesotho; however, these conflicting distribution records have revealed the dire need for a detailed assessment of their potential invasiveness or invasive status in Lesotho. It is surprising to note that NES (2007) did not list *E. camaldulensis* as an invasive plant in Lesotho, although this plant occurs widely in the country. The reason for this could be that the plant is naturalised in the country and considered by most people to be a very useful naturalised plant, instead of an IAP. A more detailed assessment is required to determine whether the distribution of *E. camaldulensis* fits Pyšek et al.'s (2004) definition of naturalised plants.

Ethnobotanical uses

Despite being invasive, some of the plant species are utilised for a variety of purposes ranging from food (vegetables, fruits), medical conditions (skin, reproductive, digestive and respiratory problems) to functional uses such as building, poles, rafters, firewood and sleighs. For example, *Nasturtium officinale* and *Hypochaeris radicata* are consumed as leafy vegetables, whereas *Opuntia ficus-indica*, *Gleditsia triacanthos*, *Pyracantha angustifolia*, *Rosa rubiginosa* and *Rubus cuneifolius* are consumed for their edible fruits, with the last two species

TABLE 1: Invasive plants of Lesotho, their origin, distribution in Lesotho, toxicity information, ethnobotanical uses and references.

Species name	Common names (Sesotho names in italics)	Origin	Distribution in Lesotho	Safety/toxicity	Ethnobotanical uses	References
Agavaceae						
Agave americana L.	Century plant, *lekhala/ lekhala-le-leputsoa*	Mexico	Throughout the country	The sap may irritate the skin, poisonous	Skin problems, cosmetic (leaf used in making of petroleum), to wash sore feet, food (nectar), rafters; furniture, drums, living hedges, fibre for mats, mixed with tobacco for snuff	Bullock (1952); Moffett (2010); Moteetee and Van Wyk (2011); NES (2007); Seleteng Kose et al. (2015)
Apiaceae						
Foeniculum vulgare Mill.	Wild fennel	Mediterranean, Europe	Throughout the country	Poisonous if taken in large quantities	Medicinal	Bullock (1952); NES(2007)
Asteraceae						
Cosmos bipinnatus Cav. (=*Bidensformosa)*	Cosmos, *palesa*	Mexico, Central America, West Indies	Throughout the country	No records	Fodder, flowers used to make chaplets for girls going to a wedding	Jacot Guillarmod (1971); Moffett (2010); Phillips (1917)
Cirsium vulgare (Savi) Airy Shaw	Spear thistle, scotch thistle, *ntsoantsoane/hlaba-hlabane*	Europe, Asia, North Africa	Throughout the country	No records	Ringworm, improves appetite, honey source	NES (2007); Watt and Breyer-Brandwijk (1962)
Erigeron bonariensis L. (= *Conyza bonariensis*, *C. albida*)	hairy fleabane, *mokoteli/ lehamo*	Central or South America	Throughout the country	No records	Respiratory problems; charm to drive away evil spirits	Jacot Guillarmod (1971); Moffett (2010); Moteetee and Van Wyk (2011); Phillips (1917)
E. canadiensis L.	Canadian horseweed, *mokoteli/ lehamonyane*	North America, Central America	Throughout the country	No records	Sore throat, skin, for bathing sick children	Jacot Guillarmod (1971); Moffett (2010); Moteetee and Van Wyk (2011); Phillips (1917)
E. sumatrensis Retz	Sumatran fleabane, *mokoteli/ lehamonyane*	South America	Throughout the country	No records	No records	
Hypochaeris radicata L.	Hairy wild lettuce, spotted cat's ear, *lepheo-la-khoho*	Europe	Lowlands, foothills	Causes stringhalt in horses	Leaves eaten as vegetables	NES (2007)
Tagetes minuta L.	Khaki bush, Mexican marigold, *lechuchutha/ monkhane*	South America	Throughout the country	May cause irritation to the skin or photodermatitis	Blisters or pimples; placed under bedding to chase away bedbugs; fumigant, formulation of pesticides, perfume making, fuel	Jacot Guillarmod (1971); Moffett (2010); NES (2007)
Xanthium spinosum L.	Spiny cocklebur/prickly burweed, *hlaba-hlabane/mokoala*	South America?	Throughout the country, but more concentrated in the lowlands	New seedlings toxic to livestock, burs irritate skin	Sexually transmitted infections	Moffett (2010); Moteetee and Van Wyk (2011); Phillips (1917); Shale et al. (1999)
X. strumarium L.	Rough cocklebur/large cocklebur, *shoba/ bohome/hlaba-hlabane*	South America, Central America	Throughout the country, more in lowlands	Seeds and seedlings contain toxic carboxyatratyloside	No records	
Azollaceae						
Azolla filiculoides Lam.	Water fern	Tropical South America	Several lowlands reservoirs	Reduces quality of drinking water caused by bad odour, colour, turbidity	No records	NES (2007)
Boraginaceae						
Echium plantagineum L.	Purple echium	Europe, Asia	Throughout the country	No records	No records	NES (2007)
E. vulgare L.	Patterson's curse, blue echium	Europe, Asia	Throughout the country	No records	No records	NES (2007)
Brassicaceae						
Rorippa nasturtium-aquaticum R.Br.	Watercress, *liababa/selae/ keresi/kerese, semetsing*	Europe, Asia	Throughout the country	No records	Leafy vegetable	Fox and Norwood (1982); Jacot Guillarmod (1971); NES (2007); Phillips (1917); Van Wyk and Gericke (2000)
Cactaceae						
Cereus jamacaru DC.	Queen of the night	South America	Lowlands, mountains	No sub-acute toxicity, spines can cause injury to animals	Ornamental	NES (2007); Schwarz et al. (2010)
Cylindropuntia imbricata (Engelm.) F.M.Knuth [= *Opuntia imbricata* (Haw.) DC.]	Imbricate prickly pear, *torofeiee/ terefeie*	South-western United States, northern Mexico	Lowlands and Senqu River valley	Spines can cause injury to animals and get entangled in the wool	Ornamental	NES (2007)
Echinopsis spachiana(Lem.) Friedrich & G.D. Rowley	Golden torch/torch cactus	South America (western Argentina)	Lowlands, foothills, Senqu River, valley	Spines can cause injury to animals and get entangled in the wool	Ornamental	NES (2007)

Table 1 continues on the next page →

TABLE 1 (Continues...): Invasive plants of Lesotho, their origin, distribution in Lesotho, toxicity information, ethnobotanical uses and references.

Species name	Common names (Sesotho names in italics)	Origin	Distribution in Lesotho	Safety/toxicity	Ethnobotanical uses	References
Opuntia ficus-indica(L.) Mill.	Sweet prickly pear, Indian fig, *torofeiee/terefeie*	Mexico	Throughout the country	Cladodes are poisonous when fed to livestock in large quantities, spines and glochids are skin irritants	Edible fruits, fodder, digestive ailments, toothache	Moteetee and Van Wyk (2006); NES (2007); Schmitz (1982); Seleteng-Kose et al. (2015); Van Wyk and Gericke (2000)
O. humifusa(Raf.) Raf.	Creeping prickly pear, *torofeiee/terefeie*	North America	Lowlands, Senqu River valley	Spines can cause severe injuries	Ornamental	NES (2007)
O. robusta J.C. Wendl. ex Pfeiff	Wheel cactus, *torofeiee/terefeie*	Mexico	Throughout the country	Spines and glochids are skin irritants	Edible fruits	NES (2007)
Chenopodiaceae						
Salsola kali L.	Tumble weed, *lekoerekoere*	Europe, North Africa, the Middle East, Central Asia, China, Australia	Throughout the country	Not recorded	Fodder	Watt and Breyer-Brandwijk (1962)
Convolvulaceae						
Convolvulus arvensis L.	Field bindweed, *morarane*	Europe, Asia	Throughout the country	Contains toxic alkaloids	Honey source	NES (2007)
Cuscuta campestris Yunck.	common dodder	North and South America	Throughout the country	Poisonous to cattle and animals	None known	
Cyperaceae						
Cyperus esculentus L.	Yellow nut grass, *monakalali/motabatabane*	Southern Europe, Africa, Madagascar, Middle East, Indian subcontinent	Throughout the country, common in lowlands, foothills, Senqu River valley	Exudes toxins that suppress growth of other plants	Food (nuts, tubers); crafts (chaplets and necklets for girls and women, ropes)	Fox and Norwood Young (1982); Jacot Guillarmod (1971); Moffett (2010); Moteetee and Van Wyk (2007); NES (2007); Peters, O'brien and Drummond (1992); Phillips (1917); Van Wyk and Gericke (2000)
C. rotundus L.	Red nut grass, *monakalali*	Africa, southern and central Europe, southern Asia	Lowlands, foothills and Senqu River valley	No records	Food (nuts, tubers)	NES (2007)
Euphorbiaceae						
Ricinus communis	Castor bean, *mohlafotha*	tropical Africa	Lowlands	The whole plant is extremely poisonous	Digestive problems	Bullock (1952); Moffett (2010); NES (2007)
Fabaceae						
Acacia baileyana F.Muell.†	Bailey's wattle, *bloukatlele*	South-east Australia	Not listed	No records	Beauty (women powder their faces with pollen of the plant); firewood, building material	Moffett (2010); Schmitz (1982)
A. dealbata Link.	Silver wattle, *bloukatlele*	Australia	Throughout the country, more abundant in the lowlands	No records	Firewood	Moffett (2010)
A. decurrens Willd.	Green wattle, *bloukatlele*	Australia	Throughout the country, more abundant in the lowlands	No records	Dysentery, tanning material	Watt and Breyer-Brandwijk (1962)
A. mearnsii De Wild.	Black wattle, *bloukatlele*	Australia	Throughout the country, more abundant in the lowlands	No records	Building poles, rafters, firewood, sleighs	Jacot Guillarmod (1971); Moffett (2010); NES (2007)
Gleditsia triacanthos L.	Honey locust, *leōka*	North America	Lowlands	No records	Edible fruits and seeds, firewood	NES (2007)
Robinia pseudoacacia L.	Black locust, yellow locust, false acacia	North America	Throughout the country	Leaves, seeds, inner bark poisonous	Ornamental, firewood	NES (2007)
Sesbania punicea(Cav.) Benth.	Red sesbania	South America	Lowlands	Leaves, flowers, seeds poisonous	Ornamental	NES (2007)
Haloragaceae						
Myriophyllum aquaticum(Vell.) Verdc.	Parrot's feather	South America	Biemans dam inside National University of Lesotho, Roma	No records	Ornamental; used in aquarium tanks for aesthetic purposes	NES (2005, 2007)
Hypericaceae						
Hypericum perforatum L.†	St John's wort	Europe, Asia	To be assessed	Poisonous, skin irritant	Cultivated for medicinal purposes	Henderson (1995)

Table 1 continues on the next page →

TABLE 1 (Continues...): Invasive plants of Lesotho, their origin, distribution in Lesotho, toxicity information, ethnobotanical uses and references.

Species name	Common names (Sesotho names in italics)	Origin	Distribution in Lesotho	Safety/toxicity	Ethnobotanical uses	References
Meliaceae						
Melia azedarach L.	Syringa, bead tree, Cape lilac, Persian lilac	Asia to Australia	Lowlands	Seed is poisonous	Ornamental	Bullock (1952); NES (2007)
Moraceae						
Morus alba L.†	Common mulberry	Northern China	Lowlands	No records	Edible fruits	Henderson (1995)
Myrtaceae						
Eucalyptus camaldulensis Dehnh.†	Red river gum, *boloukomo*	Australia	Throughout the country	Safe when used in recommended doses	Respiratory problems	Moffett (2010); Moteetee et al. (2019)
Oleaceae						
Ligustrum japonicum Thunb.†	Chinese wax-leaved privet	Asia	To be assessed	Poisonous fruits and leaves	Ornamental	Henderson (2001)
L. lucidum W.T.Aiton†	Chinese wax-leaved privet	Asia	To be assessed	Poisonous fruits and leaves	Ornamental	Henderson (2001)
Papaveraceae						
Argemone ochroleuca Sweet subsp. *ochroleuca*	White-flowered Mexican poppy, *hlaba-hlabane-e-putsoa*	Mexico	Throughout the country	Toxic to animals and humans	Sore eyes, fever, menstrual flow, increases breast milk, toothache	Maliehe (1997); Moffett (2010); Moteetee and Van Wyk (2011)
A. mexicana L.	Yellow-flowered Mexican poppy	Mexico	Throughout the country	Poisonous	No records	Bullock (1952)
Phytolaccaceae						
Phytolacca octandra L.	Forest inkweed, *monatja*	Tropical America	Throughout the country	Skin rash (fruits)	Medicinal (no details)	NES (2007)
Pinaceae						
Pinus halepensis Mill.	Aleppo pine, *phaena*	Mediterranean	Lowlands, foothills, Senqu River valley	No records	Timber, firewood, tanning purposes	Watt and Breyer-Brandwijk (1962) NES (2007); Van Wyk, Van Oudshoorn and Gericke (1997)
Poaceae						
Arundo donax L.	Giant reed, *lehlaka*	Mediterranean	Lowlands, foothills	No records	Ornamental	NES (2007)
Avenafatua L.	Wild oats, *belete/bele*	Europe, Asia	Mountains, foothills and lowlands	Poisonous to animals and humans	Fodder medicinal – rheumatism, fever, constipation, swelling	NES (2005); Watt and Breyer-Brandwijk (1962)
Pennisetum clandestinum Chiov.	Kikuyu grass, *mohloa-tšepe*	Tropical, North East Africa	Throughout the country	No records	Fodder, styptic	NES (2005); Watt and Breyer-Brandwijk (1962)
P. villosum R.Br. ex Fresen.†	Feathertop	North Africa (Ethiopia)	To be assessed	No records	Ornamental and for cover	https://invasives.org.za/component/k2/item/300-feathertop-pennisetum-villosum
Sorghum halepense (L.) Pers.†	Johnson grass, Aleppo grass	Mediterranean	To be assessed	Wilted foliage and young sprouts are poisonous	Fodder	https://www.invasives.org.za/component/k2/item/341-johnson-grass-sorghum-halepense
Polygonaceae						
Polygonum aviculare L.	Prostrate knotweed, *lira-hali-bonoe*	Europe, Asia, North America	Throughout the country	No records	Fodder	NES (2007)
Rosaceae						
Agrimonia procera Wallr.†	Fragrant agrimony	North America	To be assessed	Poisonous to animals	Used traditionally to treat coughs and intestinal worms	Moffett (2010); Pooley (1998)
Pyracantha angustifolia (Franch.) C.K.Schneid.	Yellow firethorn, *k'hok'ho/ ponaponana*	South-western China	Lowlands, foothills, Senqu River valley	Fruits are poisonous	Edible fruits, firewood	NES (2005)
P. crenulata(Roxb. ex D.Don) M.Roem.	Himalayan firethorn, *k'hok'ho/ ponaponana*	Western China	Lowlands, foothills, Senqu River valley	Seeds are poisonous if ingested	Edible fruits, firewood	NES (2005)
Rosa rubiginosa L. (= *R. eglanteria*)	Sweet briar, eglantine, *khunoane/ morobei*	Europe, western Asia	Throughout the country, more abundant in the mountain zone	No records	Edible fruits, firewood	Moteetee and Van Wyk (2007); NES (2007); Van Wyk and Gericke (2000)
Rubus cuneifolius Pursh	American bramble, *monokotšoai*	North America	Lowlands	No records	Edible fruits, jam making	NES (2007)

Table 1 continues on the next page →

TABLE 1 (Continues...): Invasive plants of Lesotho, their origin, distribution in Lesotho, toxicity information, ethnobotanical uses and references.

Species name	Common names (Sesotho names in italics)	Origin	Distribution in Lesotho	Safety/toxicity	Ethnobotanical uses	References
Salicaceae						
Populus x *canescens*(Aiton) Sm.	Grey poplar, *popoliri*	Europe, Asia	Throughout the country	No records	STIs, firewood, building material, rafters	Moffett (2010); NES (2007); Seleteng-Kose et al. (2015)
P. nigra var. italica Münchh.	Black poplar, *maipopo*	Europe, southwest and central Asia, northwest Africa	Lowlands, foothills	No records	Ornamental, source of honey	NES (2007)
Simaroubaceae						
Ailanthus altissima (Mill.) Swingle	Tree of hell, tree of heaven	China	Lowlands	Exudes allelopathic toxins	Ornamental	NES (2007)
Solanaceae						
Datura stramonium L.	Common thorn-apple, *letjoi*	Mexico, North America	Throughout the country	Seeds poisonous to animals and humans	Bruises, boils, dyestuff, asthma, headache, fuel	Maliehe (1997); Moffett (2010); NES (2007); Phillips (1917); Schmitz (1982); Van Wyk et al. (2009)
D. ferox L.	Large thorn-apple, *letjoi*	tropical South America	Lowlands	Seeds poisonous to animals and humans	None known	
Nicotiana glauca Graham	Tree tobacco, mustard tree *koae*	South America	Throughout the country	Poisonous to livestock	Poisonous	Bullock (1952); NES (2007)
*Solanum sisymbriifolium*Lam.	Wild tomato, dense-thorned bitter apple, *thōla*	South America	Lowlands	Fruits poisonous	None known	NES (2007)
Verbenaceae						
Glandularia aristigera (S.Moore) Tronc. (= *Verbena aristigera* S.Moore)	Wild verbena	South America	Lowlands, foothills, Senqu river valley	None known	Ornamental	NES (2007)
Verbena bonariensis L.	Tall verbena, *seona-se-seholo*	South America	Throughout the country	Poisonous to animals	Ornamental	https://www.invasives.org.za/component/k2/item/836-tall-verbena-verbena-bonariensis
V. brasiliensis Vell.†	Brazilian verbena	South America	Not listed	None known	Ornamental	https://www.invasives.org.za/component/k2/item/897-brazilian-verbina-verbena-brasiliensis
V. rigida Spreng.†	Veined verbena, *morōli*	Brazil, Argentina	Not listed	None known	Ornamental	https://www.invasives.org.za/component/k2/item/863-veined-verbena-verbena-rigida

Note: Plants highlighted in bold are listed as invasive in Lesotho, but not listed as such according to NEMBA No. 10 (2004) of South Africa. Species marked with † are not listed as invasive in Lesotho but are listed as invasive according to NEMBA No. 10 (2004) of South Africa.

also used in jam making. In addition, *Convolvulus arvensis* is used by bees for producing honey. Animal feeds include such species as *O. ficus-indica, Pennisetum clandestinum*, *Salsola kali* and *S. halepense*. The tubers of *Cyperus esculentus* are eaten raw or roasted (pers. obs.).

A total of 17 species is used for medicinal purposes. Four of these (*Agave americana, Datura stramonium*, *S. halepense* and *Tagetes minuta*) are used for a variety of skin problems, namely bruises, blisters, sore feet, pimples, swelling and boils (Jacot Guillarmod 1971; Moffett 2010; Moteetee & Van Wyk 2011; NES 2007; Seleteng-Kose et al. 2015). Interestingly, the leaves of *A. americana* are used in the making of petroleum jelly in Lesotho. Other plants of medicinal importance include those used in the treatment of digestive ailments such as dysentery and constipation, and these include: *A. dealbata* (Moffett 2010), *A. mearnsii* De Wild. (Jacot Guillarmod 1971; Moffett 2010; NES 2007), *O. ficus-indica* (Moteetee & Van Wyk 2006; NES 2007; Schmitz 1982; Seleteng-Kose et al. 2015; Van Wyk & Gericke 2000) and *S. halepense* (http://www.invasives.org.za/component/k2/item/341-johnson-grass-sorghum-halepense). Three species (*Argemone ochroleuca* Sweet, *S. halepense* and *D. stramonium*) are used for respiratory ailments, including asthma and fever. Moreover, *D. stramonium* is also used to treat headache (Maliehe 1997; Moffett 2010; NES 2007; Phillips 1917; Schmitz 1982; Van Wyk, Van Oudtshoorn & Gericke 2009). Three species are used for the treatment of reproductive problems: *Xanthium spinosum* (Moffett 2010; Moteetee & Van Wyk 2011; Phillips 1917; Shale, Stirk & Van Staden 1999) and *Populus* x *canescens* (Moffett 2010; NES 2007; Seleteng-Kose et al. 2015) are used specifically for sexually transmitted infections (STIs) and *A. ochroleuca* is used by women for controlling menstrual flow and increasing breast milk. In addition, *A. ochroleuca* is utilised for the treatment of sore eyes (Maliehe 1997; Moffett 2010; Moteetee & Van Wyk 2011). Other medicinally important species include *S. halepense*, which is used for the treatment of rheumatism, and *A. americana* and *T. minuta*, which are ground into powder and taken as snuff (Jacot Guillarmod 1971; Moffett 2010; Moteetee & Van Wyk 2011; Seleteng-Kose et al. 2015).

Functional uses (such as poles, rafters, hedges and sleighs) are observed in several *Acacia* species, such as *A. dealbata, A. decurrens, A. mearnsi*, as well as *Populus* x *canescens* and *A. americana*. Leaves of *A. americana* are also used to make fibres used in floor mats (Moteetee et al. 2019). The importance of trees such as *A. decurrens* and *Pinus halepensis* Mill. as sources of firewood is highly significant in remote areas where electricity and other sources of fuel are scarce. Other species used for making fire include *D. stramonium, G. triacanthos, P. angustifolia, R. rubiginosa* and *T. minuta*. Some species are used as ornaments, namely *Ailanthus altissima, Arundo donax, Cereus jamacaru, Echinopsis spachiana, G. triacanthos, Melia azedarach, M. aquaticum, O. humifusa* and *Robinia pseudoacacia*. Women and girls use *C. esculentus* for making chaplets and necklets. In addition, they use pollen from *A. baileyana* as powder. Other useful species include *T. minuta*, which is used as a fumigant and in the formulation of pesticides as well as perfume. In addition, it is placed under bedding to deter bed bugs. *Nicotiana glauca* is used as a rat or cockroach poison, whereas *M. aquaticum* is used in aquarium tanks for aesthetic purposes. Many of the plants (18 in total) are used for ornamental purposes. Interestingly, in a study by Weber, Sun and Li (2008), the use of AIPs for ornamental purposes in China was identified as the most frequent economic use, with medicinal uses second. This seems to be the case for Lesotho as well.

On the other hand, some of the IAPs seem to be making notable impact in the commercial arena, for example *A. americana* and *R. rubiginosa* have entered local and international biotrade industries for making useful products for the food, pharmaceutical and cosmetic industries (Department of Environment 2014). In fact, Lesotho is currently exporting *R. rubiginosa* fruits to Germany (through the Rosehip Company) for making tea and jam, as well as for the production of essential oils used in the cosmetics industry. In addition, the remaining residue is reported to induce fertility in animals. To this end, it is projected that by 2040 the country may witness depleting number and abundance of commercially useful native species and increasing number and abundance of commercially used IAS (Department of Environment 2014).

Origin and distribution

A majority of the plants have originated from Europe (16), the Americas (North America = 8; Central and South America = 20) and Asia (16), with a few species from the rest of Africa (8) and China (Northern, Western) (5). Lesotho is divided into four agro-ecological zones, namely Lowlands, Foothills, Mountains and Senqu Valley, most of the recorded species have spread throughout the country across the four zones. The plants include *Acacia* species, *A. americana, A. ochroleuca* subsp. *ochroleuca, Cirsium vulgare*, *Populus* x *canescens* and *R. rubiginosa*. It is worth noting that an estimation of IAP infestation for Lesotho by Kotze et al. (2004) showed that most parts of the country, including all the four zones, have infestations ≥ 40%. On the other hand, a limited number of species are confined to specific zones because of varying altitudinal and climatic preferences which are different in the four zones. For example, *A. filiculoides*, *G. triacanthos*, *M. azedarach* and *P. halepensis* are confined to the lowlands, which is characterised by warmer temperatures and low altitude (below 1820 m.a.s.l.). However, the distribution of *C. esculentus, E. spachiana, Cylindropuntia imbricata* and *H. radicata* also extends to the Foothills and Senqu Valley, with the former having altitude of more than 1820 m.a.s.l. and the latter being the most degraded and driest zone. Only one species, *C. jamacaru*, is confined to the mountain zone; it is worth noting that in its natural habitat in eastern and north-eastern Brazil, the species occurs in dry, open forest areas and prefers less dry areas (Tropical Plants Database, Ken Fern. tropical.theferns.info.; tropical.theferns.info/viewtropical.php?id=Cereus+jamacaru).

Potential risks

Some of the plants are reported to be unsafe. For example, the fruits of *P. octandra* are said to be poisonous and capable of causing skin irritation, *T. minuta* causes irritation of the skin or photodermatitis yet it is used as a snuff (Jacot Guillarmod 1971), *Ricinus communis* and *Sesbania punicea* are extremely poisonous and the seeds are lethal. In fact, *R. communis* is regarded as the most poisonous plant for humans in the world, although it is used for medicinal purposes in many parts of Africa (Kuete 2014). In addition, *A. ochroleuca* subsp. *ochroleuca* is reported to be poisonous and an irritant, while the seeds can contaminate sheep's wool (Bosch 2007). Although *O. indica* has many uses, the cladodes are reported to be poisonous when fed to livestock in large quantities. Young seedlings of *X. spinosum* and *X. strumarium* are toxic to livestock and burs may irritate the skin. Similarly, *R. pseudoacacia* (leaves, seeds and inner back) and *D. stramonium* (seeds) are poisonous to both animals and humans (NES 2007). Species of *Datura* including *D. stramonium* are used as narcotics in many parts of the world (https://www.cabi.org/ISC/datasheet/18006).

Control

If properly planned and executed, many IAPs can be controlled through three primary methods of control: mechanical, chemical or biological. However, we are not aware of any control or eradication programmes in Lesotho, and we are also not aware of any early detection programmes. Mechanical methods may include physical removal of rhizomes, roots, cultivation and repeated cutting of the stem (Bromilow 2010). The removal can be done by hand-pulling, using hand-held tools or even bulldozers, and can be done in combination with burning (Van Wilgen et al. 2001). However, many species are difficult to control because they have extensive underground systems and produce large quantities of seeds and therefore regenerate vigorously. Furthermore, if the area is heavily invaded, mechanical controls can be laborious and therefore costly. Other mechanical methods include ring-barking (which can be used to kill large trees such as *Populus* x *canescens*) as well as cut-stumping and frilling of small trees such as *A. altissima* and *R. pseudoacacia*. In the case of trees, these methods should be followed by an application of herbicides as unremoved fragments may re-sprout and grow after the initial cutting. Herbicides can also be applied to kill seedlings of targeted IAPs, for example *D. stramonium* is susceptible to a wide range of herbicides that can be applied to the soil or leaves, including acifluorfen, bentazone, atrazine, cyanazine, simazine, bromoxynil, metolachlor and 2,4-D (https://www.cabi.org/ISC/datasheet/18006). However, there are concerns regarding the use of herbicides because of their negative impact on the environment (Van Wilgen et al. 2001). Biological control is preferred over mechanical and chemical controls as it is regarded to be more cost-effective and safer. In South Africa, the programme goes as far back as 1913 and since then 63 control agents have been successfully released (Zimmerman, Moran & Hoffman 2004). For example, the release of the mealybug (*Hypogeococcus pungens* Granara de Willink) is reported to have been successful in curbing the spread of *C. jamacaru* across most parts of the country (Paterson et al. 2011).

Legal instruments have also been instituted to control and eradicate invasive species in Lesotho, namely *Laws of Lerotholi* (1959), *Weeds Eradication Act* 18 of 1969, as well as the *Environmental Act* (2001). However, the biggest challenge is the establishment of prevention programmes for minimising further damage of ecosystems by IAPs. Several initiatives have been undertaken, such as manual removal of the species in some areas. Although the *Lesotho Environment Act* of 2001 prohibits the introduction of invasive alien species into ecosystems, 'there are no provisions for the necessary instruments to prevent introductions, spread and management of invasions, both for alien and indigenous species' (NES 2007). Furthermore, unlike in the neighbouring South Africa, where a national strategy for dealing with biological invasions has been developed (National Strategy 2014), no such legislation or guidelines exist in Lesotho. In addition, there is no national list of invasive species or their categorisation based on their level of impact or risk as is the case for South Africa (http://invasives.org.za/resources/national-status-reports).

According to Shackleton et al. (2007), the reliance on IAS by rural livelihoods is often not considered when control measures are put in place. While we did not consider the possible effects of the regulation and/or eradication of IAPs to the livelihoods of the rural communities in the current study, it can be inferred from the previous sections that despite the invasive nature of these plants, many of them have numerous uses in Lesotho. In a country with high unemployment rates between 24% and 28% and 53.7% of the population living below the poverty line (https://www.worldbank.org/en/country/lesotho/overview), the importance of these plants cannot be overemphasised. For example, we (all three authors) have personally observed scores of people (both men and women, young and old) collecting bucket loads of *R. rubiginosa* fruits, most likely to supply the export market. In this instance, the resource use benefit could outweigh its threat to biodiversity and the ecosystem; however, this warrants a more detailed analysis.

Conclusions

Several efforts have been made to assess and record occurrence of IAS in Lesotho; however, several gaps have been identified. The current study builds on the previous reports with the purpose of extensively documenting species that have been introduced into the country and have spread displacing indigenous species. Although this study recorded only four more IAPs than the previous study (58 vs. 54), the uncertain invasive status of 11 other species has been identified. However, 10 of the recorded species are reported as invasive in Lesotho but are not regarded as such in South Africa. Information on origin, distribution in

Lesotho, potential risks and ethnobotanical uses of the documented IAPs has also been recorded. Interestingly, many of these IAPs have a wide range of ethnobotanical uses, such as food and medicine as well as functional uses such as building, poles, rafters, firewood and sleighs, despite some of them being toxic to both humans and animals. In fact some of the species such as *R. rubiginosa* have entered international trade, being exported to Germany for manufacturing of products in the pharmaceutical and cosmetic industries. Unfortunately, the current legislation relating to the prevention and management of the spread of IAPs is inadequate and does not provide appropriate guidelines and implementation strategies. A concerted effort is also required from scientists to conduct comprehensive and multidisciplinary research on biological invasions in Lesotho in order to influence policymaking; however, this will require a strong political will and substantial amounts of funding.

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Authors' contributions

A.M. conceptualised the research project, L.S.-K. compiled the original manuscript and K.K. compiled the list of alien invasive plant species. All authors contributed equally to the editing of the manuscript.

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Disclaimer

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