EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION
ORGANISATION EUROPEENNE ET MEDITERRANEENNE POUR LA PROTECTION DES PLANTES

18-23432 (17-22732)

Pest Risk Analysis for *Hakea sericea*

2018

EPPO
21 Boulevard Richard Lenoir
75011 Paris
www.eppo.inthq@eppo.int

This pest risk analysis scheme has been specifically amended from the EPPO Decision-Support Scheme for an Express Pest Risk Analysis document PM 5/5(1) to incorporate the minimum requirements for risk assessment when considering invasive alien plant species under the EU Regulation 1143/2014. Amendments and use are specific to the LIFE Project (LIFE15 PRE FR 001) ‘Mitigating the threat of invasive alien plants to the EU through pest risk analysis to support the Regulation 1143/2014’.

Cite this document as:
EPPO (2018) *Pest risk analysis for* Hakea sericea. EPPO, Paris.
Available at:XXX

Photo: *Hakea sericea* (Portugal) Elizabete Marchante EPPO Global Database.

EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION

Pest risk analysis for *Hakea sericea*

This PRA follows EPPO Standard PM5/5 Decision support scheme for an Express Pest Risk Analysis

Composition of the Expert Working Group

ALBERT Arnaud (Mr)	Fédération des Conservatoires botaniques nationaux, 18 rue Beaumarchais - BP 87, 93511 Montreuil Cedex, France - arnaud.albert@fcbn.fr
Chapman Daniel (Mr)	Centre for Ecology and Hydrology Bush Estate, Penicuik, Edinburgh , UK, dcha@ceh.ac.uk
LE ROUX Jaco (Mr)	Centre for Invasion Biology, Department of Botany and Zoology, Stellenbosh University, Private Bag X1, 7602 Matieland, South Africa - jleroux@sun.ac.za
LINNAMÄGI Merike (Ms)	Ministry of Environment, Nature Conservation Department, Narva mnt 7a - 329, 15712 Tallinn, Estonia - merike.linnamagi@envir.ee
MARCHANTE Elizabete (Ms)	Centre for Functional Ecology, Department of Life Sciences, Universtiy of Coimbra, Calçada Martim de Freitas, 3000-456 Coimbra, Portugal - elizabete.marchante@gmail.com
PASIECZNIK Nick (Mr)	Agroforestry Enterprises, 16 Place Docteurs C et C Mérieux, 69007 Lyon, France - npasiecznik@wanadoo.fr
PESCOTT Oliver (Mr)	Centre for Ecology and Hydrology Wallingford, Benson Lane, Crowmarsh Gifford, OX10 8BB Wallingford, Oxfordshire, United Kingdom - olipes@nerc.ac.uk
Inderjit (Mr)	Department of Environmental Studies,University of Delhi, Department of Environmental Studies,University of Delhi, 110007 Delhi, India - inderjitdu@gmail.com
STARFINGER Uwe (Mr)	Julius Kühn Institut (JKI), Federal Research Centre for Cultivated Plants, Institute for National and International Plant Health, Messeweg 11/12, 38104 Braunschweig, Germany - uwe.starfinger@julius-kuehn.de
VICENTE Joana (Ms)	CIBIO/InBIO - Universidade do Porto, CIBIO - Centro de Investigação em Biodiversidade e Recursos Genéticos, Universidade do PortoCampus Agrário de Vairão, Rua Padre Armando Quintas, nº 7, 4485-661 Vairão Portugal. - jsvicente@fc.up.pt
TANNER Rob (Mr)	OEPP/EPPO, 21 boulevard Richard Lenoir, 75011 Paris, France - rt@eppo.int

The pest risk analysis for *Hakea sericea* has been performed under the LIFE funded project:

LIFE15 PRE FR 001

Mitigating the threat of invasive alien plants to the EU through pest risk analysis to support the Regulation 1143/2014

In partnership with

EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION

And

NERC CENTRE FOR ECOLOGY AND HYDROLOGY

Review Process

This PRA on *Hakea sericea* was first drafted by Oliver Pescott and Rob Tanner.

- The PRA was evaluated under an Expert Working Group (EWG) at the EPPO headquarters between 2017-05-15/19

- Following the finalisation of the document by the expert working group the PRA was peer reviewed by the following:

  (1) The EPPO Panel on Invasive Alien Plants (2017)
  (2) The EPPO PRA Core members (2017)
  (3) The EU Scientific Forum (2018)

Contents

Appendices

Summary[1]of the Express Pest Risk Assessment for *Hakea sericea*

PRA area: EPPO Region

Describe the endangered area: Based on the current environmental conditions, species distribution modeling combined with overlaid preferred bedrock types identified suitable areas for establishment of *H. sericea* in the Mediterranean, Atlantic, Black Sea and Macaronesia biogeographical regions (see Appendix 1 and 2). The endangered area includes Portugal (and the Azores and Madeira), and parts of France (and Corsica), Greece, Italy (and Sardinia), Spain (and Balearic Islands) and coastal areas of the Adriatic Sea (Croatia, Slovenia, Albania and Bosnia and Herzegovina) and the Black Sea (Turkey and Georgia). In addition, coastal regions of western North Africa are included in the endangered area including Algeria and Morocco.

Habitats at risk in the endangered area include woodland, grasslands, heath land and scrub.

Main conclusions

The results of the PRA show that *H. sericea* poses a high risk to the endangered area, with a low uncertainty. Impacts in the current introduced range are high, and although the risk of further introduction is considered as low, there is a high perceived risk of spread from established populations in Portugal, Spain and France.

Entry and establishment

In the EPPO region, *H. sericea* is present in the environment in France, Portugal and Spain. The risk of further entry into the EPPO region is considered low, however, the potential for establishment in both the natural and managed environment is high with a low uncertainty.

Potential impacts in the PRA area

The EWG consider that impacts on biodiversity will be similar in the PRA area as to that seen in the current area of distribution. In Portugal, and in France, *H. sericea* forms extensive dense monospecific stands which can exclude native plant species and/or change community composition, including associated fauna. Areas highly susceptible to invasion by *H. sericea* in the north of Portugal are coincident with the distribution of *Succisa pinnatifida* Lange, a rare endemic of the Iberian Peninsula (J. Vicente, pers. comm., 2017). The high spread potential of *H. sericea* also threatens to reduce the biodiversity of the Esterel Mountains in France, by eliminating less competitive native species of maquis and forest in this Mediterranean biodiversity hotspot.

In Portugal, several NATURA 2000 sites are, to some extent, invaded by *H. sericea*, *e.g.*, PTCON0001 (Serras da Peneda e Gerês), PTCON003 (Alvão/Marão), PTCON0024 (Valongo), PTCON0039 (Serra D'Arga), and PTCON0060 (Serra da Lousã).
In France, one NATURA 2000 site is invaded, FR9301628 (Estérel).
These priority habitats contain rare and endangered species. See section 7 for more information on habitats.

To date, there have been no recorded impacts on Red Data Book species in the EU.

Impacts on ecosystem services will be similar to those seen in the current area of distribution. *Hakea sericea* may increase the intensity of fire in areas where the species invades. Impacts on hydrological regimes are generally considered likely, although most evidence is indirect, or related to the impacts of particular management strategies (van Wilgen & Richardson, 1985). Within the EPPO region, cultural services are already being affected as *H. sericea* forms dense impenetrable thickets restricting access for tourism. These impacts are only likely to increase with population expansion.

---

[1]The summary should be elaborated once the analysis is completed

The EWG consider that socio-economic impacts will be similar in the PRA area as to those seen in the current area of distribution. Socio-economic impacts have been reported from the EPPO region where up to 160 000 EUR was spent in 2016-17 managing only 50% of an invasive population of approximately 12 ha in the Esterel Natural Park and Conservatoire du Littoral site (Theoule-sur-Mer, Maritimes Alps) in the south of France (G. Parodi, Maritime Alps department, pers. comm., 2017.). It has been estimated that 10000€/ha in funding is needed for the eradication of the species. These impacts are also only likely to increase with population expansion.

For impacts, the text within this section relates equally to EU Member States and non-EU Member States in the EPPO region.

Climate change

Climate change scenario RCP8.5 is predicted to increase suitability dramatically in the Atlantic and Continental regions, but decrease suitability in the Mediterranean, Macaronesia and Black Sea regions. These decreases appear largely driven by increases in summer temperatures beyond the species optima shown in Figure 3 (Appendix 1). Countries with a high suitability include: a small area of Portugal, north Spain, France, United Kingdom, Ireland, Belgium, the Netherlands, Luxembourg, Germany, Denmark, southern areas of Norway and Sweden.

The results of this PRA show that *Hakea sericea* poses a high risk to the endangered area (Mediterranean, Atlantic, Black Sea and Macaronesia biogeographical regions) with a low uncertainty.

Phytosanitary risk (including impacts on biodiversity and ecosystem services) for the *endangered area* (current/future climate) **Pathways for entry:** Plants for planting: Low/ Low Establishment (natural): High/ High Establishment (managed): High/ High Spread: High/ High **Impact (PRA area)** Impact on biodiversity: High/ High Impact on ecosystem services: High/ High Socio-economic impact: Moderate/Moderate	High X	Moderate ☐	Low ☐
Level of uncertainty of assessment (current/future climate) **Pathways for entry:** Plants for planting: Moderate/Moderate Establishment (natural): Low/High Establishment (managed): Low/High Spread: Low/Moderate **Impact (PRA area)** Impact on biodiversity: Low/High Impact on ecosystem services: Moderate/ High Socio-economic impact: Moderate/ High	High ☐	Moderate ☐	Low X

Other recommendations:

- Confirm the taxonomic status and occurrence of *Hakea* species in the EPPO region,
- Further research on impacts of the species in the EPPO region.

Express Pest Risk Assessment

……………

Hakea sericea Schrad. & J.C.Wendl.

Prepared by:

First draft: Dr Oliver L. Pescott[*], CEH Wallingford, UK, & Dr Rob Tanner, EPPO, Paris, France, E-mail: olipes@ceh.ac.uk.

Date:2nd April 2017

Stage 1. Initiation

Reason for performing the PRA:
Hakea sericea was added to the EPPO Alert List in 2007 and transferred to the List of Invasive Alien Plants in 2012 following a prioritization assessment (Brunel *et al.*, 2010a). Brunel *et al.* (2010a) also concluded that this species was a high priority for a full Pest Risk Analysis (PRA). In a separate exercise, Brunel *et al.* (2010b) considered that *H. sericea* was a species that represented "an emerging threat" to the Mediterranean Basin, with the same recommendation that the species be placed on the EPPO List of Invasive Alien Plants. In 2016, the species was prioritized (along with 36 additional species from the EPPO List of Invasive Alien Plants and a recent horizon scanning study[2]) for PRA within the LIFE funded project "Mitigating the threat of invasive alien plants to the EU through pest risk analysis to support the Regulation 1143/2014' (see www.iap-risk.eu). *Hakea sericea* was one of 16 species identified as having a high priority for PRA.

Hakea sericea (Proteaceae) is a shrub native to south-eastern Australia. The species has been introduced into other countries and continents; for example, it has naturalised and is invasive in France, New Zealand, Portugal, and South Africa. Reasons for it being considered high priority for PRA in the past include its high spread potential and its potential impacts on fire regimes and biodiversity (Brunel et al., 2010a). In addition, the species is spreading in Portugal (Martins *et al.*, 2016) and France (Fried, 2010), and there is a large area of suitable habitat in the EPPO region that the species could occupy (Brunel *et al.*, 2010a; Marchante *et al.*, 2014; Martins *et al.*, 2016). Finally, climate modelling has shown that the species has the potential to establish in more regions in the EPPO region than it currently occurs (Appendix 1). There is further potential for establishment in the Mediterranean, Atlantic, Black Sea and Macaronesia biogeographical regions (Appendices 1 and 2).

PRA area: The EPPO region (see https://www.eppo.int/ABOUT_EPPO/images/clickable_map.htm)

The risk assessments were prepared according to EPPO Standard PM5/5 (slightly adapted) which has been approved by the 51 EPPO Member Countries, and which sets out a scheme for risk analysis of pests, including invasive alien plants (which may be pests according to the definitions in the International Plant Protection Convention). EPPO engages in projects only when this is in the interests of all its member countries, and it was made clear at the start of the LIFE project that the PRA area would be the whole of the EPPO region. Furthermore, we believe that since invasive alien species do not respect political boundaries, the risks to the EU are considerably reduced if neighbouring countries of the EPPO region take equivalent action on the basis of broader assessments and recommendations from EPPO.

---

[2] http://ec.europa.eu/environment/nature/invasivealien/docs/Prioritising%20prevention%20efforts%20through%20horizon%20scanning.pdf

All information relating to EU Member States is included in the pest risk assessment and information from the wider EPPO region only acts to strengthen the information in the PRA document. The PRA defines the endangered area where it lists all relevant countries within the endangered area, including EU Member States. The distribution section lists all relevant countries in the EPPO region (including by default those of EU Member States and biogeographical regions which are specific to EU member States). Habitats and where they occur in the PRA are defined by the EUNIS categorization which is relevant to EU Member States. Pathways are defined and relevant to the EU Member States and the wider EPPO Member countries, and where the EWG consider they may differ between EU Member States and non-EU EPPO countries, this is stated. The establishment and spread sections specifically detail EU Member States. When impacts are relevant for both EU Member States and non-EU EPPO countries this is stated ‘The text within this section relates equally to EU Member States and non-EU Member States in the EPPO region’. Where impacts are not considered equal to EU Member States and non-EU Member States this is stated and further information is included specifically for EU member States. For climate change, all countries (including EU Member States) are considered.

Stage 2. Pest risk assessment

1. Taxonomy: *Hakea sericea* Schrad. & J.C.Wendl.(Kingdom Plantae; Division Tracheophyta; Class Magnoliopsida; Order Proteales; Family Proteaceae; Genus *Hakea* Schrad.). (Integrated Taxonomic Information System, accessed 13th April 2017).

During review of this PRA, issues have been raised regarding the taxonomy of the species and the validity of earlier records (see also the discussion under the **Identification** section below). Surveys in Portugal in 2018 have confirmed that some of the populations thought to be *H. sericea* are actually more likely to be *H. decurrens*, when following the *Hakea* treatment in the Flora of Australia (Barker et al. 1999). Some sources, however (e.g. Plant List 2017), follow a different delimitation for some species within the genus, including considering *H. decurrens* to be a synonym of *H. sericea*. This broader species concept of *H. sericea* implies a wider geographical range, including Queensland, New South Wales and Victoria. A biocontrol programme for *Hakea sericea* in South Africa initially worked with weevils (*Erytenna consputa*) on *Hakea sericea* from Victoria (Kluge & Neser 1991), with poor results. When shifting to a New South Wales provenance of the same weevils, success improved greatly. Barker et al. (1996) quoted this biocontrol work to further support a narrower species concept for *H. sericea*, resulting in the separation of *H. decurrens*. The distinction between *H. sericea* and *H. decurrens*, following Barker et al. (1996,1999), is principally based on a difference in the length of the pistil, as other morphological characters intergrade to some extent. It is the view of the Expert Working Group that, notwithstanding reviews of the taxonomy and nomenclature relating to earlier records, and future taxonomic revisions, the observed similarities in the behaviour of the non-native populations designated under a broad concept of *H. sericea* in New Zealand, South Africa, Portugal and France mean that the information contained in this PRA is valid and will remain so.

EPPO Code: HKASE

Common names: English: Silky hakea, needlebush, silky needle-bush, prickly hakea, silky wattle, bushy needlewood; Afrikaans: hakea boom, syerige hakea; French: hakea soyeux; Portuguese: espinheiro-bravo, háquea-picante, háquia-espinhosa, salina; Russian: хакея шелковистая.

Synonymy: From Barker (1996): *Hakea acicularis* (Sm. ex Vent.) Knight & Salisb.; *Hakea tenuifolia* (Salisb.) Britten.

Plant type: Evergreen shrub or small tree

Related species in the EPPO region:

Native species: None

Ornamental species[3]**:** *Hakea gibbosa*, *H. drupacea*, *H. salicifolia* and *H. lissosperma*.
Hakea salicifolia is also invasive and is banned for use in Portugal (Decreto-Lei 565/99). *Hakea salicifolia* is also invasive in France (Terrin *et al.*, 2014; Ducatillion *et al.*, 2015)

2. Pest overview

Introduction

Hakea sericea (Proteaceae) is a shrub or small tree native to south eastern Australia. The species has been introduced into other countries and continents; it has naturalised and has become invasive in France, New Zealand, Portugal, and South Africa (see section 6 for specific

---

[3] This list is not exhaustive and details the popular species within the PRA area.

references). There is also a small population in Spain which is likely to be established given its similar climatic conditions to Portugal (Barker, 1996). In South Africa it has become particularly well-known for its spread and impacts in the Mediterranean-type climate fynbos region, especially of the mountain catchments in the southwestern and southern regions of the Western Cape Province (Kluge & Neser, 1991). Although the species has been known from the EPPO region for some time (*e.g.* Ball, 1964), concern over the invasiveness of *H. sericea* in its non-native ranges in France, Portugal, and adjacent parts of Spain, has been increasing (Brunel *et al.*, 2010a,b; Fried, 2010; Morais *et al.*, 2017).

Reproduction

Hakea sericea has a canopy-stored seed bank from which seeds are typically released from woody follicles (fruits) following the death of the plant, frequently caused by fire (Bradstock 1991). In its native range (south-eastern Australia), flowering occurs from winter to early spring (June-September) and produces woody fruits that can persist for several years (Brown & Whelan, 1999). Fruit development begins in October, soon after flowering, and fruits have been found to rapidly contribute to the availability of germinable seeds in the canopy seed bank (Brown & Whelan 1999). Seeds are released following death of a branch; however, seeds can also be released from a small percentage of fruits that are on living branches (E. Marchante, pers. comm., 2017), particularly when unusually strong climatic conditions (e.g. drought and heat) occur (K. Diadema, pers. comm., 2017). The decline in the germinability of *H. sericea* canopy seedbanks has been found to be relatively slow, leading to a gradual increase in the size of seed banks over time (Brown & Whelan, 1999). The flowering period in part of its European invaded range (France and Portugal) is given as December-April, *i.e.*, as for the native range, winter to early spring (Paiva, 1997, Tison and Foucault, 2014).

Richardson *et al.* (1987) investigated a number of different reproductive traits that they considered might be useful in determining the invasiveness of *H. sericea* compared to two less invasive congeners (*H. gibbosa* (Sm.) Cav., *H. drupacea* (C.F.Gaertn.) Roem. & Schult., syn. *H. suaveolens* R.Br.), and one species considered non-invasive in South Africa at that time (*H. salicifolia* (Vent.) B.L.Burtt). They concluded that the most important reproductive trait determining the invasiveness of *H. sericea* was its ability to produce a large (canopy stored) seed bank, being aided in this by the absence of seed predators in South Africa. The samples of Richardson *et al.* (1987) indicated that the seed production of *H. sericea* could be four times greater than that of *H. gibbosa*, and more than 16 times greater than *H. drupacea*. The resistance of seeds to fire was also a key reproductive trait mediating its invasion of the South African fire-prone fynbos: *H. salicifolia* produced a similar number of seeds to *H. sericea*, but its small follicles provide little protection against fire (Richardson *et al.* 1987). It was also concluded that although all of the *Hakea* species' winged seeds (samaras) were well adapted for long-distance dispersal (on the order of kilometres), it is "only in *H. sericea* that colonization of distant areas constitutes a major problem" (Richardson *et al.*, 1987). This was considered to be due to the specific combination of several reproductive traits, *i.e.* high seed production, fire resistance and adaptation for wind dispersal, along with the absence of native seed predators. Rapid germination of a high proportion of seed has also been reported for the species by Richardson & van Wilgen (1984). Historical evidence for a limited extent of planting of *H. sericea* in South Africa supports the view that the species has spread rapidly independently of human activity (Shaughnessy, 1986).

In terms of specific numbers, a total above-ground biomass of 12 kg of *H. sericea* indicates around 2.9 kg of follicles and seeds, at least according to the samples and fitted model of Richardson *et al.* (1987). This equates to just over 800 fruits, where a fruit typically contains two seeds (Richardson *et al.*, 1987; Barker, 1996). A large shrub could therefore store over 1600 seeds in its canopy, although 100-200 may be a more typical figure, at least in its native range (Brown & Whelan, 1999). The number (8874) and density (1.6 m^{-2}) of seedlings reported by Beever (1988) to have been hand-weeded over three years at an invaded site in New Zealand, supports the view of a species that is able to quickly dominate local areas through the high production of viable seed. In South Africa, Kluge (1983) found seed densities of up to 7500 seeds m^{-2} in the ash bed following a fire.

Field observations in the South of France (Esterel), reported at the EWG (K. Diadema, pers. comm., 2017), provide the following additional information: *H. sericea* was seen to produce flowers and fruits within 12 months of germination, and this continues for the life of the tree (the oldest individuals in France have been estimated at up to 60 years). This leads to an accumulation of follicles in the canopy over time. Work at this site in France has led to an estimate of 52 000 seeds per tree, although some aspects of the methodology used to produce this estimate are unclear (Ducatillion *et al.*, 2015). Experiments on seed germination conditions in an invasive population in France showed a seed viability rate of 100% (Diadema *et al.*, 2017). 5 ° C, 20 ° C and 25 ° C in the dark, no seeds germinated. In contrast, at 10 ° C and 15 ° C in the dark, and alternately at 10 ° C and 20 ° C alternately dark / light, 100% of the seeds germinated after 35 days of testing (Diadema *et al.*, 2017). Also, the first inventories following post eradication in France show that seedlings in invaded soils appear some weeks after management, but strongly decreased the year after (Diadema *et al., 2017*; K. Diadema, pers. comm. 2018).

An unexplained phenomenon currently happening in France is young plants (generally less than 10 years old) naturally dying, allowing the fruits to open and release seeds. Therefore, propagation is not reliant on fire, as is frequently observed elsewhere. Although the death of young plants releases fewer seeds than the death of older plants, the process is still leading to population expansion at this site. During management programs, cutting of the plants must be realized just above the ground, in order not to leave axillary buds, from which cut plants could regenerate (K. Diadema, pers. comm., 2017). Once branches are cut, fruits may release seeds between 48 and 145 hours (Diadema *et al.*, 2017).

Habitat and environmental requirements

In its native range, *H. sericea* "is a widespread species in [the] dry sclerophyll forests and heaths of south-eastern Australia" (Brown & Whelan, 1999). The heathlands of south-eastern Australia, including the Hawkesbury area in which *H. sericea* was studied by Brown & Whelan (1999), are described by Specht (1994) as having a warm temperate climate. According to Australian native plant gardening advice, *H. sericea* also has "good drought resistance", although "very restricted watering or heavy soil" may lead to stunting (ANBG, 2017). Other gardening sources also report that the plant is resistant to drought and frost to -7 °C when established (Moore, 2004). In terms of natural regeneration and establishment in the wild, the expert-vetted species occurrence data used in this PRA (Appendix 1) indicate that the average minimum temperature of the coldest month experienced by populations of the species is -1.8 degrees Celsius (D. Chapman, CEH Edinburgh, UK, pers. comm., 2017).

The native range mapped by Barker (1996) corresponds mainly to the Köppen-Geiger climate zone Cfb (warm temperate, fully humid, warm summer), with a small overlap with Cfa, *i.e.* the same, but with a 'hot' rather than warm summer (Kottek *et al.*, 2006). The Hawkesbury area is characterised by nutrient-deficient sandstone soils, typical of those on which heathland plant communities are found (Specht, 1994). *Hakea sericea*, like other Proteaceae, is well adapted to the acidic, highly weathered, soils of such areas (Lambers *et al.*, 2008). Richardson (1984) also found quartzite and sandstone substrates to be correlated with the occurrence of *Hakea* spp. in South Africa. In its European invaded range, Martins *et al.* (2016) showed that, at a gridded 1 km × 1 km scale, schist was an important predictor of the distribution of *H. sericea*; it was not important at the larger scale of a 10 km × 10 km regional grid. In general, in its European invaded range, disturbed areas (particularly road margins), forest margins, coastal grasslands and pine forest are all highlighted as additional habitats (Fried, 2010; EPPO, 2012; Marchante *et al.*, 2014). See also Appendix 1.

Both its 'proteoid' cluster roots for extracting mineral P from ancient soils (Lambers *et al.*, 2008), and the high absolute P content of its large seeds (Mitchell & Allsopp, 1984; Kitajima & Fenner, 2000), allow the species to establish and thrive on soils with very low P availability. Mitchell & Allsopp (1984) also suggest that the high P content of its seeds gave *H. sericea* a competitive advantage over native Proteaceae in its South African invaded range.

In South Africa, *H. sericea* is reported as primarily "a problem in the sclerophyll vegetation type known as mountain 'fynbos'" (Kluge & Neser, 1991). Kluge & Neser (1991) also state that "[t]here are various characteristics of the local habitat which enhance the invasiveness of *H. sericea* [in South Africa]". These include the virtual absence of competition from native tree species (Macdonald and Richardson, 1986), the frequent occurrence of fire which is an important natural phenomenon in the Cape region (Kruger and Bigalke, 1984) […] various kinds of disturbance by man (e.g. altered fire regimes) (Macdonald, 1984) and the lack of specialized natural enemies of the plant (Neser, 1968)."

Fire is a key part of the life cycle of *H. sericea*, with the heat-resistant fruits accumulating on a plant throughout its lifetime. The plant itself is "absolutely fire sensitive" (Morrison & Renwick, 2000). However, after plant death, typically through fire, the fruits release their seeds (Kluge & Neser, 1991). The strategy of storing seeds in the canopy in fire-resistant woody fruits is not unusual in fire-prone ecosystems (Cowling *et al.*, 1987), and has been referred to as 'serotiny' (Lamont *et al.*, 1991) or 'bradyspory' (Whelan, 1995). The strategy has been viewed as an adaptation to fire by some authors (Bradstock *et al.*, 1994), although it is found in many parts of the world, and is not always associated with fire (Bond & van Wilgen, 1996). Fire frequency, seasonality and intensity are all important for the natural regeneration of *H. sericea* (*e.g.* Brown & Whelan, 1999); for example, frequent fires may kill seedlings after the initial stimulation of seed release and germination. Fire dynamics are therefore important determinants of community composition in any ecosystem which is burnt at a frequency that regularly influences the regeneration cycles of any of its constituent species (Bond & van Wilgen, 1996). For example, Brown & Whelan (1999), studying *H. sericea* in its native Australia in the context of fire seasonality and community diversity, found that fire too early in the fruit ripening process could reduce the supply of viable seeds, due to the unripe fruits still containing enough moisture to make heating lethal to young tissue. The EWG also notes that, reciprocally, community composition itself can influence fire dynamics (Mandle *et al.*, 2011). *Hakea sericea* has been identified as influencing fire regimes both positively and negatively (Mandle *et al.*, 2011), increasing fuel loads and intensity, but decreasing spread and frequency (van Wilgen & Richardson, 1985; Holmes *et al.*, 2000; van Wilgen *et al.*, 2007). In France, the legal requirement for brush cutting as a measure of fire protection, helps the spread of *H. sericea* (K. Diadema, pers. comm. 2018).

Identification

Hakea sericea is an erect, single-stemmed, woody shrub or small tree, 0.6-4.5 m in height, with somewhat angular stems. It has simple, needle-like leaves, which are terete (*i.e.* circular in cross section), spiny, and moderately appressed silky-hairy when young, but quickly becoming glabrous; these leaves are (1.3)2-4.3-(5.3) cm long and 0.7-1(1.1) mm wide, with a longitudinal groove on the lower side (Barker, 1996). The inflorescence is an axillary umbel, consisting of (1)4-5(6) cream-coloured flowers, each with a moderately to densely white-hairy pedicel (2.2-5.0 mm long). One to two woody follicles or fruits, sometimes also referred to as capsules, are formed in each axil; the fruits are (2)2.5-3(4) cm long and 2-2.5 cm in diameter (Barker, 1996; Kluge & Neser, 1991). The seeds are elliptic to obovate-elliptic, (16)19-25(31) mm long, (6)7-10(11.5) mm wide, each with a wing, either completely encircling the seed (although of unequal width on each side) or along one side only (Barker, 1996).

Hakea sericea can be distinguished from the other main *Hakea* species naturalised outside of Australia (*i.e. H. gibbosa*, *H. drupacea* and *H. salicifolia*) according to the following key, adapted from the Flora of Webb *et al.* (1988) of the non-native plants of New Zealand. In Australia, 149 species (all endemic) are currently recognised by *Hakea* experts; see Barker *et al.* (1999) for guidance on distinguishing these. Also note that, in some cases, the genus *Hakea* may be hard to distinguish from some morphologically similar *Grevillea* species (Barker, 2010).

1 Lvs flattened, not spiny…………………………………………………………...**salicifolia**
Lvs terete and spiny…...……………………………………………………………………2

2 Lvs downy at maturity; fruits *c.* 4 cm long………………………………..……………**gibbosa**
Lvs glabrous or almost glabrous at maturity; fruits 2-3 cm long……………………………...3

3 Lvs always simple; pedicels ± hairy; stigma oblique or lateral…………………………..…**sericea**
Lvs simple or pinnate with 2-7 terete pinnae (different forms on one plant); pedicels glabrous; stigma erect……………………………………………………………....................**drupacea**

It is also noted here that the species *H. decurrens* R.Br., peripatric with *H. sericea* in its native range (Barker, 1996), can be easily confused with *H. sericea* (Q-bank, 2017). According to the key of Barker (1996), the length of the pistil (< 9mm = *H. sericea*; > 9 mm = *H. decurrens*) is the main diagnostic feature.

William Barker (1996, p. 198) states that the material of *Hakea* seen by him from Europe is *H. decurrens*, going on to note that "the published records of *H. sericea* from southern Europe (*e.g.* Ball, 1964) may also be that species". The reference to Ball (1964) refers to the species entry in *Flora Europaea Vol 1.* (1st ed.), where it is stated that *H. sericea* is "[p]lanted for reclamation of arid land in Spain and Portugal, and locally naturalized". Indeed, under his entry for *H. decurrens* ssp. *physocarpa*, Baker (1996) lists a specimen in **BR** (the National Botanic Garden of Belgium), giving the following details "E. Orey, D. Pereina & Reis 56, 15.xi.1966, Lusitania. Reg. Estremadura, Estrada da Pimanceira, proximo de e Mafra". The situation remains to be clarified: Paiva (1997) does not list *H. decurrens* for Portugal, and the Plant List currently considers *H. decurrens* to be a synonym of *H. sericea* (Plant List, 2017). Robyn Barker (2010) however, on her webpage for *H. decurrens*[4], gives the name *H. sericea auct. non* Schrad. & J.C.Wendl. in the section on synonymy for that species, indicating that specimens, now referable to *H. decurrens*, have been subsumed within *H. sericea* by some taxonomists (but not explicitly by Schrader and Wendland, whose taxonomic concept is considered to circumscribe the 'true' *H. sericea* and exclude *H. decurrens*).

Given the fact that there is genetic evidence that South African populations of *H. sericea* may have originated from two separate source populations (Dyer & Richardson, 1992), and that biocontrol programs for *H. sericea* have previously been complicated by confusion between *H. sericea* and *H. decurrens* in their native ranges (Kluge & Neser, 1991; Hosking *et al.*, 2000; Barker, 2010), the possibility that Portugal (and/or Spain) harbours additional species (*sensu* Barker 1996 and Barker 2010) should be investigated.

Symptoms

Dense thickets of *H. sericea* are not unusual in the species' invaded range, with van Wilgen & Richardson (1985) estimating densities of 8,900 plants ha^{-1} at one study site. The effects of such invasions on the local environment are complex, and they may not always alter fire regimes (van Wilgen & Richardson, 1985). However, van Wilgen & Richardson (1985) also considered that an increased fire risk was likely under certain circumstances, for example, when extreme (*i.e.* hot, dry) weather might allow for the ignition of *H. sericea* canopies, resulting in more intense fires than those seen in native vegetation (although van Wilgen & Richardson [1985] note that "this cannot be simulated as the processes governing fire behaviour in such stands are not clearly understood").

---

[4] http://www.flora.sa.gov.au/efsa/lucid/Hakea/key/Australian%20Hakea%20species/Media/Html/Hakea_decurrens_ssp._decurrens.htm

Van Wilgen & Richardson (1985) also note the low cover of native *Protea* L. shrub species within stands of *Hakea*. Fugler (1982) states that “dense thickets of *Hakea* suppress the natural vegetation, make access difficult or impossible, increase fire risk and are suspected of adversely reducing water run-off”. Richardson *et al.* (1989) reviewed existing data, and recorded new quadrats in invaded and uninvaded fynbos, including five *H. sericea* sites, demonstrating lower native plant diversity in invaded stands on average (although the statistical analysis also included sites invaded by *Acacia saligna* (Labill.) Wendl., *Acacia melanoxylon* R.Br., *Pinus pinaster* Aiton and *Pinus radiata* D.Don).The lower cover and richness of native species after the burning of sites invaded by *Hakea*, contrasted with burnt uninvaded sites, also implies impacts of *H. sericea* on native plant communities (Richardson & van Wilgen, 1986). Breytenbach (1986) also cites unpublished survey data regarding the impacts of *H. sericea* on native fynbos species, ascribing these to changes in light regimes in invaded stands. Given the similar structure and size of *H. sericea* and many native Proteaceae shrubs in South Africa, it is perhaps not surprising that dense stands of *Hakea* shrubs tend to exclude native species, although we note that much of the existing evidence in the literature is indirect. This may be due, at least in part, to the difficulty of access associated with stands of the plant, and the challenges associated with experimental work in this area. The fact that *H. sericea* invasions may be associated with human-mediated disturbance may be another reason why impacts on native species are sometimes ambiguous.

Breytenbach (1986) reports impacts of low density *H. sericea* populations on native *Protea* species, report reduced leaf durations in *Protea lorifolia* Fourc. and *Leucadendron salignum* R.Br. along increasing gradients of *Hakea* cover; changes in leaf duration may also influence soil nutrient dynamics (Breytenbach, 1986). Breytenbach (1986) speculates that this may be due to increased competition for water in invaded communities. Breytenbach (1986) also reviews the impacts of *H. sericea* on non-plant taxon groups, and this work is cited in van Wilgen *et al.* (2000) as the main evidence for statements on this topic. Some evidence was found for impacts of *Hakea* on small mammal communities (Breytenbach *et al.*, 1984, cited in Breytenbach, 1986), with herbivores (one to three species of *Otomys* F. Cuvier, 1824; African vlei rats) being reduced relative to uninvaded stands. Breytenbach (1986) also reports unpublished observations of impacts on bird communities, with some insectivores (such as the spotted prinia, *Prinia maculosa* (Boddaert, 1783)) increasing in invaded sites, and specialist nectarivores (e.g. the Cape sugarbird, *Promerops cafer* (Linnaeus, 1758)) decreasing.

Statements concerning the impacts of *H. sericea* on water availability are also regularly encountered (*e.g.* van Wilgen *et al.*, 1996; Richardson & van Wilgen, 2004), although these mostly appear to be reliant on indirect links between alien plants, wildfire, soil erosion and the resulting hydrological impacts (*e.g.* Scott, 1993; Scott & van Wyk, 1990), rather than studies on stands of *H. sericea per se* (van Wilgen *et al.*, 1996). The work of Breytenbach (1989) demonstrated links between increased fire intensity and soil runoff for *H. sericea*, although this was specifically in the context of a particular management technique for control (cutting the plant, and then subsequently burning the stacked stems in order to kill off the next generation of seedlings), rather than an impact of *H. sericea* in itself. This study, relating as it does to a specific management action, appears to be the main evidence for an impact of *H. sericea* on hydrological processes (*e.g.* van Wilgen *et al.*, 2000).

Elsewhere in its non-native range, Marchante *et al.* (2014) list the following impacts for Portugal: “forms dense and impenetrable thickets preventing the development of native vegetation, affecting wildlife, reducing the amount of water available and increasing the probability of fire occurrence”.

Existing PRAs

Australia: A weed risk assessment tool designed for botanic gardens was tested by Virtue *et al.* (2008) on a range of plant species, including *H. sericea*. Although the plant is native in

Australia, the exercise was intended to highlight where plants that are at risk of naturalising outside of their native range within Australia. Botanic garden workers who responded to this survey classified *H. sericea* as a “low risk weed” on average; this contrasted with a literature review rating of “high risk weed”, as compiled by Virtue *et al.* (2008). The literature review rating assessed information for both the native and invaded range.

Europe: *Hakea sericea* was evaluated through the EPPO prioritisation scheme in 2010, and was considered to be a high priority for a PRA. The species has been on the EPPO “List of Alien Invasive Plants” since 2012; prior to that it was on the EPPO “Alert List” from 2007. The current PRA is being conducted under the LIFE project (LIFE15 PRE FR 001) within the context of European Union regulation 1143/2014, which requires that a list of invasive alien species (IAS) be drawn up to support future early warning systems, control and eradication of IAS.

France: Using the protocol of Weber & Gut (2004), *H. sericea* scored 36 out of 39 highlighting a high risk to the Mediterranean biogeographical region of France (Terrin *et al.*, 2014). In addition, Fried (2010) scored the species 30 out of 39 using the same protocol, again, highlighting a high risk to the Mediterranean biogeographical region of France.

Portugal: Morais *et al.* (2017) used a version of the Australian Weed Risk Assessment (A-WRA) adapted for Portugal (P-WRA) to assess the risk from a number of invasive alien plants. *Hakea sericea* scored a relatively high score of 21, resulting in a “reject” decision from both the A-WRA and P-WRA methodologies.

South Africa: Tucker & Richardson (1995) developed an expert screening tool for assessing invasion potential in South African fynbos, and classified *H. sericea* within their highest risk category using this tool (although the tool was developed with the aim of separating low- and high-risk invaders, rather than for ranking; Tucker & Richardson, 1995).

USA: The USDA and APHIS performed a Weed Risk Assessment (WRA) in 2013, using the Plant Protection and Quarantine WRA method (Koop *et al.*, 2012). This resulted in an assessment of High Risk, with strong confidence in the outcome based on an associated uncertainty simulation (USDA-APHIS, 2013). Parker *et al.* (2007) ranked *H. sericea* in the top ten species out of250 assessed for potential future invasiveness in the USA using their own novel methodology; in addition, Brusati *et al.* (2014) identified *H. sericea* as a potential future invasive in California, recommending a full WRA and/or “[s]pecific guidelines or recommendations” for dealing with the species.

Socio-economic benefits

The species has been used for a range of purposes, including ornament and hedging (including use as a windbreak; Marchante *et al.*, 2014). Henderson (2001) lists shelter, shade and ornament as its main uses. Reva *et al.* (2010) reviewed the possibility of promoting its use as biofuel, partly as means of control, in Portugal. Huryn & Moller (1995) report that the plant is used by honey bees (*Apis mellifera* Linnaeus, 1758) for both nectar and pollen in New Zealand. Use for honey production is also noted by Vieira (2002) for Madeira.

There is little information on the value of the species in trade within the EPPO region. The UK Royal Horticulture Society list only one supplier (https://www.rhs.org.uk/Plants/Nurseries-Search-Result?query=125445). The species is also available from five suppliers via the German PPP Index http://www.ppp-index.de/. A further internet search did not detail any additional suppliers within the EU.

3. Is the pest a vector? **Yes** ☐ **No** X

4. Is a vector needed for pest entry or spread? **Yes** ☐ **No** X

5. Regulatory status of the pest

Israel: The species is considered to be a potential future risk to Israel, and is included in a recent list of “Israel's Least Wanted Alien Ornamental Plant Species”. Although this “black list” does not currently appear to have any legislative basis, it is being used by the Israel Ministry of Environmental Protection to advise planners on non-native species to avoid in planting schemes (Dufour-Dror, 2013).

New Zealand: The species has been included on many weed lists in New Zealand (Howell, 2008), including the “consolidated list” of Howell (2008). It should be noted, however, the consolidated list itself does not have regulatory status.

Portugal: In 1999 legislation (Decreto-Lei 565/99) was passed to address the issue of invasive alien species. Associated with the legislation is a list of invasive alien species. *H. sericea* was included in this list, meaning that cultivation, use as an ornamental plant, release, sale, exchange and transport are all prohibited.

South Africa: Control of the species was enabled by the Conservation of Agricultural Resources (CARA) Act 43 of 1983, as amended, in conjunction with the National Environmental Management: Biodiversity (NEMBA) Act 10 of 2004. *Hakea sericea* was specifically defined as a Category 1b “invader species” on the NEMBA mandated list of 2014 (Government of the Republic of South Africa, 2014). Category 1b means that the invasive species “must be controlled and wherever possible, removed and destroyed. Any form of trade or planting is strictly prohibited” (www.environment.gov.za).

Spain: *Hakea sericea* is included in the Annex II list of the Real Decreto (Royal Decree) 1168/2011. This is a list of potentially invasive species. Inclusion on this list means, among other things, that the introduction of the species listed is prohibited, and that necessary measures should be taken for management, control and eradication (translated and abridged from Article 8 of Real Decreto 1168/2011).

France: Although there is no national regulation covering *H. sericea* specifically, at the department-level, individual applications have been made for control orders against this species (Arrêtés préfectoraux n°2016-767 and n°2017-607 Maritime Alps department. *Hakea sericea* is also included on the invasive plant list in the Provence-Alpes-Côte d’Azur regional strategy for (Terrin *et al.*, 2014).

6. Distribution

Continent	***Distribution** (list countries, or provide a general indication , e.g. present in West Africa)*	***Provide comments on the pest status in the different countries where it occurs** (e.g. widespread, native, non-native, established….)*	***Reference***
Africa	Angola, South Africa	Introduced, widespread and invasive in South Africa. Current status unknown in Angola.	Shaughnessy (1986); Instituto de Investigação Científica Tropical (2008-2017a,b)
America	North America	Present as an ornamental, but not naturalised	USDA-APHIS (2013); Brusati *et al.*(2014)
Asia	Absent	-	-
Europe	France, Portugal Biogeographical region: Atlantic, Mediterranean Spain Biogeographical region: Atlantic, Mediterranean Madeira Biogeographical region: Macaronesia	Invasive Only invasive in Galicia Introduce and planted	Sañudo (2006); Romero Buján (2007); Freitas *et al.* (2008); Fried (2010); Terrin *et al.* (2014); EPPO (2015); Xunta de Galicia (n.d.) Press & Short (1994); Vieira (2002)
Oceania	Australia (New South Wales, Queensland) Australia (Victoria, Norfolk Island, Tasmania) New Zealand	Native Naturalised Introduced and invasive	Beever (1988); Barker (1996); Owen (1996); Cameron (1994)

Introduction

Hakea sericea is native to south-eastern Australia. Specifically, it is found in south-eastern Queensland (Mt Barney, Mt Maroon and Mt Mee) and south-eastern New South Wales, with non-native occurrences in South Africa, New Zealand and south-west Europe (Barker, 1996; CABI, 2017).

Africa

In South Africa, *Hakea sericea* was first recorded in 1858 (Shaughnessy, 1986). Dense stands now occur in the Western and Eastern Cape Provinces (Richardson et al., 1987). CABI (2017), details '[f]ollowing its introduction into South Africa the plant became naturalized in nearly all the major coastal mountain ranges of the Western and Eastern Cape Provinces. Some farmers in the Bathurst district, Eastern Cape, recognized the plant as a potential threat as early as 1863. By 1925 the Knysna Farmers Union, Western Cape, requested that *H. sericea* be declared a noxious weed as it was invading valuable pasture land (Phillips, 1938)'. The species has also been collected from Angola, although the current status is not known (Instituto de Investigação Científica Tropical, 2008-2017a,b).

Europe

In Europe, *H. sericea* has been cultivated as a hedge plant in Portugal (including Madeira) since the 1930s (Espírito Santo and Arsénio, 1999). Early records exist for the introduction of the species into European botanical gardens, for example according to Hortus Kewenis *H. sericea* was introduced in the UK around 1790. In addition, *Hakea sericea* is listed in the volume "Hortus Nympheburgensis" dated 1821, in the catalog for the Royal Botanic Garden of Glasgow (1825),

The species has been known to have naturalised in the environment since 1940 and has since become highly invasive in some areas (Espírito Santo and Arsénio, 1999) Marchante *et al.*, 2014; Martins *et al.*, 2016). In Spain, *H. sericea* is known only from Galicia (Sañudo, 2006; Xunta de Galicia, n.d.). In France, *H. sericea* is present in the south east of the country (Provence-Alpes-Cote d'Azur; EPPO, 2015) in the Esterel Mountains, both in the Var and the Maritime Alps departments (SILENE-Flore, 2017; Fried, 2010). Fried (2010) states that it is naturalised in France and Terrin et al. (2014) states that is invasive species. It is reported to have been first recorded in France in 1917[5] in Saint-Raphaël (Invmed, 2017).

Oceania

Hakea sericea is native to south-eastern Australia (Barker, 1996). *Hakea sericea* is recorded in New Zealand as a non-native species which invades native plant communities (*Leptospermum* and gumland communities (Beever, 1988)).

---

[5] http://www.invmed.fr

7. Habitats and where they occur in the PRA area

Habitat (main)	**EUNIS habitat types**	**Status of habitat (e.g. threatened or protected)**	**Is the pest present in the habitat in the PRA area**	**Comments (e.g.** ***major/minor habitats*** **in the PRA area)**	***Reference***
G. Woodlands	G.2. Broadleaved evergreen woodland G.3 Coniferous woodland	European Red List: G2.7. Macaronesian heathy woodland	Yes	Major	Fried, 2010; Marchante *et al.* (2014)
E. Grasslands	E1. Dry grasslands E7. Sparsely wooded grasslands	European Red List: E1.3.Mediterranean xeric grassland Habitats Directive Annex 1: 6220 Pseudo-steppe with grasses and annuals	Yes	Major	EWG opinion; Marchante *et al.*(2014)
X. Habitat complexes	X13.Land sparsely wooded with broadleaved deciduous trees X14.Land sparsely wooded with broadleaved evergreen trees X15. Land sparsely wooded with coniferous trees X18. Wooded steppe X35. Inland sand dunes	-	Yes	Major	EWG opinion; Marchante *et al.*(2014)
F. Heathland, scrub and Tundra	F.3. Temperate and Mediterranean-montane scrub F4. Heathland, Scrub and Tundra F5. Maquis, arborescent matorral and thermo-Mediterranean brushes F6. Garrigue F7. Spiny Mediterranean heaths F8. Thermo-Atlantic xerophytic scrub F.9. Riverine and fen scrubs	European Red List: F4.1. Wet heath F5.5.Thermo-Mediterranean scrub F8.1. Canary Island xerophytic scrub F8.2.Madeiran xerophytic scrub Habitats Directive Annex 1: 4030 European dry heaths 5330 Thermo-Mediterranean and pre-desert scrub	Yes	Major	EWG opinion; Espírito Santo and Arsénio (1999)

In its introduced European range, *H. sericea* is present in disturbed areas (particularly road margins and railway cuttings); forest margins, coastal grasslands and pine forest are all highlighted as additional habitats (Fried, 2010; EPPO, 2012; Marchante *et al.*, 2014). Martins *et al.* (2016) showed that, at a gridded 1 km × 1 km scale, schist was an important predictor of the distribution of *H. sericea*; it was not important at the larger scale of a 10 km × 10 km regional grid. See also Appendix 1.

8. Pathways for entry

Possible pathway *(in order of importance)*	**Pathway:** Plants for planting **(CBD terminology: Escape from confinement)**
Short description explaining why it is considered as a pathway	The plant is known to be used as an ornamental and hedging species, and therefore could be imported as seeds or plants for this purpose (Marchante *et al.*, 2014; Henderson, 2001). The plant is available via mail order from Australia to worldwide destinations. For example: http://www.ebay.com/itm/HAKEA-SERICEA-pink-Silky-Hakea-10-seeds-/232260977095?hash=item3613d541c7:g:~XUAAOSw9NdXt7gD
Is the pathway prohibited in the PRA area?	Yes in part. In Portugal, the species is banned from sale as an ornamental species. The species is also prohibited in Spain (Real Decreto (Royal Decree) 1168/2011)
Has the pest already intercepted on the pathway?	Yes, the species has entered the PRA area as an ornamental species and is available from one supplier in the UK (https://www.rhs.org.uk/Plants/Nurseries-Search-Result?query=125445. Five suppliers list the species on the German PPP Index website http://www.ppp-index.de
What is the most likely stage associated with the pathway?	Seeds are the most likely stage to be associated with the pathway.
What are the important factors for association with the pathway?	The plant is available via mail order from Australia to worldwide destinations. For example: http://www.ebay.com/itm/HAKEA-SERICEA-pink-Silky-Hakea-10-seeds-/232260977095?hash=item3613d541c7:g:~XUAAOSw9NdXt7gD. Note that for Britain and Ireland a Royal Horticultural Society publication considers that specimens for horticulture labelled as *H. sericea* are typically *H. lissosperma*R.Br. (Cubey, 2016).
Is the pest likely to survive transport and storage along this pathway?	Yes, particularly for pathways associated with planting for ornamental purposes.
Can the pest transfer from this pathway to a suitable habitat?	Yes, seeds are dispersed by wind and water into new areas beyond where it is planted away from mother plants.
Will the volume of movement along the pathway support entry?	There is no strong evidence that the species is commonly imported into the EPPO region for horticultural purposes. Only one supplier has been identified from the UK. Therefore, it is unlikely that the volume of movement along this pathway will support entry.
Will the frequency of	There is no strong evidence that the species is commonly

movement along the pathway support entry?	imported into the EPPO region for horticultural purposes. Therefore, it is unlikely that the frequency of movement along this pathway will support entry.
Rating of the likelihood of entry	*Low* X *Moderate*☐ *High*☐
Rating of uncertainty	*Low*☐ *Moderate* X *High*☐

All European biogeographical regions will have the same likelihood of entry and uncertainty scores.

9. Likelihood of establishment in the natural environment in the PRA area

The species is already established in the PRA area, with large populations in Portugal spread over a large area (Martins *et al.*, 2016), and smaller, more localised, populations in France and Spain (Sañudo, 2006; Fried, 2010). In its European invaded range, recorded habitats include disturbed areas (particularly road margins), forest margins, coastal grasslands and pine forest (Fried, 2010; EPPO, 2012; Marchante *et al.*, 2014). The likelihood of further establishment in similar habitats within suitable areas (Appendix 1) is considered to be high.

The species has a degree of shade tolerance and is able to establish under tree canopies although it does not normally reach high densities in these habitat types (EWG, pers. comm., 2017). However, it should be noted that in France the species shows no degree of shade tolerance and seedlings only occur in open habitat (pers. comm. K Diadema, 2018).

Hakea sericea exhibits drought resistance, although very restricted watering or heavy soil may lead to stunting (ANBG, 2017), and the plant is resistant to frost to -7 degrees Celsius when established (Moore, 2004). In terms of natural regeneration and establishment in the wild, the expert-vetted species occurrence data used in this PRA (Appendix 1) indicate that the average minimum temperature of the coldest month experienced by populations of the species is -1.8 degrees Celsius (D. Chapman, CEH Edinburgh, UK, pers. comm., 2017).All individuals died in Esterel arboretums in France during the 1985 freeze that recorded temperatures of -12°C (Allemand, 1989) with more than 10 days with a negative minimum but average minimum temperature of the coldest month around 0°C.

Both its ‘proteoid’ cluster roots for extracting mineral P from ancient soils (Lambers *et al.*, 2008), and the high absolute P content of its large seeds (Mitchell & Allsopp, 1984; Kitajima & Fenner, 2000), allow the species to establish and thrive on soils with very low P availability, these soils are also often low pH. Establishment on low nutrient soils through the PRA area is therefore highly likely, as demonstrated by its current populations in Europe (Fried, 2017; Martins *et al.*, 2016). Mitchell & Allsopp (1984) also suggest that the high P content of its seeds gives *H. sericea* a competitive advantage over native Proteaceae in its South African invaded range. Martins *et al.* (2016) showed that, at a 1 km^{2}scale, schist was an important predictor of the distribution of *H. sericea*. Where the species in established in France, only in the Esterel mountains, the underlying geology is also siliceous (A. Albert, pers. comm., 2017).

Fire is a key part of the life cycle of *H. sericea*, with the heat-resistant fruits accumulating on a plant throughout its lifetime (a canopy seed bank). The plant itself is “absolutely fire sensitive” (Morrison & Renwick, 2000), however, after plant death, typically through fire, the fruits release their seeds (Kluge & Neser, 1991). Fire is an important ecological driver in many habitats, including in the Mediterranean.

As the species is currently established in Portugal, Spain and France, and the likelihood of further establishment in similar habitats within suitable areas (Appendix 1) is considered to be high, a high rating of likelihood of establishment is given, with a low rating of uncertainty.

Rating of the likelihood of establishment in the natural environment	*Low*☐	*Moderate*☐	*High* **X**
Rating of uncertainty	*Low* **X**	*Moderate*☐	*High*☐

10. Likelihood of establishment in managed environment in the PRA area

The species is already established in managed habitats in the PRA area; for example, roadsides are given as a main habitat in Portugal by Marchante *et al.* (2014). The likelihood of further establishment in similar habitats (see section **7** above and Appendix 1) is also therefore high.

Rating of the likelihood of establishment in the managed environment	*Low*☐	*Moderate*☐	*High* X
Rating of uncertainty	*Low* X	*Moderate*☐	*High*☐

11.Spread in the PRA area

Natural spread

In its introduced European range, *H. sericea* is present in disturbed areas (particularly road margins and railway cuttings); forest margins, coastal grasslands and pine forest (see section for further information). Seed release from open fruit is normally linked to the death of the plant through fire, although death from other causes is possible. Following this, dispersal of winged seed is primarily by wind (Richardson *et al.*, 1987), although local spread from seed fall and the force generated by fruit splitting (expulsion) is also important (E. Marchante, pers. comm., 2017). The rate of spread of *H. sericea* has been dramatic in the south-western region of the Western Cape province, with estimates of the area invaded increasing from 9000 ha to 360,000 ha between 1939 and 1983; increases in the area estimates of *Hakea* in other South African provinces were also large (Kluge & Neser, 1991).

Hakea sericea seed has been shown to spread up to 31 m in an arboretum (Ducatillion *et al.*, 2015). However, because of the winged seed, dispersal distances can be on the order of one kilometre or more (Richardson *et al.*, 1987; Le Maitre *et al.*, 2008).

In terms of specific numbers, a total above-ground biomass of 12 kg of *H. sericea* indicates around 2.9 kg of follicles and seeds, at least according to the samples and fitted model of Richardson *et al.* (1987). This equates to just over 800 fruits, where a fruit typically contains two seeds (Richardson *et al.*, 1987; Barker, 1996). A large shrub could therefore store over 1600 seeds in its canopy, although 100-200 may be a more typical figure, at least in its native range (Brown & Whelan, 1999). Note also that Ducatillion *et al.* (2015) estimated 52 000 seeds per plant at a site in France, although aspects of the methodology used to make this estimate are ambiguous.

The number (8874) and density (1.6 m^{-2}) of seedlings reported by Beever (1988) to have been hand-weeded over three years at an invaded site in New Zealand, supports the view of a species that is able to quickly dominate local areas through the high production of viable seed. In South Africa, Kluge (1983) found seed densities of up to 7500 seeds m^{-2} in the ash bed following a fire. In France, one year after management of the species a seedling density of up to 51 m^{-2} was recorded, with an average of 19 seedlings m^{-2} in the most invaded site (Diadema *et al.*, 2017).

Human-assisted spread

Human-assisted spread has played a role in the spread of the species within the PRA area, and further use for ornamental, windbreak or honey-producing services is likely (Marchante *et al.*, 2014; Vieira, 2002).

Disposal of fruit-bearing brash (woody debris) after hedge cutting is also likely to contribute to the spread of the species given that the woody fruits open on the death of the supporting branch.

Based on the detailed information on the spread of the species in the PRA area and the potential for further spread a high rating of spread has been given with a low uncertainty.

There is little historical evidence that this plant was actively dispersed by humans in South Africa, and its widespread distribution, often in remote locations (JJ Le Roux, pers. obs.), has therefore been attributed to its own ability to spread and establish in suitable habitats

(Shaughnessy, 1986). In France, legal requirement for brush cutting in the context of fire protection contributes to the spread of the species (K. Diadema, pers. comm. 2018).

Rating of the magnitude of spread in the PRA area	*Low*☐	*Moderate*☐	*High* X
Rating of uncertainty	*Low* X	*Moderate*☐	*High*☐

12. Impact in the current area of distribution

12.01 Impacts on biodiversity

In South Africa, dense *H. sericea* infestations threaten the biodiversity of the Cape Floral Kingdom, which is one of the six Floral Kingdoms of the world (Goldblatt, 1997). Dense stands of *H. sericea* have brought about significant reductions in species richness in the unique and floristically rich mountain fynbos of the Western and Eastern Cape provinces of South Africa (Richardson *et al.*, 1989). The relevant 'Symptoms' described in section **2** above are repeated here for reference: Dense thickets of *H. sericea* are not unusual in the species' invaded range, with van Wilgen & Richardson (1985) estimating densities of 8,900 plants ha^{-1} at one study site. The effects of such invasions on the local environment are complex, and they may not always alter fire regimes (van Wilgen & Richardson, 1985). However, van Wilgen & Richardson (1985) also considered that an increased fire risk was likely under certain circumstances, for example, when extreme (*i.e.* hot, dry) weather might allow for the ignition of *H. sericea* canopies, resulting in more intense fires than those seen in native vegetation.

Van Wilgen & Richardson (1985) note the low cover of native *Protea* L. shrub species within stands of *Hakea*. Fugler (1982) states that "dense thickets of *Hakea* suppress the natural vegetation, make access difficult or impossible, increase fire risk and are suspected of adversely reducing water run-off". Richardson *et al.* (1989) reviewed existing data, and recorded new quadrats in invaded and uninvaded fynbos, including five *H. sericea* sites, demonstrating lower native plant diversity in invaded stands on average (although the statistical analysis also included sites invaded by *Acacia saligna* (Labill.) Wendl., *Acacia melanoxylon* R.Br., *Pinus pinaster* Aiton and *Pinus radiata* D.Don). The lower cover and richness of native species after the burning of sites invaded by *Hakea*, contrasted with burnt uninvaded sites, also implies impacts of *H. sericea* on native plant communities (Richardson & van Wilgen, 1986). Breytenbach (1986) also cites unpublished survey data regarding the impacts of *H. sericea* on native fynbos species, ascribing these to changes in light regimes in invaded stands. Given the similar structure and size of *H. sericea* and many native Proteaceae shrubs in South Africa, it is perhaps not surprising that dense stands of *Hakea* shrubs tend to exclude native species, although we note that much of the existing evidence in the literature is indirect. This may be due, at least in part, to the difficulty of access associated with stands of the plant, and the challenges associated with experimental work in this area.

Breytenbach (1986) reports impacts of low density *H. sericea* populations on native *Protea* species, reporting reduced leaf durations in *Protea lorifolia* Fourc.and *Leucadendron salignum* R.Br. along gradients of increasing *Hakea* cover; changes in leaf duration may also influence soil nutrient dynamics (Breytenbach, 1986). Breytenbach (1986) speculates that this may be due to increased competition for water in invaded communities. Breytenbach (1986) also reviews the impacts of *H. sericea* on non-plant taxon groups, and this work is cited in van Wilgen *et al.* (2000) as the main evidence for statements on this topic. Some evidence was found for impacts of *Hakea* on small mammal communities (Breytenbach *et al.*, 1984, cited in Breytenbach, 1986), with herbivores (one to three species of *Otomys* F. Cuvier, 1824; African vlei rats) being reduced relative to uninvaded stands. Breytenbach (1986) also reports unpublished observations of impacts on bird communities, with some insectivores (such as the spotted prinia, *Prinia maculosa* (Boddaert, 1783)) increasing in invaded sites, and specialist nectarivores (e.g. the Cape sugarbird, *Promerops cafer* (Linnaeus, 1758)) decreasing.

Rating of magnitude of impact on biodiversity in the current area of distribution	*Low*☐	*Moderate*☐	*High* X
Rating of uncertainty	*Low* X	*Moderate*☐	*High*☐

12.02. Impact on ecosystem services

Hakea sericea is an invader of the floristically rich and unique mountain fynbos in the Western Cape Province, South Africa. Infestations become so dense they alter the composition of plant and animal communities (Macdonald & Richardson, 1986). Thickets of *H. sericea* also increase fire hazard, particularly fire intensity (van Wilgen & Richardson, 1985). van Wilgen & Richardson (1985) found that *H. sericea* invading two fynbos sites resulted in a 60% increase in fuel loads and lowered the moisture content of live foliage. The relevant 'Symptoms' described in section **2** above are repeated here for reference: Statements concerning the impacts of *H. sericea* on water availability are also regularly encountered (*e.g.* van Wilgen *et al.*, 1996; Richardson & van Wilgen, 2004), although these mostly appear to be reliant on indirect links between alien plants, wildfire, soil erosion and the resulting hydrological impacts (*e.g.* Scott, 1993; Scott & van Wyk, 1990), rather than studies on stands of *H. sericea per se* (van Wilgen *et al.*, 1996). The work of Breytenbach (1989) demonstrated links between increased fire intensity and soil runoff for *H. sericea*, although this was specifically in the context of a particular management technique for control (cutting the plant, and then subsequently burning the stacked stems in order to kill off the next generation of seedlings), rather than an impact of *H. sericea* in itself. This study, relating as it does to a specific management action, appears to be the main evidence for an impact of *H. sericea* on hydrological processes (*e.g.* van Wilgen *et al.*, 2000). Dense thickets of *H. sericea*, with its spiny leaves, may also affect cultural ecosystem services.

Ecosystem service	**Does the pest impact on this ecosystem service?** Yes/No	**Short description of impact**	**Reference**
Provisioning	Yes	*H. sericea* could reduce genetic diversity by displacing native species. Can invade and degrade agricultural, pasture and forestry land.	Breytenbach (1986); Phillips (1938) E. Marchante, pers. comm. (2017).
Regulating	Yes	*H. sericea* can increase the intensity of fire in areas where the species invades. Impacts on hydrological regimes are generally considered likely, although most evidence is indirect, or related to the impacts of particular management strategies. (It has been suggested that *H. sericea* invasions may influence soil nutrient cycling in the long term, although we are not aware of specific evidence for this).	van Wilgen & Richardson (1985); Breytenbach (1989); van Wilgen *et al.*(2000), Breytenbach (1986)

Ecosystem service	**Does the pest impact on this ecosystem service?** Yes/No	**Short description of impact**	**Reference**
Cultural	Yes	*H. sericea* is a prickly plant that forms dense impenetrable thickets restricting access.	van Wilgen & Richardson (1985)

A high rating has been given for impacts on ecosystem services and a low uncertainty based on the published information

Rating of magnitude of impact on ecosystem services in the current area of distribution	*Low*☐	*Moderate*X	*High*
Rating of uncertainty	*Low*☐	*Moderate* X	*High*☐

12.03. Socio-economic impact

Between 1965 and 2000, the biocontrol programme against *H. sericea* in South Africa cost 10 million South African RAND (ca. EUR 633 741; van Wilgen *et al.*, 2004). The initial clearing of dense stands of *H. sericea* (75–100%canopy cover) costs about 70 US\$ ha^{-1} compared with about 7 US\$$ha^{-1}$ for sparse stands with 1–5% cover (Marais *et al.*, 2004). Wilson *et al.* (2014) estimates that the overall cost of clearing *Hakea* spp. is around 15 400 ZAR ha^{-1}.

Socio-economic impacts have been reported from the EPPO region where up to 160 000 EUR was spent in 2016-17 managing a population of approximately 12 ha in the Esterel Natural Park in the south of France which included costs of transport of removed plants by helicopters (G. Parodi, Maritime Alps department, pers. comm., 2017). In Portugal, control costs are estimated at EUR 1 500 ha^{-1} (E. Marchante, pers. comm., 2017).

Dense thickets of the plant are likely to restrict access for livestock, grazing, hunting and recreation in Mediterranean regions, thus having potential economic impact. As with any spiny shrub, *H. sericea* can injure people with its sharp leaves. CABI (2017) states that *H. sericea* poses a threat to the US\$40 million industry exporting ornamental *Protea* spp. from South Africa. It should be noted that there may also be indirect, but considerable, costs from impacts on water resources, biodiversity (in a socio-economic context), and amenities, but these are difficult to determine.

Control measures

The species can be controlled using chemical and mechanical methods (see section 3 Risk management methods).

As a result, a moderate impact has been given with a moderate uncertainty where the latter reflects the lack of quantitative studies on these impacts.

Rating of magnitude of socio-economic impact in the current area of distribution	*Low*☐	*Moderate* X	*High*☐
Rating of uncertainty	*Low*☐	*Moderate* X	*High*☐

13. Potential impact in the PRA area

Will impacts be largely the same as in the current area of distribution? **Yes**

Impact on biodiversity in the PRA area

The EWG consider that impacts on biodiversity will be similar in the PRA area as to that seen in the current area of distribution. In Portugal, *H. sericea* forms extensive dense monospecific stands which can exclude native plant species and/or change community composition, including associated fauna. Areas highly susceptible to invasion by *Hakea sericea* in the north of Portugal, are coincident with the distribution area of *Succisa pinnatifida* Lange, a rare endemic of the Iberian Peninsula (J. Vicente,pers. comm., 2017). The high spread potential of the species acts to threaten and reduce the biodiversity of the Esterel Mountains in France, by eliminating less competitive native species of maquis and forest.

In Portugal, several NATURA 2000 sites are to some extent invaded by *H. sericea*, e.g., PTCON0001 (Serras da Peneda e Gerês), PTCON003 (Alvão/Marão), PTCON0024 (Valongo), PTCON0039 (Serra D'Arga), and PTCON0060 (Serra da Lousã). In France, one NATURA 2000 site is invaded, FR9301628 (Estérel).

These priority habitats contain rare and endangered species. See section **7** for more information on habitats.

To-date there have been no recorded impacts on Red Data Book species in the EU.

A high rating has been given with a low uncertainty due to the sites of high conservation value the species invades and the displacement of native species.

Rating of magnitude of impact on biodiversity in the PRA area	*Low*☐	*Moderate*☐	*High* X
Rating of uncertainty	*Low* X	*Moderate*☐	*High*☐

Impact on ecosystem services in the PRA area

Impacts on ecosystem services will be similar to those seen in the current area of distribution. *Hakea sericea* can potentially increase the intensity of fire in areas where the species invades (pers comm. EWG). Impacts on hydrological regimes are generally considered likely, although most evidence is indirect, or related to the impacts of particular management strategies (van Wilgen & Richardson, 1985). Within the EPPO region, cultural services are already being impacted on as *H. sericea* forms dense impenetrable thickets, restricting access. These impacts are only likely to increase with population expansion. As a result, a high impact has been given with a moderate uncertainty where the latter reflects the lack of scientific studies on these impacts.

Rating of magnitude of impact on ecosystem services in the PRA area	*Low*☐	*Moderate*☐	*High* X
Rating of uncertainty	*Low*☐	*Moderate* X	*High*☐

Socio-economic impact in the PRA area

The EWG consider that socio-economic impacts will be similar in the PRA area as to that seen in the current area of distribution. Socio-economic impacts have been reported from the EPPO region where up to 160 000 EUR was spent in 2016-17 managing a population of approximately 12 ha in the Esterel Natural Park in the south of France (G. Parodi, Maritime Alps department,, pers. comm., 2017). In Portugal, control costs are estimated at EUR 1 500 ha^{-1} (E. Marchante, pers. comm., 2017). These impacts are only likely to increase with population expansion.

As a result, a moderate impact has been given with a moderate uncertainty where the latter reflects the lack of quantitative studies on these impacts.

Rating of magnitude of socio-economic impact in the PRA area	*Low*☐	*Moderate* X	*High*☐
Rating of uncertainty	*Low*☐	*Moderate* X	*High*☐

The text within this section relates equally to EU Member States and non-EU Member States in the EPPO region.

14. Identification of the endangered area

Based on the current environmental conditions, species distribution modeling combined with overlaid preferred bedrock types identified suitable areas for establishment of *H. sericea* in the Mediterranean, Atlantic, Black Sea and Macaronesia biogeographical regions (see Appendix 1 and 2). The endangered area includes Portugal (and the Azores and Madeira), and parts of France (and Corsica), Greece, Italy (and Sardinia), Spain (and Balearic Islands) and coastal areas of the Adriatic Sea (Slovenia, Croatia, Albania and Bosnia and Herzegovina) and the Black Sea (Turkey and Georgia). In addition, coastal regions of western North Africa are included in the endangered area including: Algeria and Morocco. .

Habitats at risk in the endangered area include woodland, grasslands, heath land and scrub.

15. Climate change

Climate change

Climate change scenario RCP8.5 is predicted to increase suitability dramatically in the Atlantic and Continental regions, but decrease suitability in the Mediterranean, Macaronesia and Black Sea regions. These decreases appear largely driven by increases in summer temperatures beyond the species optima shown in Figure 3 (Appendix 1). Countries with a high suitability include: a small area of Portugal, north Spain, France, United Kingdom, Ireland, Belgium, the Netherlands, Luxembourg, Germany, Denmark, southern areas of Norway and Sweden.

15.01. Define which climate projection you are using from 2050 to 2100*

Climate projection **RCP 8.5 2070**

Note: RCP8.5 is the most extreme of the RCP scenarios, and may therefore represent the worst-case scenario for reasonably anticipated climate change.

15.02. Which component of climate change do you think is the most relevant for this organism?

Temperature **(yes)**	Precipitation **(yes)**	CO_2 levels **(minor)**
Sea level rise **(no)**	Salinity **(no)**	Nitrogen deposition **(unknown)**
Acidification **(yes)**	Land use change **(yes)**	Other (please specify)

15.03. Consider the influence of projected climate change scenarios on the pest.

The influence of projected climate change scenarios has not been taken into account in the overall scoring of the risk assessment based on the high levels of uncertainty with future projections.

The EWG note that the 2070 model projection may underestimate the suitable range in the Iberian Peninsula and overestimated the suitable range for non Mediterranean and non siliceous range. This may be linked to the coarse-scale modelling that does not capture local/habitat environmental conditions.

Are the **pathways** likely to change due to climate change?**(If yes, provide a new rating for likelihood and uncertainty)**	**Reference**
No, introduction into the EPPO region of plants for planting is unlikely to change as a result of climate change. However, the areas suitable for the species is predicted to increase and thus the demand for the species in horticulture may increase. The overall rating for introduction pathways will not change from low rating of likelihood of entry with a moderate uncertainty. .	EWG opinion
Is the **likelihood of establishment** likely to change due to climate change? **(If yes, provide a new rating for likelihood and uncertainty)**	**Reference**
Climate change scenario RCP8.5 is predicted to increase suitability dramatically in the Atlantic and Continental regions, but decrease suitability in the Mediterranean, Macaronesia and Black Sea regions (Figure 7). The overall rating for establishment for both the natural and managed environment will not change(high) but the uncertainty rating will increase from low to high.	See Costa *et al.* (2016) and Appendix 1
Is the magnitude of **spread** likely to change due to climate change?**(If yes, provide a new rating for the magnitude of spread and uncertainty)**	**Reference**
The risk of spread may potentially increase as a result of climate change leading to increased fire risk. This in turn may promote higher seed release and spread. The overall ratings for spread will not change from high but uncertainty will increase from low to moderate.	EWG opinion
Will **impacts** in the PRA area change due to climate change? **(If yes, provide a new rating of magnitude of impact and uncertainty for biodiversity, ecosystem services and socio-economic impacts separately)**	**Reference**
Warmer temperatures may increase the predicted impacts and also impacts may affect a larger area. However, the current score impacts on biodiversity (high), ecosystem services (high) and socio-economic (moderate) in the PRA area will remain the same for the future 2070 projection. Uncertainty will increase for all categories of impact to high.	EWG opinion

16. Overall assessment of risk

Plants for planting

Rating of the likelihood of entry for the pathway, plants or seeds for planting	*Low* ***X***	*Moderate*	*High*
Rating of uncertainty	*Low*	*Moderate* **X**	*High*

Rating of the likelihood of establishment in the natural environment in the PRA area

Rating of the likelihood of establishment in the natural environment	*Low*	*Moderate*	*High* **X**
Rating of uncertainty	*Low* X	*Moderate*	*High*

Rating of the likelihood of establishment in the managed environment in the PRA area

Rating of the likelihood of establishment in the natural environment	*Low*	*Moderate*	*High* X
Rating of uncertainty	*Low* X	*Moderate*	*High*

Magnitude of spread

Rating of the magnitude of spread	*Low*	*Moderate*	*High* X
Rating of uncertainty	*Low* X	*Moderate*	*High*

Impact on biodiversity

Rating of the magnitude of impact in the current area of distribution (Biodiversity)	*Low*	*Moderate*	*High* X
Rating of uncertainty	*Low* X	*Moderate*	*High*

Impact on ecosystem services

Rating of the magnitude of impact in the current area of distribution (ecosystem services)	*Low*	*Moderate*	*High* X
Rating of uncertainty	*Low*	*Moderate* X	*High*

Impact on socio-economics

Rating of the magnitude of impact in the current area of distribution (ecosystem services)	*Low*	*Moderate* X	*High*
Rating of uncertainty	*Low*	*Moderate* X	*High*

Will impacts be largely the same as in the current area of distribution? **YES**

18. Uncertainty

The EWG note that the 2070 model projection may underestimate the suitable range in the Iberian Peninsula and overestimate for the non-Mediterranean biogeographical region. This may be linked to the coarse-scale modelling that does not capture local/habitat environmental conditions.

In addition, to remove spatial recording biases, the selection of the background sample was weighted by the density of Tracheophyte records on the Global Biodiversity Information Facility (GBIF). While this is preferable to not accounting for recording bias at all, a number of factors mean this may not be the perfect null model for species occurrence:

- The GBIF API query used to did not appear to give completely accurate results. For example, in a small number of cases, GBIF indicated no Tracheophyte records in grid cells in which it also yielded records of the focal species.
- We located additional data sources to GBIF, which may have been from regions without GBIF records.

Other variables potentially affecting the distribution of the species, such as soil nutrients, were not included in the model.

Model outputs were classified as suitable or unsuitable using a threshold of 0.5, effectively a ‘prevalence threshold’ given the prevalence weighting of model-fitting. There is disagreement about the best way to select suitability thresholds so we evaluated the threshold selected by the commonly-used ‘minROCdist’ method. This would have selected a threshold of 0.42, increasing the region predicted to be suitable for *H. sericea*.

The climate change scenario used is the most extreme of the four RCPs. However, it is also the most consistent with recent emissions trends and could be seen as worst case scenario for informing risk assessment.

19. Remarks

Confirm the taxonomic status and occurrence of *Hakea* species in the EPPO region,
Further research on impacts of the species in the EPPO region.

20. REFERENCES

Allemand, P. (1989), *Espèces exotiques utilisables pour la reconstitution du couvert végétal en région méditerranéenne. Bilan des arboretums forestiers d'élimination*. Paris. INRA. 146 p. (Coll. *Techniques etpratiques).*

ANBG (2017). Growing Native Plants: *Hakea sericea*. https://www.anbg.gov.au/gnp/gnp3/hakea-sericea.html [Accessed 23rd April 2017]

Andreu, J., Vila, M., & Hulme, P. E. (2009). An assessment of stakeholder perceptions and management of noxious alien plants in Spain. *Environmental Management*, 43(6), 1244.

Ball, P.W. (1964). Proteaceae. In: Tutin, T.G. *et al.* (Eds) *Flora Europaea. Vol. 1: Lycopodiaceae to Platanaceae*. Cambridge University Press: Cambridge.

Barker, R.M. (2010). *Australian* Hakea *species: identification and information. Version 1. An interactive Lucid key and information system*. http://www.flora.sa.gov.au/id_tool.html [Accessed on April 18th 2017]

Barker, W. R. (1996) Novelties and taxonomic notes relating to *Hakea* Sect. *Hakea* (Proteaceae), mainly of eastern Australia. *Journal of the Adelaide Botanic Garden* 17: 177-209.

Barker, W.R.,Barker, R.M.& Haegi, L.(1999) Hakea. In:Wilson, A. (Ed.) (1999). *Flora of Australia, Vol. 17B, Proteaceae 3 Hakea to Dryanda*. Australian Biological Resources Study and CSIRO, Canberra, Australia. Available online at http://www.environment.gov.au/biodiversity/abrs/online-resources/flora/index.html [Accessed 18th April 2017]

Beever, R. (1988) Gumland scrub. *Auckland Botanical Society Journal* 43:12-18.

Bond, W.J. & van Wilgen, B.W. (1996) *Fire and Plants*.Chapman & Hall, London, UK.

Bradstock, R.A. (1991) The role of fire in establishment ofseedlings of serotinous species from the Sydney region.*Australian Journal of Botany* 39: 347-356.

Bradstock, R.A., Gill, A.M., Hastings, S.M., & Moore,P.H.R. (1994) Survival of serotinous seedbanks during bushfires: comparative studies of *Hakea* species fromsoutheastern Australia. *Australian Journal of Ecology*, 19, 276-282.

Breytenbach, G.J. (1986) Impacts of alien organisms on terrestrial communities with emphasis oncommunitiesof the south-western Cape. In I.A.W. Macdonald, F.J. Kruger and A.A.Ferrar (eds.), *The ecology and management of biological invasions in southern Africa*, Cape Town, Oxford University Press, pp. 229–238.

Breytenbach, G. J. (1989). Alien control: Can we afford to slash and burn hakea in fynbos ecosystems?. *South African Forestry Journal*, 151(1), 6-16.

Breytenbach, G.J., Breytenback, W., & Vlok, J. (1984) Ecological disruption in Fynbos. In: Dell, B. (Ed) *MEDECOS IV: Proceedings of the 4th International Conference on Mediterranean Ecosystems*. Botany Department University of Western Australia, Nedlands, pp. 16-17.

Brown, C. L., & Whelan, R. J. (1999). Seasonal occurrence of fire and availability of germinable seeds in *Hakea sericea* and *Petrophile sessilis*. *Journal of Ecology* 87(6), 932-941.

Brunel S., Branquart E., Fried G., van Valkenburg J., Brundu G., Starfinger U., Buholzer S., Uludag A., Joseffson M. & Baker R. (2010a) The EPPO prioritization process for invasive alien plants. *Bulletin OEPP/EPPO Bulletin* 40, 407-422.

Brunel, S., Schrader, G., Brundu, G., & Fried, G. (2010b). Emerging invasive alien plants for the Mediterranean Basin. *OEPP/EPPO Bulletin* 40(2), 219-238.

Brunel, S., Brundu, G. & Fried, G.(2013). Eradication and control of invasive alien plants in the Mediterranean Basin: towards better coordination to enhance existing initiatives. *OEPP/EPPO Bulletin*, 43(2), pp.290-308.

Brusati, E., Johnson, D., & DiTomaso, J. (2014). Predicting invasive plants in California. *California Agriculture* 68(3), 89-95.

CABI (2017).*Hakea sericea*(silky hakea).http://www.cabi.org/isc/datasheet/27302 [Accessed 1st April 2017]

Cameron, E. K. (1994). Environmental vascular plant weeds and new records for Motutapu, Waitemata Harbour. *Auckland Botanical Society Journal* 49 (1), 3340.

Costa, R., Fraga, H., Fernandes, P. M., & Santos, J. A. (2016). Implications of future bioclimatic shifts on Portuguese forests. *Regional Environmental Change*, 1-11.

Cowling, R.M., Lamont, B.B. & Pierce, S.M. (1987) Seedbank dynamics of four co-occurring *Banksia*species.*Journal of Ecology*, 75, 289-302.

Cubey, J. (ed.) (2016) *RHS Plant Finder 2016.*Royal Horticultural Society,pp. 952, ISBN 1907057668.

Diadema, K., Le Berre, M., Dixon, L. 2017. Gestion de l'hakea soyeux (Hakea sericea Schrad. & J.C. Wendl.), espèce exotique envahissante-Massif de l'Estérel (Alpes-Maritimes). Rapport Conservatoire botanique national méditerranéen.

Ducatillion, C., Badeau, V., Bellanger, R., Buchlin, S., Diadema, K., Gili, A., & Thévenet, J.(2015). Détection précoce du risque d'invasion par des espèces végétales exotiques introduites en arboretum forestier dans le Sud-Est de la France. Émergence des espèces du genre Hakea. Mesures de gestion. *Revue d'Ecologie (Terre et Vie)*, 70(12): 139-150.

Dufour-Dror, J.-M. (ed.) (2013)*Israel's Least Wanted Alien Ornamental Plant Species – First Edition, July 2013.*http://www.sviva.gov.il/English/env_topics/biodiversity/Documents/InvasiveSpecies-July2013.pdf [Accessed 16th May 2017]

Dyer, C., & Richardson, D. M. (1992). Population genetics of the invasive Australian shrub *Hakea sericea* (Proteaceae) in South Africa. *South African Journal of Botany*, 58(2), 117-124.

EPPO (2012). *Hakea sericea* IAP list profile. https://www.eppo.int/INVASIVE_PLANTS/iap_list/Hakea_sericea.htm [Accessed 23rd April 2017]

EPPO (2015).*PQR - EPPO database on quarantine pests (available online).*http://www.eppo.int [Accessed 10th April 2017]

Esler, K.J., van Wilgen, B.W., Te Roller, K.S., Wood, A.R., & van der Merwe, J.H. (2010). A landscape-scale assessment of the long-term integrated control of an invasive shrub in South Africa. *Biological Invasions*, 12(1), 211.

Espírito Santo, M.D. & Arsénio, P. (1999) O género Hakea Schrad. em Portugal. 1o Encontro sobre Invasoras Lenhosas. SPCF/ADERE, Gerês, pp 58–65

Fourie, A., Gordon, A.J., Krug, R.M. (2012). *Invasive Hakeas Biological Control Implementations.*http://thekrugs.free.fr/HakeaHandbook. Accessed 19th May 2017.

Freitas R., J. R., Crespí, A. L., Castro, A., Castro, C., Bennett, R. N., Alves, P., & Amich, F. (2008). The occurrence of alien species for Northern of Portugal and the floristic corridors: a biogeographical approach. *Studia Botanica*, (27), 163-182.

Fried, G. (2017). *Guide des plantes invasives*. Nouvelle Edition. Collection « L'indispensable guide des…Fous de Nature! (Ed. G. Eyssartier). Editions Belin, 302 p.

Fried, G. (2010). Prioritization of Potential Invasive Alien Plants in France. In *Proceedings of the International Workshop ''Invasive Plants in Mediterranean Type Regions of the World* (pp. 2-6).

Fugler, S. R. (1982). Infestations of three Australian *Hakea* species in South Africa and their control. *South African Forestry Journal*, 120(1), 63-68.

Gaertner, M., Den Breeyen, A., Hui, C., & Richardson, D.M.(2009). Impacts of alien plant invasions on species richness in Mediterranean-type ecosystems: a meta-analysis. *Progress in Physical Geography*, 33(3), pp.319-338.

Goldblatt, P. (1997). Floristic diversity in the Cape flora of South Africa. *Biodiversity and Conservation*, 6(3), 359-377.

Gordon, A.J. (1993). The impact of the Hakea seed-moth *Carposina autologa* (Carposinidae) on the canopy-stored seeds of the weed *Hakea sericea* (Proteaceae). *Agriculture, Ecosystems & Environment*, 45(1-2), 105-113.

Gordon, A.J. (1999). A review of established and new insect agents for the biological control of *Hakea sericea* Schrader (Proteaceae) in South Africa. *African Entomology Memoir No. 1*: 35–43

Gordon, A.J., & Fourie, A. (2011). Biological control of *Hakea sericea* Schrad. & JC Wendl. and *Hakea gibbosa* (Sm.) Cav. (Proteaceae) in South Africa. *African Entomology*, 19(2), 303-314.

Gordon, A.J. & Lyons, C.L. (2017). Current status of *Carposina autologa* (Lepidoptera: Carposinidae), a biological control agent of silky hakea, *Hakea sericea* (Proteaceae) and rock hakea, *Hakea gibbosa* (Proteaceae) in the Western Cape, South Africa. *African Entomology*, 25(1), 250-253.

Government of the Republic of South Africa. (2014). *Government Gazette. 12 February 2014*. No. 37320, pp. 3-96.

Henderson, L. (2001). *Alien weeds and invasive plants: A complete guide to declared weeds and invaders in South Africa*. Agricultural Research Council, South Africa. 300 pp.

Heywood, V. H., & Brunel, S. (2009). *Code of conduct on horticulture and invasive alien plants*. Council of Europe Publishing.

Holmes, P.M., Richardson, D.M., van Wilgen, B.W., & Gelderblom, C.(2000). Recovery of South African fynbos vegetation following alien woody plant clearing and fire: implications for restoration. *Austral Ecology*, 25(6), pp.631-639.

Howell, CJ. (2008). *Consolidated list of environmental weeds in New Zealand*. Science & Technical Pub., Department of Conservation.

Hosking, J.R., Sainty, G.R., & Jacobs, S.W.L. (2000) Certainty and Uncertainty in Plant Identification. *The New Mexico Botanist*, 15: 1-4.

Huryn, V. M. B., & Moller, H. (1995). An assessment of the contribution of honey bees (*Apis mellifera*) to weed reproduction in New Zealand protected natural areas. *New Zealand Journal of Ecology*, 111-122.

Instituto de Investigação Científica Tropical (2008-2017a). *Hakea sericea*, 1932. http://actd.iict.pt/view/actd:LISC049867 [Accessed 10/05/2017]

Instituto de Investigação Científica Tropical (2008-2017b). *Hakea sericea*, 1964. http://actd.iict.pt/view/actd:LISC049868[Accessed 10/05/2017]

Invmed (2017). Plateforme informatique sur les espèces végétales exotiques envahissantes Alpes-Méditerranée. Conservatoires botaniques nationaux méditerranéen et alpin. *Hakea sericea.* http://invmed.fr [Accessed 10/12/2017]

Kitajima, K. & Fenner, M.(2000). Ecology of seedling regeneration. In: Fenner, M. (Ed.) *Seeds: The Ecology of Regeneration in Plant Communities*. 2nd ed. CABI International: Wallingford, pp.331-359.

Kluge, R.L. (1983). The hakea fruit weevil,*Erytenna consputa*Pascoe (Coleoptera: Curculionidae),and the biological control of *Hakea sericea* Schrader in South Africa. PhD Thesis,Rhodes University, Grahamstown, 132 pp. (unpublished).

Kluge, R. L., & Neser, S. (1991). Biological control of *Hakea sericea* (Proteaceae) in South Africa. *Agriculture, Ecosystems & Environment* 37(1-3), 91-113.

Koop, A. L., Fowler, L., Newton, L. P., & Caton, B. P. (2012). Development and validation of a weed screening tool for the United States. *Biological Invasions* 14(2), 273-294.

Kottek, M., Grieser, J., Beck, C., Rudolf, B. & Rubel, F. (2006). World Map of Köppen-Geiger Climate Classification updated. *Meteorol. Z.* 15, 259-263.

Kruger, F.J. and Bigalke, R,C. (1984). Fire in fynbos. In: P. de V. Booysen and N.M. Tainton (Eds)*Ecological Effects of Fire in South African Ecosystems*. Springer: Berlin, pp. 67-114.

Lambers, H., Raven, J.A., Shaver, G.R., & Smith, S.E.(2008). Plant nutrient-acquisition strategies change with soil age. *Trends in Ecology & Evolution* 23(2),95-103.

Lamont, B.B., Le Maitre, D.C., Cowling, R.M. & Enright ,N. J. (1991) Canopy seed storage in woody plants.*Botanical Review*, 57, 278-311.

Le Maitre, D. C., Krug, R. M., Hoffmann, J. H., Gordon, A. J., & Mgidi, T. N. (2008). Hakea sericea: development of a model of the impacts of biological control on population dynamics and rates of spread of an invasive species. *Ecological Modelling*, 212(3), 342-358.

Macdonald, I.A.W. (1984). Is the fynbos biome especially susceptible to invasion by alien plants?A re-analysis of available data. *South African Journal of Science* 80: 369-377.

Macdonald, I.A.W. and Richardson, D.M.(1986). Alien species in the terrestrial ecosystems of the fynbos. In: I.A.W. Macdonald, F.J. Kruger and A.A. Ferrar (Eds)*The Ecology and Management of Biological Invasions in Southern Africa*. Oxford University Press: Cape Town,pp. 77-91.

Mandle, L., Bufford, J.L., Schmidt, I.B.,& Daehler, C.C.(2011). Woody exotic plant invasions and fire: reciprocal impacts and consequences for native ecosystems. *Biological Invasions*, 13(8), pp.1815-1827.

Marais C, van Wilgen BW, Stevens D (2004) The clearing of invasive alien plants in South Africa: a preliminaryassessment of costs and progress. *S Afr J Sci* 100:97–103.

Marchante, H., Morais, M., Freitas, H.&Marchante, E. (2014) *Guia prático para a identificação de Plantas Invasoras em Portugal*.Imprensa da Universidade de Coimbra, Coimbra.

Martins, J., Richardson, D.M., Henriques, R., Marchante, E., Marchante, H., Alves, P., Gaertner, M., Honrado, J.P. and Vicente, J.R., 2016. A multi-scale modelling framework to guide management of plant invasions in a transboundary context. *Forest Ecosystems*, 3:17. DOI:10.1186/s40663-016-0073-8

Mitchell, D. T., & Allsopp, N. (1984). Changes in the phosphorus composition of seeds of *Hakea sericea* (Proteaceae) during germination under low phosphorus conditions. *New Phytologist* 96(2), 239-247.

Moore, G. (2004). Proteaceae. In: P.M. Browse (Ed.) *Gardening on the Edge*. A. Hodge: Penzance, Cornwall.

Morais, M., Marchante, E., & Marchante, H. (2017). Big troubles are already here: risk assessment protocol shows high risk of many alien plants present in Portugal. *Journal for Nature Conservation*, 35, 1-12.

Morrison, D. A., & Renwick, J. A. (2000). Effects of variation in fire intensity on regeneration of co-occurring species of small trees in the Sydney region. *Australian Journal of Botany*, 48(1), 71-79.

Neser, S.(1968). *Studies on some potentially useful insect enemies of needle-bushes (*Hakea *spp. - Proteaceae)*. PhD Thesis, Australian National University, Canberra, 194 pp. (unpublished).

Neser, S. & Kluge, R.L. (1985). A seed-feeding insect showing promise in the control of a woody, invasive plant: the weevil *Erytenna consputa* on *Hakea sericea* (Proteaceae) in South Africa. In: *Proceedings of the VI International Symposium on Biological Control of Weeds Ottawa, Canada*; Agriculture Canada, pp. 805-809

Owen, S.J.(1996). *Ecological weeds on conservation land in New Zealand: A database.* Department of Conservation, Wellington, New Zealand: DOC Science Publications. http://www.hear.org/weedlists/other_areas/nz/nzecoweeds.htm

Paiva, J. (1997) *Hakea*. In: Castroviejo, S. *et al.* (Eds) (1997). *Flora Ibérica: Haloragaceae-Euphorbiaceae (Vol. 8)*. Editorial CSIC-CSIC Press: Madrid.

Parker, C., Caton, B. P., & Fowler, L. (2007). Ranking nonindigenous weed species by their potential to invade the United States. *Weed Science*, 55(4), 386-397.

Plant List (2017) http://www.theplantlist.org/tpl1.1/record/kew-2837665 [Accessed 20th April 2017]

Phillips, E.P. (1938). The naturalized species of hakea. *Farming in South Africa*, 13:424.

Press, J., & Short, M.J.(1994). *Flora of Madeira*. Natural History Museum, London.

Q-bank (2017) http://www.q-bank.eu/Plants/BioloMICS.aspx?Table=Plants%20-%20Species&Rec=979&Fields=All [Accessed 20th April 2017]

Reva, V., Pita, L. P., Lousada, J. L., & Viegas, D. X. (2010). Small-scale bioenergy production as an incentive for forest fire prevention. In *Proceedings of the 6th International Conference on Forest Fire Research (*pp. 15-18).

Richardson, D.M. (1984). A Cartographic Analysis of Physiographic Factors Influencing the Distribution of *Hakea* spp, in the South-Western Cape. *South African Forestry Journal*, 128(1), 36-40.

Richardson, D.M. and van Wilgen, B.W. (1984). Factors affecting the regeneration success of*Hakea sericea*. *South African Forestry Journal* 131: 63-68.

Richardson, D. M., & van Wilgen, B. W. (1986). The effects of fire in felled *Hakea sericea* and natural fynbos and implications for weed control in mountain catchments. *South African Forestry Journal*, 139(1), 4-14.

Richardson, D.M. & van Wilgen, B.W.(2004). Invasive alien plants in South Africa: how well do we understand the ecological impacts? *South African Journal of Science*, 100(1-2), pp.45-52.

Richardson, D. M., van Wilgen, B. W., & Mitchell, D. T. (1987). Aspects of the reproductive ecology of four Australian *Hakea* species (Proteaceae) in South Africa. *Oecologia*, 71(3), 345-354.

Richardson, D.M., Macdonald, I.A.W., & Forsyth, G.G.(1989). Reductions in plant species richness under stands of alien trees and shrubs in the fynbos biome. *South African Forestry Journal*, 149(1), pp.1-8.

Romero Buján, M. I. (2007). Flora exótica de Galicia (noroeste ibérico). *Botanica Complutensis*, 31: 113-125.

Sañudo, Í.P. (2006). Aportaciones a la flora del sur de Galicia (NO España). *Botanica Complutensis*, 30, 113.

Scott, D. F. (1993). The hydrological effects of fire in South African mountain catchments. *Journal of Hydrology*, 150(2-4), 409-432.

Scott, D. F., & van Wyk, D. B. (1990). The effects of wildfire on soil wettability and hydrological behaviour of an afforested catchment. *Journal of Hydrology*, 121(1), 239-256.

Shaughnessy, G.L.(1986). A case study of some woody plant introductions to the Cape Town area. In: Macdonald, I.A.W., Kruger, F.J., Ferrar, A.A. (Eds)*The ecology and management of biological invasions in southern Africa.* Cape Town, South Africa: Oxford University Press, pp. 37-43.

SILENE-Flore : CBNMed & CBNA (Admin.) (2007-2018) http://flore.silene.eu [Accessed 10th December 2017]

Specht, R.L. (1994) Heathlands. In: Groves, R.H. (Ed.) *Australian Vegetation* pp. 321-344.Cambridge: Cambridge University Press.

Terrin E., Diadema K., Fort N. (2014). *Stratégie régionale relative aux espèces végétales exotiques envahissantes en Provence-Alpes-Côte d'Azur et son plan d'actions*. Conservatoires botaniques nationaux alpin et méditerranéen.

Tison J-M., de Foucault, B., 2014. Flora Gallica. Flore de France. Biotope éditions, Mèze. 1196 p.

Tucker, K. C., & Richardson, D. M. (1995). An expert system for screening potentially invasive alienplants in South African fynbos. *Journal of Environmental Management*, 44(4), 309-338.

USDA-APHIS (2013). *Weed Risk Assessment for* Hakea sericea *Schrad. & J. C. Wendl. (Proteaceae) – Bushy needlewood.* Version 2, April 4 2013.

van Wilgen, B.W. and Kruger, F.J. (1985) The physiography and fynbos vegetation communitiesof the Zachariashoek Catchments, south-western Cape Province. *South African Journal of Botany* 51: 379-399.

van Wilgen, B.W. & Richardson, D.M.(1985). The effects ofalien shrub invasions on vegetationstructure and fire behaviour in South African fynbos shrublands: a simulation study. *Journal of Applied Ecology*, 22: 955-966.

van Wilgen, B. W., Cowling, R. M., & Burgers, C. J. (1996). Valuation of ecosystem services. *BioScience*, 46(3), 184-189.

van Wilgen, B. W., Richardson, D. M., Le Maitre, D. C., Marais, C., & Magadlela, D. (2001). The economic consequences of alien plant invasions: examples of impacts and approaches to sustainable management in South Africa. *Environment, Development and Sustainability*, 3(2), 145-168.

Van Wilgen, Brian W., M. P. De Wit, H. J. Anderson, D. C. Le Maitre, I. M. Kotze, S. Ndala, B. Brown, and M. B. Rapholo. (2004) Costs and benefits of biological control of invasive alien plants: case studies from South Africa: working for water. *South African Journal of Science* 100, no. 1-2: 113-122.

van Wilgen, B.W., Nel, J.L., & Rouget, M.(2007). Invasive alien plants and South African rivers: a proposed approach to the prioritization of control operations. *Freshwater Biology*, 52(4), pp.711-723.

Vieira, R. M. da S. (2002). Flora da Madeira: plantas vasculares naturalizadas no arquipélago da Madeira.*Boletim do Museu Municipal do Funchal*, Suplemento 8 pp. 152. Cámara Municipal do Funchal, Funchal.

Virtue, J. G., Spencer, R. D., Weiss, J. E., & Reichard, S. E. (2008). Australia's Botanic Gardens weed risk assessment procedure. *Plant Protection Quarterly*, 23(4), 166-178.

Webb, C.J., Sykes, W.R., & Garnock-Jones, P.J. (1988).*Flora of New Zealand. Vol. IV. Naturalised Pteridophytes, Gymnosperms, Dicotyledons.* Botany Division DSIR, Christchurch.

Weber, E., & Gut, D. (2004). Assessing the risk of potentially invasive plant species in central Europe. *Journal for Nature Conservation*, 12(3), p. 171-179

Whelan, R.J. (1995).*The Ecology of Fire*. CambridgeUniversity Press, Cambridge, UK.

Wilson, J.R., Gaertner, M. , Griffiths, C.L., Kotzé, I., Le Maitre, D.C., Marr, S.M., Picker, M.D., Spear, D., Stafford, L., Richardson, D.M., van Wilgen, B.W., & Wannenburgh, A. (2014). Biological invasions in the Cape Floristic Region: history, current patterns, impacts, and management challenges. In: Allsopp, N., Colville, J.F., Verboom, G.A. (Eds) *Fynbos: Ecology, Evolution, and Conservation of a Megadiverse Region*. Oxford University Press: Oxford.

Xunta de Galicia (n.d.) *Plantas Invasoras de Galicia: Bioloxía, distribución e métodos de control*. Xunta de Galicia: Galicia. http://www.ciencias-marinas.uvigo.es/bibliografia_ambiental/plantas/Plantas%20aloctonas/Plantas%20invasoras%20de%20Galicia.pdf [Accessed 19th May 2017]

Appendix 1: Projection of climatic suitability for *Hakea sericea* establishment

Aim
To project the suitability for potential establishment of *Hakea sericea* in the EPPO region, under current and predicted future climatic conditions.

Data for modelling
Climate data were taken from 'Bioclim' variables contained within the WorldClim database (Hijmans *et al.*, 2005)originally at 5 arcminute resolution (0.083 x 0.083 degrees of longitude/latitude) and aggregated to a 0.25x 0.25 degree grid for use in the model. Based on the biology of the focal species, the following climate variables were used in the modelling:

- Mean minimum temperature of the coldest month (Bio6 °C) reflecting exposure to frost. Horticultural reports suggests that *H. sericea* con tolerate moderate frosts in its native range, but it may be restricted from regions with harsh frost.
- Mean temperature of the warmest quarter (Bio10 °C) reflecting the growing season thermal regime.
- Climatic moisture index (CMI, ratio of mean annual precipitation, Bio12, to potential evapotranspiration) reflecting plant moisture regimes. For calculation of CMI, monthly potential evapotranspirations were estimated from the WorldClim monthly temperature data and solar radiation using the simple method of Zomer *et al.* (2008)which is based on the Hargreaves evapotranspiration equation (Hargreaves, 1994).
- Precipitation seasonality (Bio15, coefficient of variation for monthly precipitations, log+1 transformed), which was considered potentially important for *H. sericea* by the risk assessment expert working group.

To estimate the effect of climate change on the potential distribution, equivalent modelled future climate conditions for the 2070s under the Representative Concentration Pathway (RCP) 8.5 were also obtained. This assumes an increase in atmospheric CO_2 concentrations to approximately 850 ppm by the 2070s. Climate models suggest this would result in an increase in global mean temperatures of 3.7 °C by the end of the 21st century. The above variables were obtained as averages of outputs of eight Global Climate Models (BCC-CSM1-1, CCSM4, GISS-E2-R, HadGEM2-AO, IPSL-CM5A-LR, MIROC-ESM, MRI-CGCM3, NorESM1-M), downscaled and calibrated against the WorldClim baseline (see http://www.worldclim.org/cmip5_5m). RCP8.5 is the most extreme of the RCP scenarios, and may therefore represent the worst case scenario for reasonably anticipated climate change.
In the models we also included the following habitat variables:

- Annual burning probability as *H. sericea* is a fire-adapted species, and especially relies on fire for seed release (York & Whelan, 1998, Brown & Whelan, 1999). Annual burn probabilities (proportion of years when a fire is detected anywhere in the grid cell) were calculated for each grid cell from the Global Fire Emissions Database v4.1 (GFED4s) covering 1997-2015 and based on an updated version of Van der Werf *et al.* (2010)with burned area from Giglio *et al.* (2013)boosted by small fire burned areas (Randerson *et al.*, 2012).
- Human influence index as *H. sericea*, like many invasive species, is likely to associate with anthropogenically disturbed habitats. We used the Global Human Influence Index Dataset of the Last of the Wild Project (Wildlife Conservation Society - WCS & Center for International Earth Science Information Network - CIESIN - Columbia University, 2005), which is developed from nine global data layers covering human population pressure (population density), human land use and infrastructure (built-up areas, nighttime lights, land use/land cover) and human access (coastlines, roads, railroads, navigable rivers). The index ranges between 0 and 1 and was log+1 transformed for the modelling to improve normality.

Species occurrence data were obtained from the Global Biodiversity Information Facility (GBIF), iNaturalist, Invasive Plants in Portugal (Invasoras), Système d'Information et de Localisation des Espèces Natives et Envahissantes (SILENE). We scrutinised occurrence records from regions where the species is not known to be well established and removed any that appeared to be dubious or planted specimens (e.g. plantations, botanic gardens) or where the georeferencing was too imprecise (e.g. records referenced to a country or island centroid) or outside of the coverage of the predictor layers (e.g. small island or coastal occurrences). The remaining records were gridded at a 0.25 x 0.25 degree resolution for modelling

(Figure 1). To improve the model's ability to resolve the species' relationship with burning using the crude global GIS layers available to us, a small number of records from coastal areas and small islands where there is little land surface and consequently little detected burning were removed from the analysis. These were principally from New Zealand. Following this, there were 2 grid cells with established occurrence records available for the modelling (Figure 1).

Figure 1. Occurrence records obtained for *Hakea sericea* and used in the modelling.

Species distribution model

A presence-background (presence-only) ensemble modelling strategy was employed using the BIOMOD2 R package v3.3-7 (Thuiller *et al.*, 2014, Thuiller *et al.*, 2009). These models contrast the environment at the species' occurrence locations against a random sample of the global background environmental conditions (often termed 'pseudo-absences') in order to characterise and project suitability for occurrence. This approach has been developed for distributions that are in equilibrium with the environment. Because invasive species' distributions are not at equilibrium and subject to dispersal constraints at a global scale, we took care to minimise the inclusion of locations suitable for the species but where it has not been able to disperse to. Therefore the background sampling region included:

- The area accessible by native *H. sericea* populations,in which the species is likely to have had sufficient time to disperse to all locations. To define the native range, we divided Australian records into native east coast populations and non-native populations on the south coast and Tasmania (http://www.florabank.org.au/lucid/key/Species%20Navigator/Media/Html/Hakea_sericea.htm). Then the accessible region was defined as a 200 km buffer around the minimum convex polygon bounding all native occurrences in Australia; AND
- A relatively small 30 km buffer around all non-native occurrences (including Australian ones), encompassing regions likely to have had high propagule pressure for introduction by humans and/or dispersal of the species; AND
- Regions where we have an *a priori* expectation of high unsuitability for the species (see Figure 2). Absence from these regions is considered to be irrespective of dispersal constraints. The following rules were applied to define a region expected to be highly unsuitable for *H. sericea* at the spatial scale of the model:
    - Mean minimum temperature of the coldest month (Bio6) <-2 °C. *H. sericea* is sensitive to severe frosts and the coldest occurrence has Bio6 = -1.8 °C suggesting this is its minimum tolerance.
    - Mean temperature of the warmest quarter (Bio10) <15 °C. All *H. sericea*were in regions warmer than this, with the exception of a single outlying record that had Bio10 = 13.7 °C.
    - Climatic moisture index < 0.2. All *H. sericea*were in regions wetter than this, with the exception of two outlying records.
    - Soil pH > 8. *H. sericea* is generally restricted to acidic soils (CABI, 2015), and no records had soil pH > 7.7.

Within this sampling region there will be substantial spatial biases in recording effort, which may interfere with the characterisation of habitat suitability. Specifically, areas with a large amount of recording effort will appear more suitable than those without much recording, regardless of the underlying suitability for occurrence. Therefore, a measure of vascular plant recording effort was made by querying the Global Biodiversity Information Facility application programming interface (API) for the number of phylum Tracheophyta records in each 0.25 x 0.25 degree grid cell. The sampling of background grid cells was then weighted in proportion to the Tracheophyte recording density. Assuming Tracheophyte recording density is proportional to recording effort for the focal species, this is an appropriate null model for the species' occurrence.

To sample as much of the background environment as possible, without overloading the models with too many pseudo-absences, ten background samples of 10,000 randomly chosen grid cells were obtained (Figure 2).

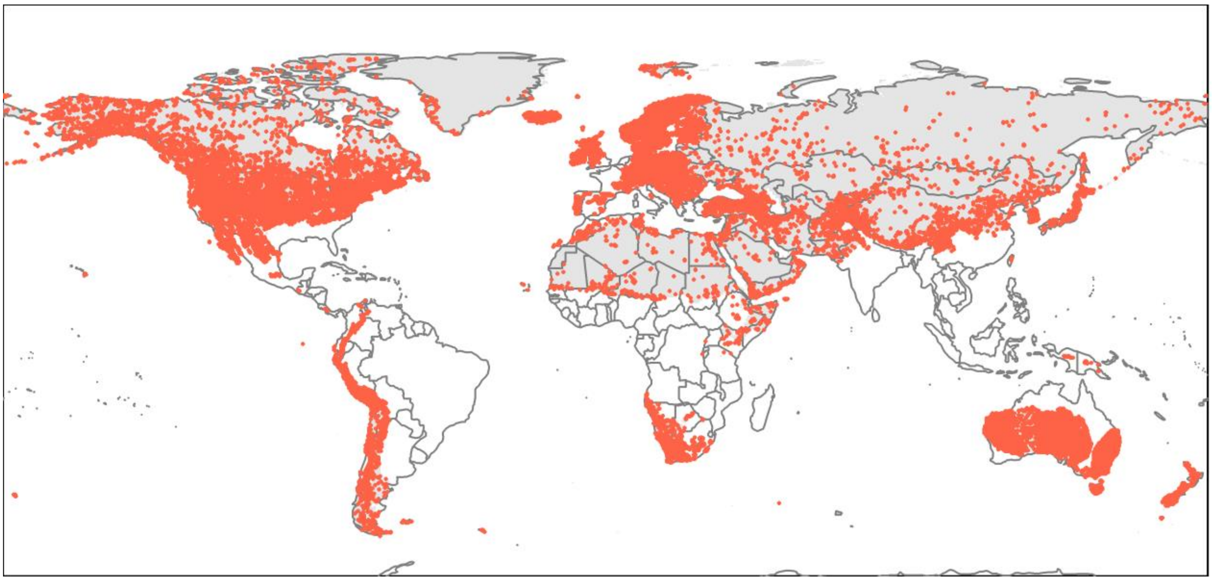


Figure 2. Randomly selected background grid cells used in the modelling of *Hakea sericea*, mapped as red points. Points are sampled from the native range, a small buffer around non-native occurrences and from areas expected to be highly unsuitable for the species (grey background region), and weighted by a proxy for plant recording effort.

Each dataset (i.e. combination of the presences and the individual background samples) was randomly split into 80% for model training and 20% for model evaluation. With each training dataset, ten statistical algorithms were fitted with the default BIOMOD2 settings and rescaled using logistic regression, except where specified below:

- Generalised linear model (GLM)
- Generalised boosting model (GBM)
- Generalised additive model (GAM) with a maximum of four degrees of freedom per smoothing spline.
- Classification tree algorithm (CTA)
- Artificial neural network (ANN)
- Flexible discriminant analysis (FDA)
- Multivariate adaptive regression splines (MARS)
- Random forest (RF)
- MaxEnt
- Maximum entropy multinomial logistic regression (MEMLR)

Since the background sample was much larger than the number of occurrences, prevalence fitting weights were applied to give equal overall importance to the occurrences and the background. Normalised variable importance was assessed and variable response functions were produced using BIOMOD2's default procedure. Model predictive performance was assessed by calculating the Area Under the Receiver-Operator Curve (AUC) for model predictions on the evaluation data, that were reserved from model fitting. AUC can be interpreted as the probability that a randomly selected presence has a higher model-predicted suitability than a randomly selected absence.

An ensemble model was created by first rejecting poorly performing algorithms with relatively extreme low AUC values and then averaging the predictions of the remaining algorithms, weighted by their AUC. To identify poorly performing algorithms, AUC values were converted into modified z-scores based on their difference to the median and the median absolute deviation across all algorithms (Iglewicz & Hoaglin, 1993). Algorithms with $z < -2$ were rejected. In this way, ensemble projections were made for each dataset and then averaged to give an overall suitability.

Results

The ensemble model suggested that suitability for *H. sericea* was most strongly determined by the minimum temperature of the coldest month, mean temperature of the warmest quarter, climatic moisture index and soil pH (Table 1). From Figure 3, the ensemble model estimated suitable conditions for occurrence with:

- Minimum temperature of the coldest month =6.2 °C (>50% suitability for -0.3 – 23.1 °C)
- Mean temperature of the warmest quarter = 20.0 °C (>50% suitability for 15.5 – 24.8 °C)
- High climatic moisture index
- Low soil pH

Annual burn probability and precipitation seasonality had little influence on the model predictions (Table 1, Figure 3). All these estimates are conditional on the other predictors being at their median value in the data used in model fitting.

There was substantial variation among modelling algorithms in the partial response plots (Figure 3). In part this will reflect their different treatment of interactions among variables. Since partial plots are made with other variables held at their median, there may be values of a particular variable at which this does not provide a realistic combination of variables to predict from. It also demonstrates the value of an ensemble modelling approach in averaging out the uncertainty between algorithms.

Global projection of the model in current climatic conditions indicates that the native and known invaded records generally fell within regions predicted to have high climatic suitability (Figure 4). The model predicts potential for further expansion of the non-native range of the species into southeast Australia, and in parts of southeast Asia, southwest Africa, temperate and Mediterranean regions of South America, Mexico and the west coast of USA (Figure 4).

The projection of suitability in Europe and the Mediterranean region suggests that *H. sericea* may be capable of establishing further populations in Portugal and northern Spain, France, Italy, the eastern Adriatic coast and the southern Black sea coast (Figure 5). There are also areas of marginal climatic suitability predicted for northern France, Belgium, Netherlands and UK (Figure 5). The main limiting factor for climatic suitability in northern Europe appeared to be low winter temperatures.

By the 2070s, under climate change scenario RCP8.5, the suitability region in Europe is predicted to expand north eastwards and cover most of temperature Europe from Germany in the east, to Ireland in the west and as far north as the south coasts of Sweden and Norway (Figure 6).

A caveat on these predictions is that the modelling did not fully account for edaphic factors that might restrict establishment in climatically suitable locations. *Hakea sericea* mainly establishes on well drained soils derived from sandstone and quartzite rock with low nutrient levels (CABI, 2015). Overlaying the climatic suitability projections with the distributions of the favoured rock types (Figure 7), suggests lithology may restrict establishment in some regions considered climatically suitable at present. This includes northern Spain, southwest, northeast and southeast France, Italy, the southern Black Sea coastline (Figure 7a). Likewise, northern range expansion under climate change may be restricted to lithologically suitable regions (Figure 7b).

In terms of Biogeographical Regions (Bundesamt fur Naturschutz (BfN), 2003), those predicted to be most climatically suitable (ignoring edaphic constraints) for *H. sericea* establishment in the current climate are Mediterranean, Atlantic, Black Sea and Macaronesia (Figure 8). Climate change scenario RCP8.5 is predicted to increase suitability dramatically in the Atlantic and Continental regions, but decrease suitability in the Mediterranean, Macaronesia and Black Sea regions (Figure 8). These decreases appear largely driven by increases in summer temperatures beyond the species optima shown in Figure 3.

Table 1. Summary of the cross-validation predictive performance (AUC) and variable importances of the fitted model algorithms and the ensemble (AUC-weighted average of the best performing seven algorithms). Results are the average from models fitted to ten different background samples of the data.

Algorithm	**Predictive AUC**	**Used in the ensemble**	**Variable importance**					
			Minimum temperature of coldest month	**Mean temperature of warmest quarter**	**Precipitation seasonality**	**Climatic moisture index**	**Soil pH**	**Annual burning probability**
GLM	0.9668	yes	50%	36%	1%	1%	11%	1%
ANN	0.9655	yes	40%	28%	3%	18%	6%	4%
MARS	0.9653	yes	52%	34%	0%	12%	2%	0%
GAM	0.9649	yes	51%	36%	3%	4%	6%	1%
GBM	0.9627	yes	48%	37%	0%	7%	2%	5%
FDA	0.9571	yes	66%	22%	0%	9%	3%	1%
RF	0.9412	no	42%	25%	4%	11%	10%	8%
MEMLR	0.9348	no	51%	1%	10%	1%	15%	24%
CTA	0.9345	no	48%	38%	0%	7%	6%	0%
Maxent	0.8215	no	59%	22%	0%	4%	4%	10%
Ensemble	0.9673		51%	32%	1%	9%	5%	2%

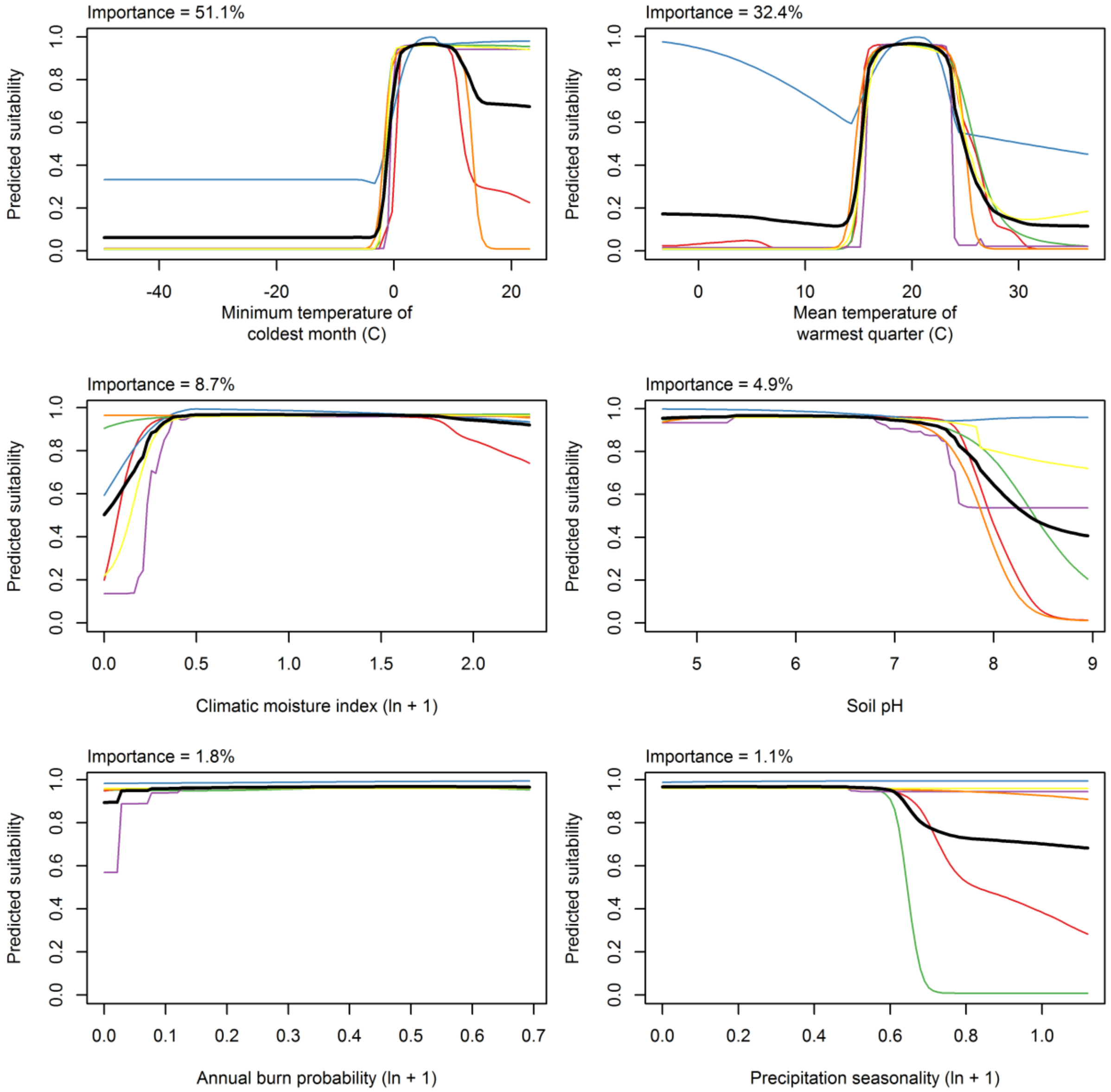


Figure 3. Partial response plots from the fitted models, ordered from most to least important. Thin coloured lines show responses from the seven algorithms, while the thick black line is their ensemble. In each plot, other model variables are held at their median value in the training data. Some of the divergence among algorithms is because of their different treatment of interactions among variables.

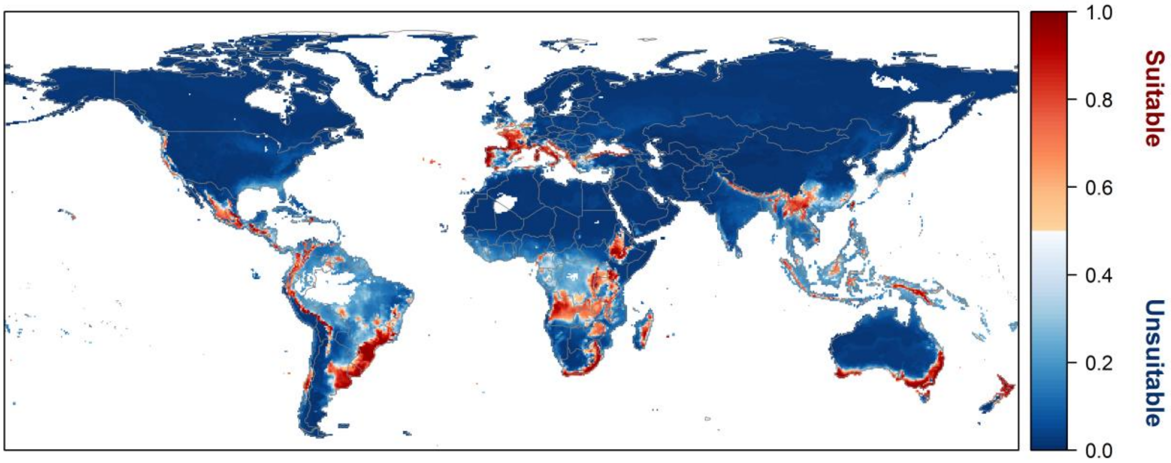


Figure 4. Projected global suitability for *Hakea sericea* establishment in the current climate. For visualisation, the projection has been aggregated to a 0.5 x 0.5 degree resolution, by taking the maximum suitability of constituent higher resolution grid cells. Values > 0.5 may be suitable for the species. The white areas have climatic conditions outside the range of the training data so were excluded from the projection.

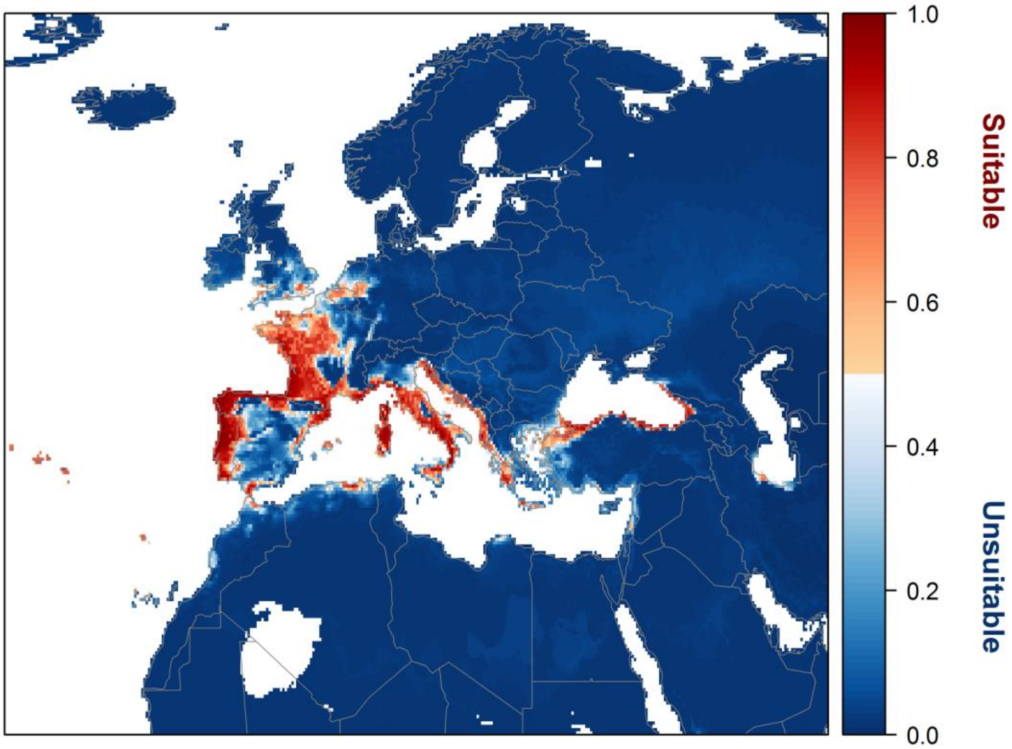


Figure 5. Projected current climatic suitability for *Hakea sericea* establishment in Europe and the Mediterranean region. The white areas have climatic conditions outside the range of the training data so were excluded from the projection.

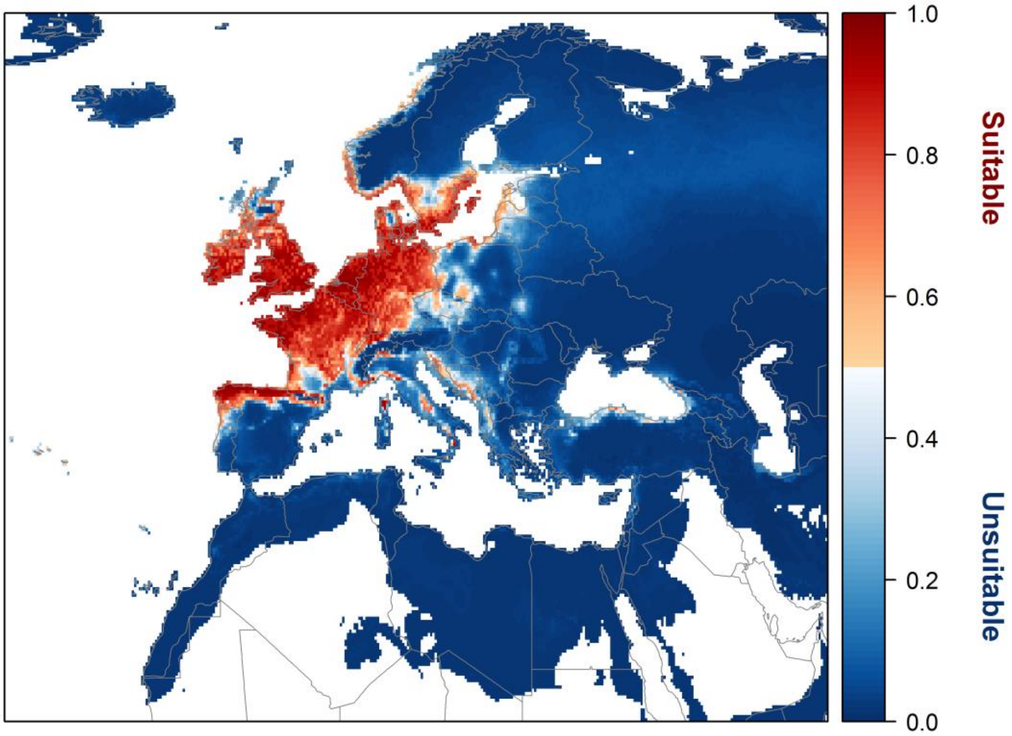
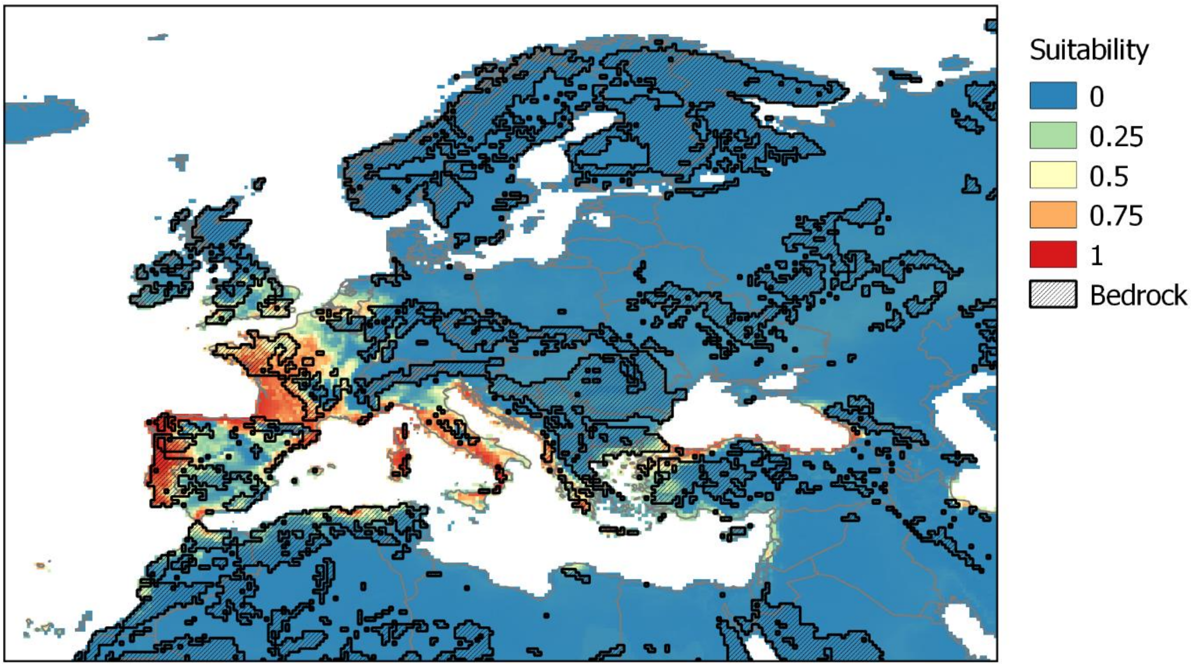


Figure 6. Projected climatic suitability for *Hakea sericea* establishment in Europe and the Mediterranean region in the 2070s under climate change scenario RCP8.5, equivalent to Figure 5.

(a) Current climate



(b) RCP8.5 climate in the 2070s

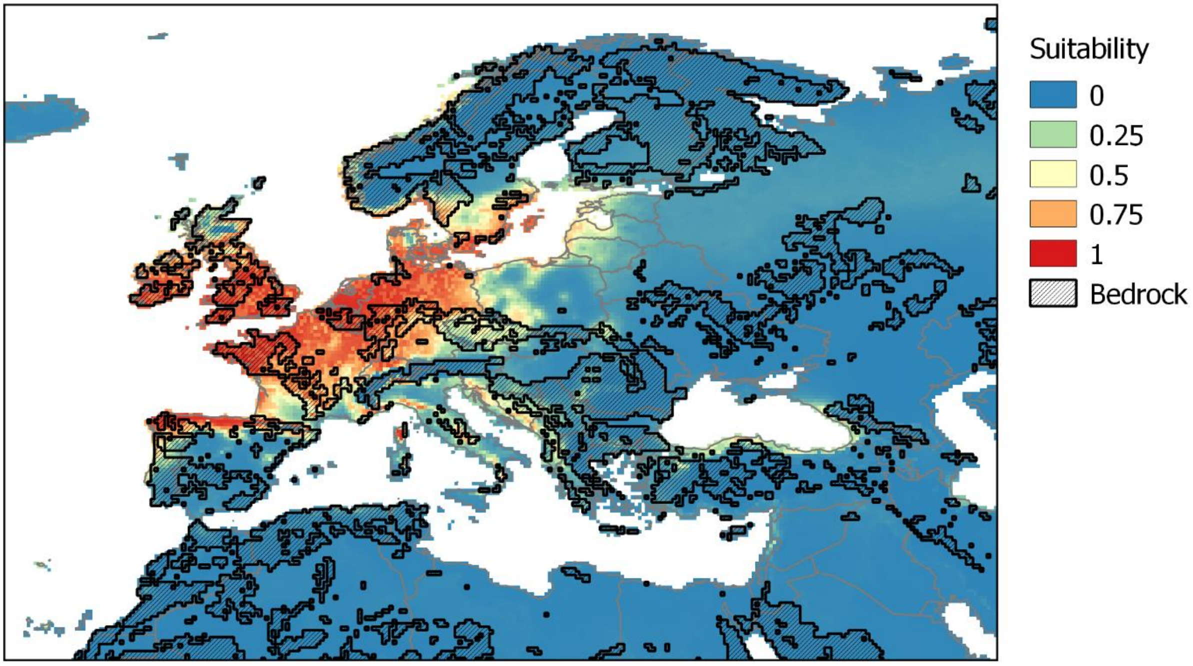


Figure 7. Overlay of the climatic suitability maps for *Hakea sericea* in Figures 5 and 6 with the distribution of its preferred bedrock types. Map shading indicates modelled climatic suitability. The hatched polygons in the maps show regions with >25% coverage of siliclastic sedimentary or metamorphic rock, derived from the GLiM Global Lithology Map (Hartmann & Moosdorf, 2012). These are *Hakea*'s preferred bedrock types (CABI, 2015) and capture nearly all of the species distribution records.

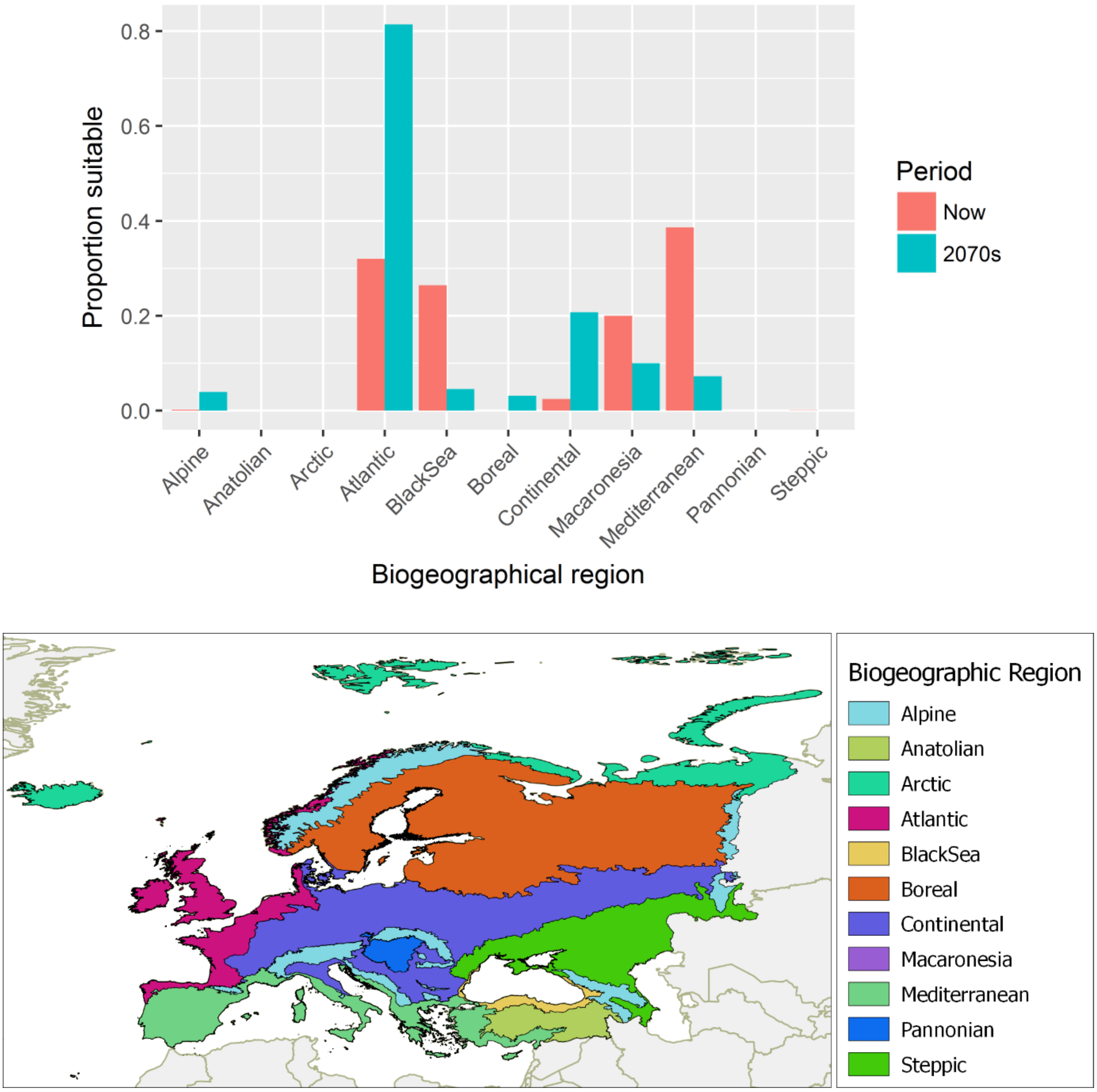


Figure 8. Variation in projected climatic suitability among Biogeographical regions of Europe (Bundesamt fur Naturschutz (BfN), 2003). The bar plots show the proportion of grid cells in each region classified as suitable in the current climate and projected climate for the 2070s under emissions scenario RCP8.5. The coverage of each region is shown in the map below. Climatic suitability may over-estimate potential occurrence in climatically suitable regions where edaphic constraints restrict occurrence.

Caveats to the modelling

To remove spatial recording biases, the selection of the background sample was weighted by the density of Tracheophyte records on the Global Biodiversity Information Facility (GBIF). While this is preferable to not accounting for recording bias at all, a number of factors mean this may not be the perfect null model for species occurrence:

- The GBIF API query used to did not appear to give completely accurate results. For example, in a small number of cases, GBIF indicated no Tracheophyte records in grid cells in which it also yielded records of the focal species.
- We located additional data sources to GBIF, which may have been from regions without GBIF records.

Other non-climatic variables potentially affecting the distribution of the species were not included in the model. As indicated in Figure 7, occurrence of the species may be restricted to preferred bedrock types within the climatically suitable region, and other factors such as high nutrient availability may further restrict occurrence of the species.

Model outputs were classified as suitable or unsuitable using a threshold of 0.5, effectively a ‘prevalence threshold’ given the prevalence weighting of model-fitting. There is disagreement about the best way to select suitability thresholds so we evaluated the threshold selected by the commonly-used ‘minROCdist’ method. This would have selected a threshold of 0.42, increasing the region predicted to be suitable for *H. sericea*.

The climate change scenario used is the most extreme of the four RCPs. However, it is also the most consistent with recent emissions trends and could be seen as worst case scenario for informing risk assessment.

References

R. J. Hijmans, S. E. Cameron, J. L. Parra, P. G. Jones & A. Jarvis (2005) Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology* **25**, 1965-1978.

R. J. Zomer, A. Trabucco, D. A. Bossio & L. V. Verchot (2008) Climate change mitigation: A spatial analysis of global land suitability for clean development mechanism afforestation and reforestation. *Agriculture, Ecosystems & Environment* **126**, 67-80.

G. H. Hargreaves (1994) Defining and Using Reference Evapotranspiration. *Journal of Irrigation and Drainage Engineering* **120**.

J. York & R. J. Whelan (1998) Post-fire germination of Hakea sericea and Petrophile sessilis after spring burning. *Australian Journal of Botany* **46**, 367-376.

C. L. Brown & R. J. Whelan (1999) Seasonal occurrence of fire and availability of germinable seeds in Hakea sericea and Petrophile sessilis. *Journal of Ecology* **87**, 932-941.

G. R. Van der Werf, J. T. Randerson, L. Giglio, G. Collatz, M. Mu, P. S. Kasibhatla, D. C. Morton, R. DeFries, Y. v. Jin & T. T. van Leeuwen (2010) Global fire emissions and the contribution of deforestation, savanna, forest, agricultural, and peat fires (1997–2009). *Atmospheric Chemistry and Physics* **10**, 11707-11735.

L. Giglio, J. T. Randerson & G. R. Werf (2013) Analysis of daily, monthly, and annual burned area using the fourth-generation global fire emissions database (GFED4). *Journal of Geophysical Research: Biogeosciences* **118**, 317-328.

J. Randerson, Y. Chen, G. Werf, B. Rogers & D. Morton (2012) Global burned area and biomass burning emissions from small fires. *Journal of Geophysical Research: Biogeosciences* **117**.

Wildlife Conservation Society - WCS & Center for International Earth Science Information Network - CIESIN - Columbia University (2005) Last of the Wild Project, Version 2, 2005 (LWP-2): Global Human Influence Index (HII) Dataset (Geographic). NASA Socioeconomic Data and Applications Center (SEDAC), Palisades, NY.

W. Thuiller, D. Georges & R. Engler (2014) biomod2: Ensemble platform for species distribution modeling. R package version 3.3-7 *Available at: https://cran.r-project.org/web/packages/biomod2/index.html*.

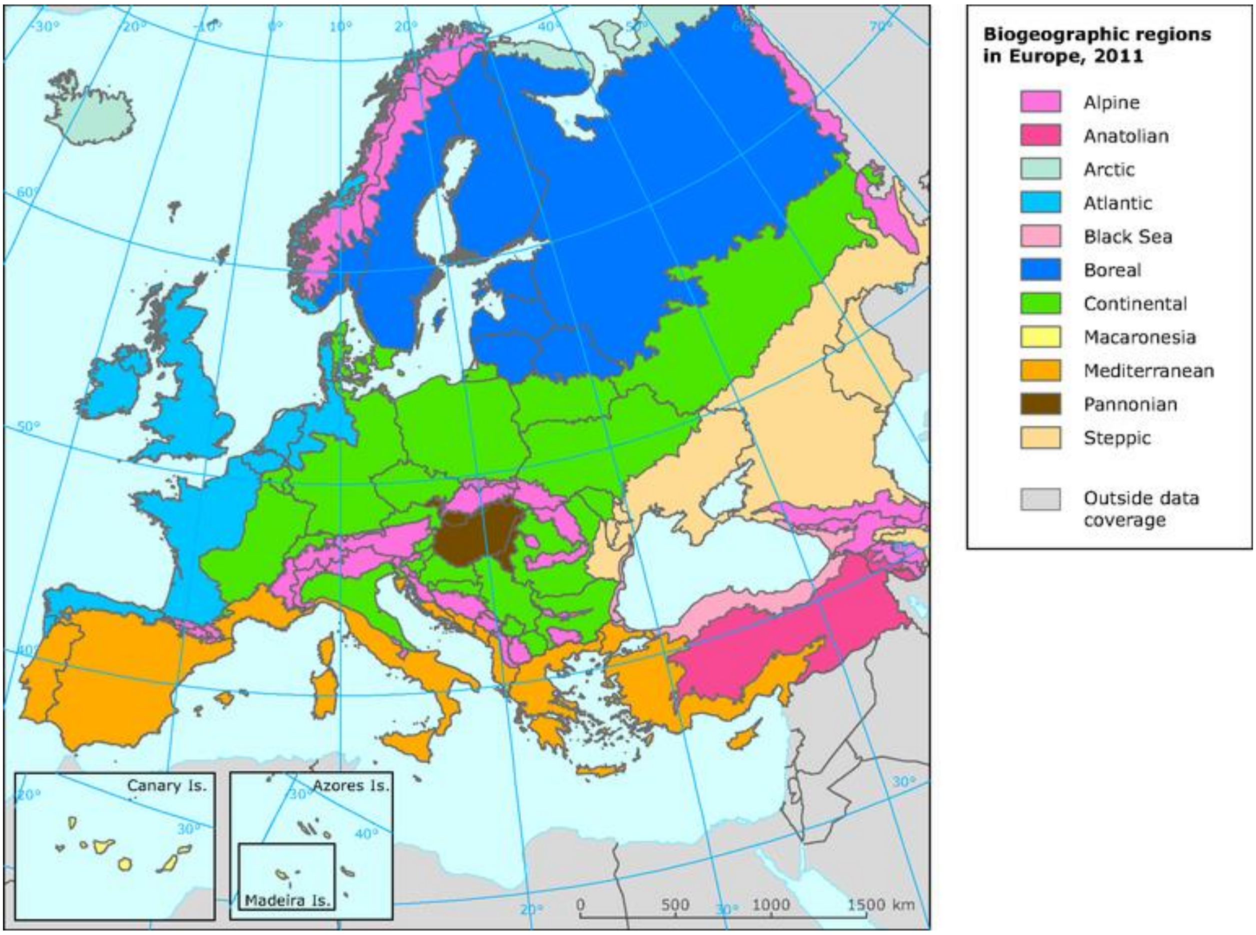
W. Thuiller, B. Lafourcade, R. Engler & M. B. Araújo (2009) BIOMOD–a platform for ensemble forecasting of species distributions. *Ecography***32**, 369-373.

CABI (2015) *Hakea sericea* (silky hakea). In *Invasive Species Compendium*, Wallingford, UK.

B. Iglewicz & D. C. Hoaglin (1993) *How to detect and handle outliers*. Asq Press.

Bundesamt fur Naturschutz (BfN) (2003) Map of natural vegetation of Europe. Web site: http://www.bfn.de/. National data included.

Appendix 2 Biogeographical regions



Appendix 3. Relevant illustrative pictures (for information)

Figure 1. A flowering stand of *Hakea sericea*

Figure 2. Mature seed pods of *Hakea sericea*

Figure 3. Habitat invaded by *Hakea Sericea*

Figure 4. Seed pods opened by fire

Figure 5. Flowers and leaves of *Hakea sericea*

Figure 6. Monoculture of *Hakea sericea* in Portugal

Figure 7. Seed pods opened by fire on the ground

Figure 8. Seedling with cotyledons

Appendix 4: Distribution summary for EU Member States and Biogeographical regions

Member States:

	Recorded	Established (currently)	Established (future)	Invasive (currently)
Austria	–	–	–	–
Belgium	–	–	YES	–
Bulgaria	–	–	–	–
Croatia	–	–		
Cyprus	–	–	–	–
Czech Republic	–	–	–	–
Denmark	–	–	YES	–
Estonia	–	–	–	–
Finland	–	–	–	–
France	YES	YES	YES	YES
Germany	–	–	YES	–
Greece	–	–	–	–
Hungary	–	–	–	–
Ireland	–	–	YES	–
Italy	–	–	-	–
Latvia	–	–	–	–
Lithuania	–	–	–	–
Luxembourg	–	–	YES	–
Malta	–	–	–	–
Netherlands	–	–	YES	–
Poland	–	–	–	–
Portugal	YES	YES	YES	YES
Romania	–	–	–	–
Slovakia	–	–	–	–
Slovenia	–	–	–	–
Spain	YES	YES	YES	YES
Sweden	–	–	YES	–
United Kingdom	–	–	YES	–

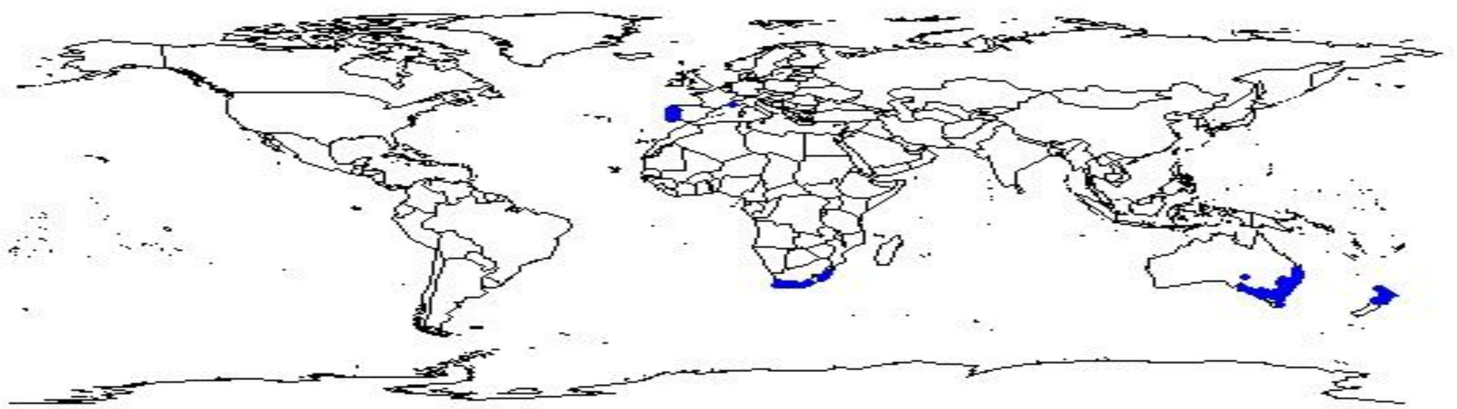
Biogeographical regions

	Recorded	Established (currently)	Established (future)	Invasive (currently)
Alpine	–	–	–	–
Atlantic	YES	YES	YES	YES
Black Sea	–	–	YES	–
Boreal	–	–		YES
Continental	–	–	YES	YES
Mediterranean	YES	YES	YES	YES
Pannonian	–	–	–	–
Steppic	–	–	–	–

YES: if recorded in natural environment, established or invasive or can occur under future climate; **–** if not recorded, established or invasive; **?** Unknown

Appendix 5[6]

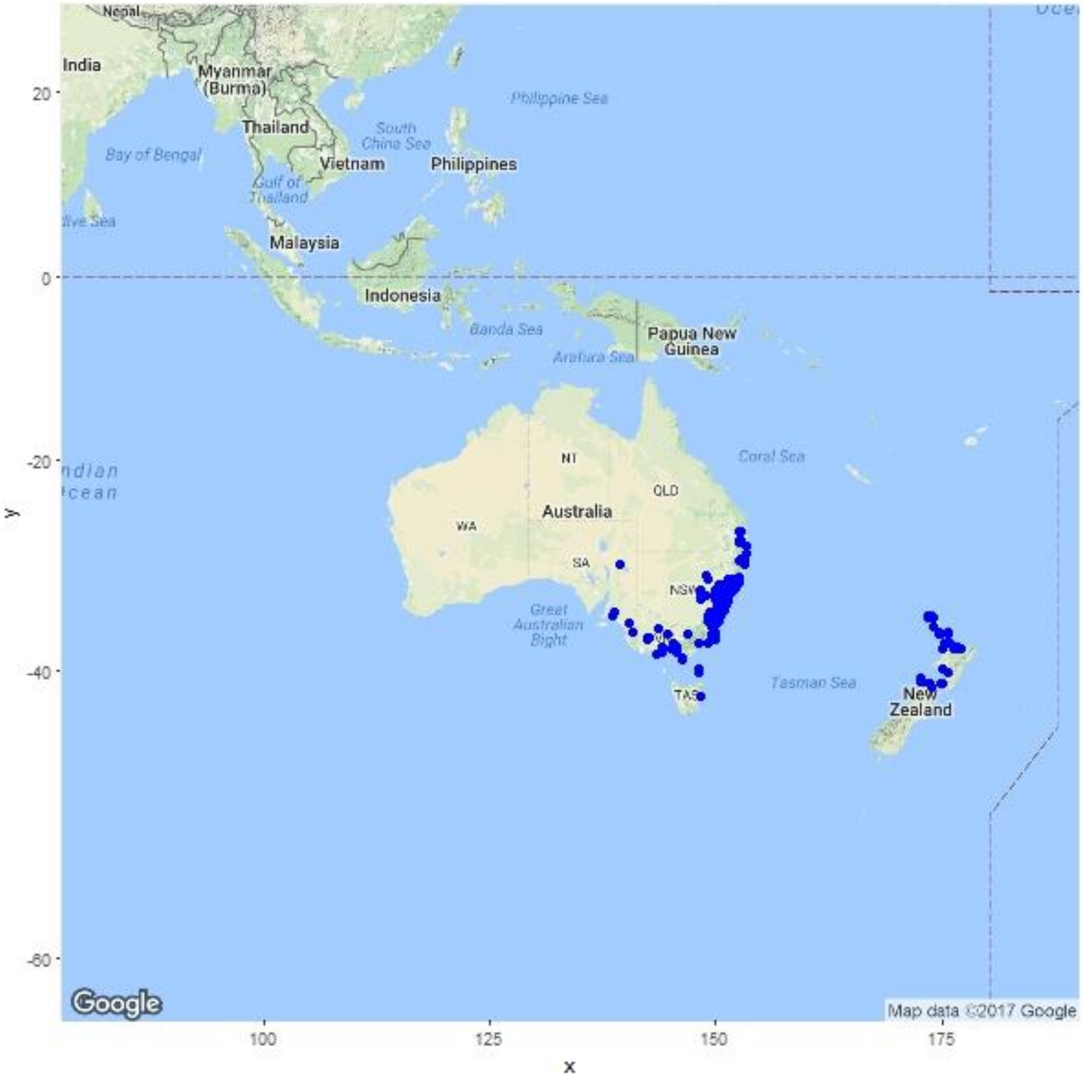
Distribution maps for *Hakea sericea*: world map

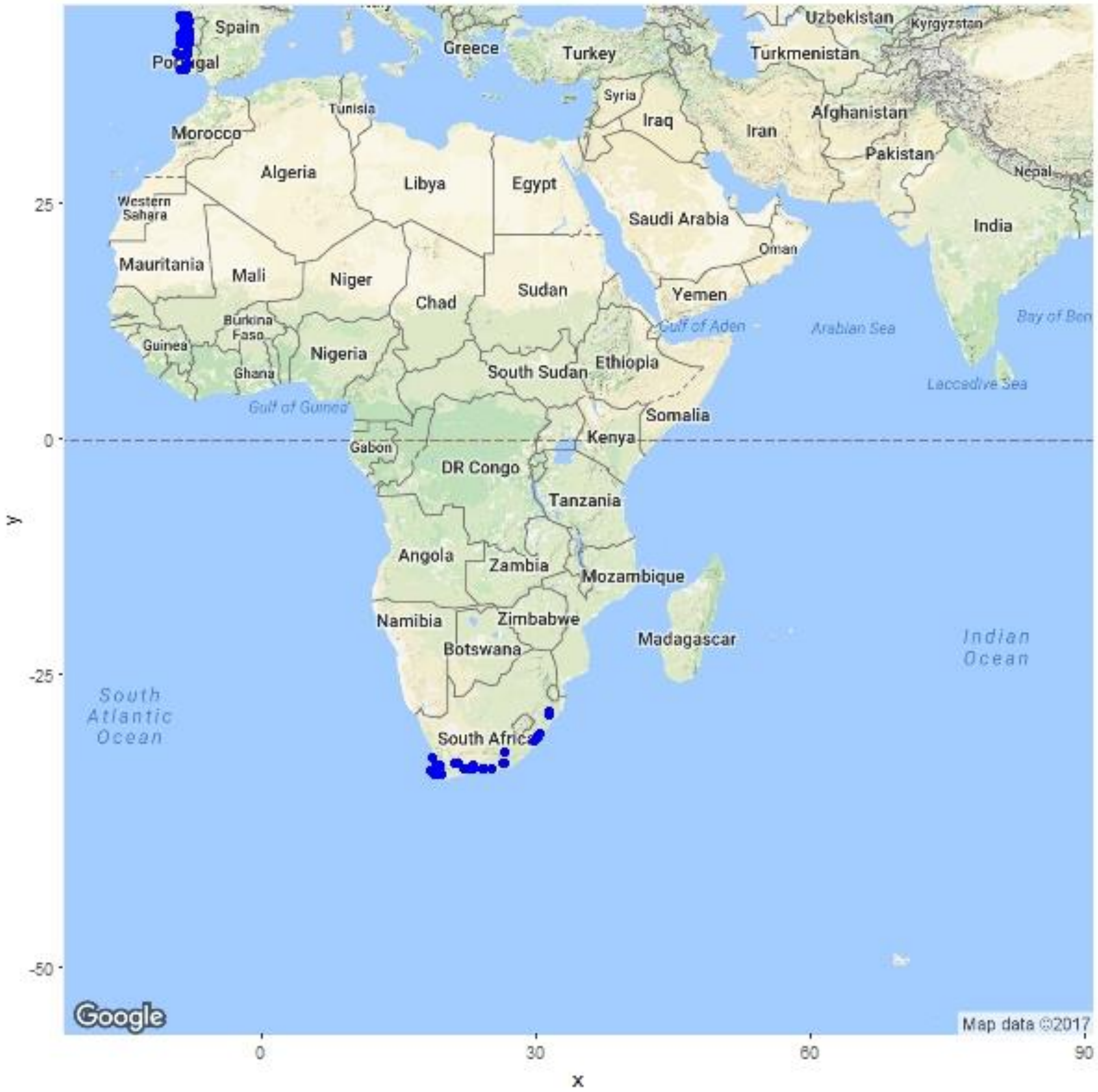


---

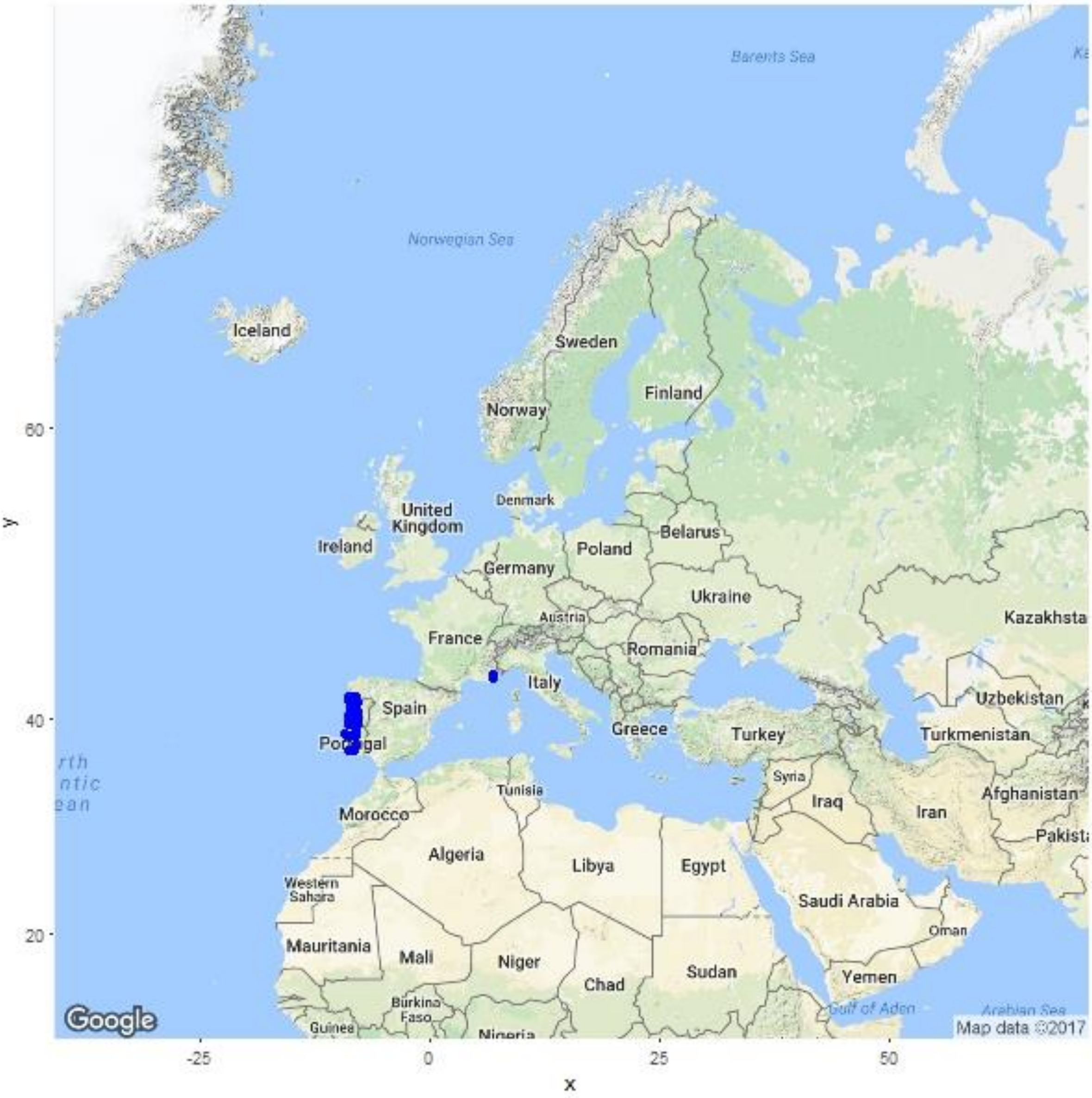
[6] Note that these maps may contain records, e.g. herbarium records, that were not considered during the climate modelling stage. Date to compile the maps were taken from various sources including GBIF, scientific literature and grey material

Distribution maps for *Hakea sericea*: Australia





Distribution maps for *Hakea sericea*: Africa



Distribution maps for *Hakea sericea*: Europe