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

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Pest risk assessment for *Prosopis juliflora*

2018, EPPO
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This pest risk assessment 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'.

Photo: *P. juliflora invading native Acacia tortillis dominated savanna scrub, Djibouti. Nick Pasiecznik*

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

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The pest risk assessment for *Prosopis juliflora* 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 *Prosopis juliflora* was first drafted by Nick Pasiecznik

- 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)

Approved by the IAS Scientific Forum on 26/10/2018

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Summary[1] of the Express Pest risk assessment for *Prosopis juliflora*

PRA area: https://www.eppo.int/ABOUT_EPPO/images/clickable_map.htm

Describe the endangered area:
Based on the current environmental conditions, species distribution modeling identified suitable areas for establishment of *Prosopis juliflora* in the Mediterranean and Macaronesian biogeographical region. Largely frost-free coastal and low-lying inland areas are suitable, including parts of Cyprus, Greece (and the islands), Italy (including Sardinia and Sicily), Malta, Portugal (including Madeira and the Azores), Spain (including Gran Canaria (Canary Islands)) and the wider EPPO region - Turkey, North African countries (Algeria, Morocco and Tunisia), and Israel, the West Bank and Jordan (see appendix 1 and 2).

Arid or semi-arid habitats in the endangered area are those at highest risk. The main limiting factor restricting suitability for the species appears to be low winter temperatures.

Main conclusions
The results of the PRA show that *P. juliflora* poses a moderate risk to the endangered area. The EWG consider this the case as, notwithstanding the high score for impact, indisputable in the current area and considered high for the PRA area, the risk of introduction and the potential area for establishment are both perceived as low, leading the EWG to propose an overall phytosanitary risk score of moderate.

Entry and establishment
In the EPPO region, *P. juliflora* is recorded as established in Israel, the West bank and Jordan, and two trees planted in Spain in 1988 still survive. In addition, the species is naturalised in a small area in Gran Canaria (Canary Islands). The likelihood of *P. juliflora* entering the EPPO region is low with a moderate uncertainty. The species is traded from outside the region.

Potential impacts in the PRA area
To date, there have been no studies on the impact of *Prosopis juliflora* in the EPPO region. Dufour-Dror and Shmida (2017) suggests that the establishment of *Prosopis* species along streams with a permanent water flow in the Dead Sea Valley will impact on biodiversity, displacing native plant species like *Acacia raddiana*, *Salvadora persica* or *Moringa peregrina* and goes on to suggest that the potential impacts in Jordan will be greater than Israel.

In addition to impacts on biodiversity, impacts on ecosystem services will potentially be similar to those impacts seen in the current area of distribution, with the exception, potentially, of significant impacts on communities and local livelihoods. The potential establishment of *Prosopis* species along protected stream systems around the Dead Sea may have significant impacts on water flow and availability (Dufour-Dror and Shmida, 2017).

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

The EWG is of the opinion that impacts will be restricted to a small area of the EPPO region where the species can establish (the endangered area, see above). In the absence of specific data on impacts in the PRA area the rating of magnitude of impacts remains high for impacts on biodiversity, ecosystem services and socio-economic impacts, however, uncertainty is raised to high for all categories, as it is not clear if these impacts will be realised throughout areas of potential establishment in the PRA area (EWG opinion). However, the text within this section does not relate equally to EU Member States and non-EU Member States in the EPPO region (see section 13.04). In the EU, in frost-free coastal and low-lying inland areas of Cyprus, Greece, Italy, Malta, Portugal, and Spain, impacts on biodiversity and impacts on ecosystem services could be similar to those impacts seen in the current area of distribution and the isolated areas of establishment in the EPPO region, with the exception, potentially, of significant impacts on communities and local livelihoods (EWG opinion). However, for this to be realised extensive populations of the species would need to establish and this would be more uncertain of occurring compared to areas in Israel and Jordan. In addition, even though the species has been sold as an ornamental species and as a forestry species globally, this is unlikely to be a significant pathway into the EU in future. Therefore, for EU Member States detailed in the endangered area (as above) a moderate rating has been given for impacts on biodiversity, ecosystem services and socio-economic impacts with a high uncertainty.

Climate change

By the 2070s, under climate change scenario RCP8.5, the suitable region for *P. juliflora* in Europe is predicted to increase somewhat, but still be restricted to the same regions. The Biogeographical Regions most suitable for establishment are predicted to be Macaronesia and the Mediterranean, with both projected to become more suitable under the climate change scenario evaluated. Ranges may increase in countries where it is already predicted to be suitable (Cyprus, Greece, Italy, Malta, Portugal, Spain and Turkey, North Africa (Algeria, Morocco and Tunisia), and Israel, the West Bank and Jordan), with the addition of Albania and Croatia. The influence of projected climate change scenarios has not been considered in the overall scoring of the risk assessment based on the high levels of uncertainty with future projections.

Phytosanitary measures

The results of this PRA show that *Prosopis juliflora* poses a moderate risk to the endangered area (Mediterranean and Macaronesian Biogeographical region) with a moderate uncertainty.

Phytosanitary risk (including impacts on biodiversity and ecosystem services) for the *<u>endangered area</u>* (current/future climate)* * Where the EWG consider scores will be different between EU and non-EU countries in the EPPO region an additional score is detailed. **Pathway for entry:**	High ☐	Moderate X	Low ☐

Plants for planting (horticulture): Low/Low Plants for planting (forestry) Low/Low Likelihood of establishment in natural areas (EPPO region): Moderate/High Likelihood of establishment in managed areas (EPPO region): Moderate/High Likelihood of establishment in natural areas (EU MS): Moderate/High Likelihood of establishment in managed areas (EU MS): Moderate/High Spread (EPPO region): High/High Spread (EU Member States) Moderate/Moderate **Impacts (current area of distribution)** Biodiversity and environment: High/High Ecosystem services: High/High Socio-economic: High/High **Impacts (EPPO region)** Biodiversity and environment: High/High Ecosystem services: High/High Socio-economic: High/High **Impacts (EU Member States)** Biodiversity and environment: Moderate/High Ecosystem services: Moderate/High Socio-economic: Moderate/High For EU Member States, the overall phytosanitary risk remains as moderate.			
Level of uncertainty of assessment (current/future climate)* * Where the EWG consider scores will be different between EU and non-EU countries in the EPPO region an additional score is detailed. **Pathway for entry** Plants for planting: Moderate/Moderate Plants for planting (forestry) Moderate/Moderate	High ☐	Moderate X	Low ☐

Likelihood of establishment in natural areas (EPPO region): Low/High Likelihood of establishment in managed areas (EPPO region): Low/High Likelihood of establishment in natural areas (EU Member States): High/High Likelihood of establishment in managed areas (EU Member States): High/High Spread (EPPO region): Moderate/Moderate Spread (EU Member States) High/High **Impacts (current area of distribution)** Biodiversity and environment: Low: Low Ecosystem services: Low: Low Socio-economic: Low: Low **Impacts (EPPO region)** Biodiversity and environment: High/High Ecosystem services: High/High Socio-economic: High/High **Impacts (EU Member States)** Biodiversity and environment: High/High Ecosystem services: High/High Socio-economic: High/High For EU Member States, the overall uncertainty increases from moderate to high.			
Other recommendations: • This PRA was conducted specifically for *Prosopis juliflora* as the species was identified through horizon scanning studies. However, as highlighted during the work of the EWG and noted in the text, several other *Prosopis* species are also a potential threat to the EU and the EPPO region. These are *P. chilensis* and *P. velutina* that have both been observed fruiting and the latter naturally reseeding in Almeria, south-eastern Spain (first report, Pasiecznik and Penalvo Lopes, 2016), *P. velutina* naturalising in Morocco (first report, Sukhorukov et al., 2017), and the closely related *P. glandulosa*. And noting these first reports, a detailed review may reveal further recent reports of naturalisations of these species in the EPPO region. • All three these species are also recorded as having very similar ecological and socio-economic impacts compared to *P. juliflora*, and the latter two are reported as highly invasive in Australia, South Africa and the USA. But being more frost tolerant than *P. juliflora*, they are also considered to pose an even greater threat to the PRA area. It was not possible to			

expand the PRA to cover these additional species in the current project, but it recommended that these be considered for future PRAs.

- Noting the taxonomic difficulties in distinguishing *P. juliflora* from all the other above-mentioned species, the EWG recommend careful identification of any *Prosopis* taxa entering the region. This is currently constrained by the lack of confirmed reference material and supporting systematic treatment of all introduced taxa. Further morphological and genetic analysis is recommended.

Express Pest risk assessment:

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Prosopis juliflora

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Stage 1. Initiation

Reason for performing the PRA:

Prosopis juliflora currently has a very limited naturalised distribution in the EPPO region. It is currently reported as naturalised in low lying areas in Israel, the West Bank and Jordan (Dufour-Dror and Shmida, 2017), although records of *P. juliflora* outside of the Jordan valley are considered by the Expert Working Group (EWG) to be possible mis-identifications. *Prosopis juliflora* was first confirmed as present in Jordan by Harris et al. (2003). The species is also present in Almeria (two planted trees only), south-eastern Spain (Pasiecznik and Peñalvo López, 2016) and reported as naturalised in a very limited area in Gran Canaria (Canary Islands) (Verloove, 2013, 2017). 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). *Prosopis juliflora* was one of 16 species identified as having a high priority for PRA. The species is certainly one of the most invasive woody weeds in the world's tropical drylands, and the genus as a whole was included in the widely cited '100 of the World's Worst Invasive Alien Species'. For example, of all the introductions of *Prosopis* species globally, 79% led to naturalisation of which 38 % have become invasive (for review see Shackleton et al., 2014).

PRA area: 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

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

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.

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:

Prosopis juliflora (Sw.) DC. (Spermatophyta, Dicotyledonae, Fabales, Fabaceae/Leguminosae, subfam. Mimosoideae).

EPPO Code: PRCJU

Synonyms: *Acacia cumanensis* Willd., *Acacia juliflora* (Sw.) Willd., *Acacia salinarum* (Vahl) DC., *Algarobia juliflora* (Sw.) Heynh., *Algarobia juliflora* (Sw.) Benth., *Desmanthus salinarum* (Vahl) Steud., *Mimosa juliflora* Sw., *Mimosa piliflora* Sw., *Mimosa salinarum* Vahl, Neltuma bakeri Britton & Rose, *Neltuma juliflora* (Sw.) Raf., *Neltuma occidenatlis* Britton & Rose, *Neltuma pallescens* Britton & Rose, *Prosopis bracteolata* DC., *Prosopis cumanensis* (Willd.) Kunth, *Prosopis domingensis* DC., *Prosopis dulcis* var. *domingensis* (DC.) Benth., *Prosopis vidaliana* Fern.-Vill.

Common name: English: mesquite (see Appendix 3 for additional common names)

Plant type: Evergreen, broadleaved, perennial, seed propagated, woody shrub or tree

Related species in the EPPO region:

The distantly related *P. farcta*, a low shrub/sub-shrub noted as a weed of rangelands and orchards, is the only *Prosopis* species native to parts of the EPPO region. EPPO member countries where Burkart (1976) and USDA-ARS (2017) records *P. farcta* as native include those in the southern and eastern Mediterranean (Algeria, Tunisia, Cyprus, Israel, Jordan, Turkey), the Caucasus (Georgia, Azerbaijan, southern Russia) and Central Asia (Kazakhstan, Uzbekistan). Of ‘potential EPPO member countries’, it is recorded as present in Egypt, Iran, Lebanon, Tajikistan, Turkmenistan (USDA-ARS, 2017). *Prosopis cineraria* and *P. koelziana* are also native to Iran (Shackleton *et al*., 2014).

Individuals of *P. chilensis*, *P. glandulosa* and *P. velutina* along with *P. juliflora* were planted out in trials in Almeria, Spain in 1988-89, and of particular concern, both *P. chilensis* and *P. velutina* have been observed to be fruiting. Concern was raised about the invasive potential of the latter two prosopis species and were recommended for eradication (Pasiecznik and Peñalvo López, 2016).

Both *P. juliflora* and *P. glandulosa* are available according to the PPP-Index which lists plant species available for sale in Europe.

Taxonomic confusion

The taxonomic confusion surrounding species of *Prosopis* within the Section Algarobia must be highlighted at the outset, and that some databases (incorrectly) group all *Prosopis* species together or repeat taxonomical errors of the past.

The general common name is mesquite or simply prosopis, but note, that as a common group name, species of *Prosopis* are hereby referred to in normal script (not italics) and all in lower case, as are acacia, eucalyptus, leucaena, etc. Also, as a common name, mesquite is also used for other species of Section Algarobia such as *P. glandulosa* (Lowe et al., 2000), and occasionally for others outside of this Section, either with or without a specific epithet (e.g. *P. glandulosa* should be honey mesquite, *P. velutina*, velvet mesquite, etc.).

The following information on taxonomy and nomenclature is adapted from the *P. juliflora* datasheet in the Invasive Species Compendium (CABI, 2017), including a recent review submitted (February 2017, unpublished), the most up-to-date review of the taxonomy of species.

Prosopis juliflora (Sw.) DC. has had an array of synonymy since its first description in 1788. Originally known as *Mimosa juliflora* Sw., it became both *Algarobia juliflora* (Sw.) Benth. ex Heynh. and *Neltuma juliflora* (Sw.) Raf. during the last two centuries before both genera were incorporated into the single, overarching genus *Prosopis*. Bentham (1875) noted *P. limensis* (syn. *P. pallida*) from Peru as the only *Prosopis* species of section Algarobia he was aware of that was not sympatric with others in the section. This may assume that he was either unaware of *P. juliflora* and hybrids in Ecuador and northern Peru, or that he treated them all as the same species, distinct from the *P. juliflora* of Central America, Colombia and the Caribbean.

Prosopis juliflora was used by Pasiecznik et al. (2001) in its original, restricted and certainly biological sense, re-established by Burkart (1940) and accepted by Benson (1941) and Johnston (1962). The all-embracing, collective *P. juliflora* concept of Bentham (1875) was maintained by others and, although currently rejected by most taxonomists and researchers, it is still used occasionally to this day. Much confusion occurs when referring to old literature, because the binomial *P. juliflora* was used to describe species now generally accepted as separate taxa.

The following three varieties were accepted by Burkart (1976) and without any information to the contrary, also by Pasiecznik et al. (2001): *Prosopis juliflora* (Sw.) DC. var. *juliflora*, *Prosopis juliflora* (Sw.) DC. var. *inermis* (H.B.K.) Burkart and *Prosopis juliflora* (Sw.) DC. var. *horrida* (Kunth) Burkart. However, even then, the taxonomy was still uncertain, with Burkart noting that the two varieties var. *inermis* and var. *horrida*, differed from var. *juliflora* principally in the relative presence/absence of thorns, with no other striking morphological basis for the separation. However, particularly at the range limits in Mexico and Peru/Ecuador, further revision is expected.

The '*P. pallida* – *P. juliflora* complex' was proposed by Pasiecznik et al. (2001) as a means to overcome the observed ambiguities and lack of agreement on how to taxonomically deal with tropical American prosopis, and discusses previous proposals and revisions in detail. This followed the treatment by Johnston (1962), who divided *P. juliflora* into two races, the Central American, and Colombian-Caribbean race, mainly on the basis of leaflet length, and noted the similarities and the differences between these two and the truly South American *P. limensis* (syn. *P. pallida*).

However, since then, it has been unequivocally shown that the two are distinct taxa, morphologically and genetically (e.g. Harris et al., 2003; Landeras et al., 2006; Catalano et al., 2008; Trenchard et al., 2008; Palacios et al. 2012; Sherry et al., 2012). Comparing native range material with that from introduced populations, however, highlighted a number of serious misidentifications, notable being that the 'common' prosopis in the north east of Brazil, Cape Verde and parts of Senegal is in fact *P. pallida*, and not *P. juliflora* as it has always been referred to (Harris et al., 2003). *Prosopis pallida* has also been positively identified in southern Mauritania (Pasiecznik et al., 2006) and Djibouti (Pasiecznik et al., 2013), from naturalized populations. However, scientific publications from Brazil and Cape Verde, for example, still tend to incorrectly refer to *P. julilfora* as the dominant species there (e.g. Fonseca et al., 2016; Tavares and Barros, 2016).

This PRA is specifically for *Prosopis juliflora* (Sw.) DC.

2. Pest overview

Life cycle

Prosopis juliflora usually begins to flower and fruit after 2-3 years, but this is highly dependent upon site conditions, as trees as young as 12 months old have been observed to flower in the Sahel, and trees 15 years old or more on poor exposed sites have never been seen to flower (Pasiecznik et al., 2001). Almost continuous year-round flowering of *P. juliflora* is seen in India (Goel and Behl, 1995) and Haiti (Timyan, 1996), but there is always a period of maximum fruit production. In parts of India, one or two fruiting periods occur, depending on site and the 'form' of *P. juliflora* present (Luna, 1996). With continuous flowering, periods of major fruit production may correspond to periods of increased pollinator activity and not necessarily to genetic controls, particularly with introduced germplasm.

Prosopis species are generally assumed to be self-incompatible (Solbrig and Cantino, 1975; Simpson, 1977), although some limited self-compatibility (4%) has been observed in *P. juliflora* following bagging and hand pollination (Sareen and Yadav, 1987). Insects are the main pollinators known for the species, in particular bee species (Order Hymenoptera) (Pasiecznik et al., 2001). Anther glands in *P. juliflora* release a protein-carbohydrate exudate and the flower is pollinated while the insect eats the gland (Chaudhry and Vijayaraghavan, 1992). Anther glands also exude a sticky substance to attach the pollen to the body of the insect, to protect the anthers and ovaries, and may also exude an odorous chemical attractant.

Prosopis juliflora seeds possess an inherently high level of dormancy, and the hard seed coats must be broken or weakened to allow water absorption and for germination to occur. Though seed coats soften over time and older seed that is still viable tends to germinate without pre-treatment (Pasiecznik and Felker, 1992). Seeds in entire pods or endocarp shells exhibit decreased germination, thought to be due to impeded water uptake by the seeds, although an allelopathic chemical extract from pod pericarps decreased germination in *P. juliflora* (Warrag, 1994). The passage of seed through the digestive tracts of different animal species has varying effects on germination, through the removal of the mesocarp or endocarp, or other mechanical or chemical factors. *Prosopis juliflora* seeds showed no decrease in final germination with up to 30% added sea water, although the rate of germination was retarded (Khan et al., 1987). Increasing alkalinity markedly decreased the final germination and germination rate of *P. juliflora* seed above pH 9.0 (Srinivasu and Toky, 1996). The optimum temperature for germination of *P. juliflora* seeds is 30-35°C, with germination decreasing rapidly at temperatures below 20°C or above 40°C (Pasiecznik et al., 2001). The optimum sowing depth for seed is 10 mm for *P. juliflora* with germination falling markedly when sown below 20-30 mm deep (Mutha and Burman, 1998).

All *Prosopis* species are able to survive in areas with exceptionally low annual rainfall or very lengthy dry periods, but only if the taproots are able to reach ground water or another permanent water source within the first few years. Being adapted to arid and semi-arid climates, *P. juliflora* generally germinates and establishes during the brief rainy season and seedlings must be sufficiently well established to survive the first dry season. The existence of two root systems, a deep tap root to reach ground water and a mat of surface lateral roots to make use of infrequent rainfall events, puts *Prosopis* species firmly in the category of phreatophytes, but they show a variety of mesophytic and xerophytic characteristics depending on water availability. The need for rain or high water tables is reduced in coastal areas, where sufficient atmospheric moisture exists with persistent trade winds or seasonal fog.

Prosopis juliflora seed pods can produce up to 25 seeds, commonly up to 16 seeds (Pasiecznik et al., 2001). Each tree can produce 300-420 kg of pods per year (Pasiecznik et al., 2001), with an estimate of 2000 seeds per kilogram of pods (Pasiecznik et al., 2012). Felker (1979) and Harding (1988) estimate that each tree can produce between 630,000 and 980,000 seeds per year. In the native range, the seed bank of prosopis spp. is long lived and can persist for at least 15 years (Pasiecznik and Felker, 1992). Estimates from South Africa detail the seed bank can contain as many as 2500 seeds per m^2 (Zachariades et al., 2011).

Environmental requirements

Prosopis juliflora thrives in a wide range of rainfall zones, from 100 mm mean annual rainfall or less in dry coastal zones to 1500 mm at higher altitudes, and the ability to tolerate very low annual rainfall is well known. Mean annual air temperature in the shade where *P. juliflora* is found is generally above 20°C, with optimum temperatures for growth in the range 20-30°C. There appears to be no natural upper limit to temperature, with introduced *P. juliflora* known to tolerate day-time shade temperatures of over 50°C (Pasiecznik et al., 2001).

A major limitation to the distribution of *P. juliflora* is mean minimum temperature and the frequency and duration of frost events. Light frosts cause dieback of the branches, harder frosts may cause complete stem mortality, and more severe or longer-lasting frosts can cause complete death of the plant (Felker et al., 1982). Frost damage is more severe on seedlings and younger trees of *P. juliflora* and on trees in inter-dunal or other low-lying areas (Muthana, 1974). Hyde et al. (1990) found that *P. juliflora* seedlings were killed by a -2°C frost in Spain, whereas *P. juliflora* was noted to suffer frost damage but survive when temperatures fell below 0°C in India (Muthana, 1974). There is also considerable variation in frost tolerance exhibited by different provenances of the same species, and this would be expected also in land races of *P. juliflora*.

Prosopis juliflora has a broad ecological amplitude, and is adapted to a very wide range of soils and habitat types from sand dunes and coastal flats to cracking clays. It is often found in areas where water, soil fertility and salt are the principal agents limiting plant growth, and it is able to survive and even thrive on some of the poorest land unsuitable for any other plant species. *Prosopis juliflora* has a deep tap root, and can become dominant in dry, or seasonally dry, watercourses or depressions, around wells or water points, and commonly, along canal sides, irrigation ditches and around lakes and other water bodies. It is also salt tolerant, so can also be found on beaches growing right up to the shoreline, as well as salt flats and coastal areas where the water table is saline, and is even seen growing a few metres from mangroves in Sri Lanka (Pasiecznik and Weerawardane, 2011). However, whereas it will survive periods of flooding, it tends to suffer dieback or plant mortality when areas are waterlogged for extended periods of time.

Habitats

In the native and introduced ranges, *P. juliflora* is found in a number of different habitats including: wasteland, forest, managed and natural grassland, coastal areas (including coastal dunes), wetlands, abandoned field and urban areas (for example roadside). In particular, in the introduced range, *P. juliflora* invades rangeland, where it can form impenetrable thickets over hundreds or thousands of hectares, and encroaches upon agricultural and abandoned land and can quickly invade uncultivated fields.

Detection and identification

See Appendix 5 for relevant images of the species through its native and introduced range.

The following description is taken from Burkart (1976) as the over-arching species morphology including all varieties from all parts of the world. Although some material that Burkart (1976) identified as *P. juliflora* is now likely to be *P. pallida* (Harris et al., 2003), this description is still accepted in the absence of a new acknowledged taxonomy.

Prosopis juliflora is a tree 3-12 m tall, sometimes shrubby with spreading branches; wood hard; branches cylindrical, green, more or less round- or flat-topped, somewhat spiny with persistent, green (sometimes glaucous or greyish, not reddish) foliage, glabrous or somewhat pubescent or ciliate on the leaflets; spines axillary, uninodal, divergent, paired, or solitary and paired on the same branches, sometimes absent, not on all branchlets, measuring 0.5-5.0 cm long, being largest on strong, basal shoots. Leaves bipinnate, glabrous or pubescent, 1-3 pairs of pinnae, rarely 4 pairs; petiole plus rachis (when present) 0.5-7.5 cm long; pinnae 3-11 cm long; leaflets 6 to 29, generally 11 to 15 pairs per pinna, elliptic-oblong, glabrous or ciliate, rarely pubescent, approximate on the rachis or distant a little more than their own width, herbaceous to submembranous (not sub-coriaceous as in more xerophilous species and therefore often corrugated or curved when dried), emarginated or obtuse, pinnate-reticulately curved; leaflets 6-23 mm long x 1.6-5.5 mm wide. Racemes cylindric, 7-15 cm long, rachis puberulent; florets as usual, greenish-white, turning light yellow. Legume straight with incurved apex, sometimes

falcate, straw-yellow to brown, compressed, linear with parallel margins, stalked and acuminate, 8-29 cm long x 9-17 mm broad x 4-8 mm thick; stipe to 2 cm; endocarp segments up to 25, rectangular to subquadrate, mostly broader than long; seeds oval, brown, transverse.
Prosopis species, however, exhibit high levels of variability in morphological characters in its native range. Self-incompatibility and obligate outcrossing tends to lead to large phenological variation, being a combination of both clinal (continuous) variation in response to broad climatic factors and ecotypic (discontinuous) variation in response to disjunct environmental factors. Differences in continuous climatic clines such as temperature, rainfall and day length, and discrete differences in site such as soil type, salinity or depth combine to create a variety of phenological responses.

Identifying Tropical *Prosopis* Species: A field guide (Pasiecznik et al., 2004) provides the easiest to use means of separating the eight most common prosopis species from field observations and measurements of morphological characteristics. It includes a description of the most common misidentifications, and a simple key to separate *P. juliflora* and *P. pallida* using leaf/leaflet size and number. The fact that *P. juliflora* is confirmed as the only tetraploid species in the genus means that flow cytometry analyses of genome size can be used as a tool from separating this species from others (Trenchard et al., 2008).

PRAs

Several PRAs have been undertaken on prosopis species, with those for *P. juliflora,* but also *P. glandulosa,* and '*P. spp.*', listed below. It is worth noting that many of the characteristics of *P. glandulosa* are similar to those for *P. juliflora*, thus these PRAs could be considered. Furthermore, one PRA also exists for Spain, thus making it relevant for this analysis.

P. juliflora

- Australian/New Zealand Weed Risk Assessment adapted for Hawai'i (2005), - High risk, Score 19. www.hear.org/pier/wra/pacific/prosopis_juliflora_htmlwra.htm.

P. glandulosa

- Spain –Score 22 and 32, ranking 6th and 4th in a list of 80 potential invasive plants, assessed by WRA and WG-WRA, respectively (Andreu and Vilà, 2010).
- Hawaii/Pacific - High risk, Score 19 (www.hear.org/pier/wra/pacific/Prosopis%20glandulosa.pdf)

P. spp.

- Australia - Reject, Score 20 (www.hear.org/pier/wra/australia/prosp-wra.htm)

In addition, a detailed datasheet can be found in CABI's Invasive Species Compendium.

Socio-economic benefits

Prosopis juliflora is a very valuable multi-purpose tree, but much more so where the species has been introduced than where it is native. Principal uses are wood for fuel, posts, poles and sawn timber, and pods for fodder and human food sources (Pasiecznik et al., 2001). There are numerous other tree products including wood as a biofuel for electricity generation, honey from the flowers, medicines from various plant parts, exudate gums, fibres, tannins, leaf compost, and chemical extracts from the wood or pods. It has also been widely planted for soil conservation, in hedgerows, and as an urban and general amenity tree, and continues to be planted as such in some countries (e.g. Chad, Mauritania, Niger, India, Iran, Pakistan). For a comprehensive review of the uses of *P. juliflora*, refer to Pasiecznik et al. (2001).

As with many other invasive species, it is mostly developing countries that realise the economic benefits for the species (Shackleton et al., 2014). For examples in Kenya, trade in prosopis goods and services was worth US$2,122 per household per year in some villages in 2002, and ten years was estimated to exceed US $ 1.5 million in four selected areas (Choge et al., 2012).

Within the EPPO region including EU Member States, there are no known socio-economic benefits reported apart from the very limited number of suppliers of the species.

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

Prosopis juliflora is a known host for various nematodes (e.g. *Meloidogyne* spp.) and other pests (Pasiecznik et al., 2001), but as it is not transported internationally as a pot plant, the risk of it acting as a vector is very limited.

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

5. Regulatory status of the pest

Australia

Prosopis spp. (as a genus) is listed as one of the 30 Weeds of National Significance (www.environment.gov.au/cgi-bin/biodiversity/invasive/weeds/weeddetails.pl?taxon_id=68407), and includes *P. juliflora* as one of four naturalized species (the others being *P. glandulosa, P. pallida* and *P. velutina*, and hybrids).

South Africa

Prosopis juliflora is not listed as invasive. Under the country's National Environmental Management and Biodiversity Act (NEMBA), *P. glandulosa* and *P. velutina*, and their hybrids are listed as Category 1b (may not be owned, imported or grown) in Eastern Cape, Free State, North-West and Western Cape, and Category 3 (may hold but cannot propagate or sell) in Northern Cape (www.environment.co.za/weeds-invaders-alien-vegetation/alien-invasive-plants-list-for-south-africa.html#notice1)

USA

Prosopis juliflora is not included in the USDA Federal noxious weed list (last updated 21 March 2017, (www.aphis.usda.gov/plant_health/plant_pest_info/weeds/downloads/weedlist.pdf), although 20 of the 44 *Prosopis* species recognized by Burkart (1976) are listed, 16 as A1 weeds and 4 as A2 weeds. The reasons for not being included is unclear, however, but may be due, perhaps, the mistaken view that *P. juliflora* is native to the USA, following Bentham's classification. Other native species (*P. glandulosa* and *P. velutina*) are not listed.

However, one US state, Hawaii, does include *P. juliflora* on its list of noxious weeds (see, Division of Plant Industry. List of plant species designated as noxious weeds (20 October 2003). Hawaii Department of Agriculture, Hawaii. (in https://plants.usda.gov/java/reference?symbol=PRJU3)). Many other states contain the same species as listed in the federal USDA, with some variation, e.g. the California State-listed noxious weeds (https://plants.usda.gov/java/noxious?rptType=State&statefips=06) includes *P. velutina* as the preferred name for *P. articulata* (whereas Burkart (1976) considered them as separate species and not synonyms). The whole genus is listed as a noxious weed in the State of Florida (https://plants.usda.gov/java/noxious).

6. Distribution[3]

Continent	***Distribution***	***Provide comments on the pest status in the different countries where it occurs***	***Reference***
Africa	Chad, Djibouti, Egypt, Eritrea, Ethiopia, Kenya, Mauritania, Mozambique, Namibia, Niger, Nigeria, Réunion, Senegal, Somalia, South Africa, Sudan, Tanzania, Uganda Algeria, Botswana, Burkina Faso, Cape Verde, Gambia, Ghana, Guinea-Bissau, Liberia, Libya, Madagascar, Mali, Mauritius, Morocco, Zanzibar, Tunisia, Zimbabwe	Introduced, Invasive Introduced	Burkart, 1976; Pasiecznik et al., 2001; CABI, 2017;
America	- North America - Mexico - Central America - Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica, Panama - Caribbean* - Antigua and Barbuda, Aruba, British Virgin Islands, Cuba, *Curacao, *Dominican Republic, Cuba, Haiti, Montserrat, Puerto Rico, Trinidad and Tobago, United States Virgin Islands - South America - Colombia, Venezuela - North America - Hawaii - South America - Brazil	Native (*Possibly naturalized in pre-history) Introduced and invasive	Burkart, 1976; Pasiecznik et al., 2001; CABI, 2017

[3] See also appendices 3 (supplementary information, notes on distribution) and 4 (Distribution summary for EU Member States and Biogeographical regions)

Continent	***Distribution***	***Provide comments on the pest status in the different countries where it occurs***	***Reference***
Asia	India, Iran, Iraq, Israel, Jordan, Kuwait, Myanmar, Oman, Pakistan, Saudi Arabia, Sri Lanka, United Arab Emirates, West Bank, Yemen Bahrain, Bangladesh, Brunei Darussalam, Cambodia, China (Guangdong, Hainan), Indonesia, Nepal, Philippines, Qatar, Taiwan, Thailand, Vietnam	Introduced, invasive Introduced	Burkart, 1976; Pasiecznik et al., 2001; CABI, 2017
Oceania	Australia (Queensland, Western Australia), French Polynesia Australia (NSW), Papua New Guinea	Introduced, Invasive Introduced	Burkart, 1976; Pasiecznik et al., 2001; CABI, 2017
Europe	Spain Gran Canaria (Canary Islands, Spain)	Spain, mainland: Introduced (Planted two trees only) Spain, Gran Canaria: at least locally naturalized	Pasiecznik and Penalvo-Lopez, 2016; Verloove, 2017

History of introduction and spread

Introduction

Almost no records exist of early introductions of *P. juliflora* within its non-native range but it may be assumed that there were introductions of varieties with sweeter pods made by early man during his journeys across the Americas, or inadvertently by the domesticated animals which may have followed. Routes of man-mediated introductions during pre-history may include the Pacific coast of Central American and the Caribbean. *Prosopis juliflora* is often quoted as being native to the Caribbean where it is found in coastal areas, but several authors have suggested that it was introduced (Little and Wadsworth, 1964; Burkart, 1976), possibly with the arrival of the first human settlers from Venezuela (ca 0-1000 AD) (Timyan, 1996). It is possible that trade between the Caribbean and Brazil may have led to the introduction of *P. juliflora* to the dry coastal areas of Ceará and Rio Grande do Norte in northeast Brazil from Venezuela or the Caribbean (Pasiecznik et al., 2001) where it was definitely recorded in 1879 (Burkart, 1976) and still exists. However, later introductions of *P. pallida* into Brazil from Peru beginning in the 1940s appear to be the source of the now dominant species and especially in interior regions.

Pacific islands

Pacific islands have naturalized populations of both *P. juliflora* and *P. pallida* recorded for Hawaii and the Marquesa islands (Burkart, 1976) and it might be assumed that they were introduced from Pacific coastal areas of Peru and Central America where they are native (Pasiecznik et al., 2001). The first introduction into Hawaii is thought to have been in 1828 (Perry, 1998) or 1838 (Esbenshade, 1980), probably being *P. pallida*, and it is from here that introductions to other Pacific islands such as the Marquesas were probably made. The distinction between *P. pallida* and *P. juliflora* is apparently clear in Hawaii but much less so elsewhere in the Pacific, Brazil, Cape Verde and coastal West Africa.

Australia

Prosopis was introduced into Australia around 1900 though no exact records of the first introductions exist. Major planting and possibly further introductions were made in the 1920s and 1930s (Csurhes, 1996). Later introductions may have come from the Americas, e.g. Mexico (Panetta and Carstairs, 1989) or possibly from India or South Africa where *Prosopis* species had already become naturalized. No information on the dates and sources of seed introduced to South-East Asia can be located, but it is assumed that seed was introduced from the Americas via Australia and the Pacific, although they may also have been introduced from the Indian sub-continent.

Asia

There appear to be several competing histories as to the introduction of *P. juliflora* into the Indian sub-continent, with no doubt that it first occurred in the 1800s. Reddy (1978) gives the most compelling account of the request for *Prosopis* seed made by Lt. Col. RH Bedome, Conservator of Forests of Northern Circle (Madras) to the Secretary of the Revenue Department of Madras in 1876:

> *"The Prosopis dulcis, the Prosopis pubescens and P. glandulosa - are stated to grow best on dry arid soil. They yield hard and valuable timber and also an abundance of sweet succulent*

pods which are used for cattle feeding and also ground into meal. It is very desirable to introduce these trees into the fuel plantations in our dry districts; and I have the honour to suggest that the British Consuls at Galveston and San Francisco should be applied to for the seed. The Prosopis juliflora is a species growing in Jamaica which I should be very glad to get seed of".

This letter was sent to the Secretary of State and seeds arrived and were sown that same year and outplanted in 1878 (Reddy, 1978). Mohan (1884) refers to 'cashaw', the common name for *P. juliflora* used only in Jamaica, and suggests that this may have been the origin of this introduction of *Prosopis* to India. Raizada and Chatterji (1954) state that the first introductions were of Mexican origin in 1877, with two further supplies of seed received through Kew Gardens, UK, and the India Office in 1878. Whichever account is preferred, *P. juliflora* was certainly widespread throughout present-day India, Pakistan and Sri Lanka by 1900.

Prosopis juliflora was introduced into the Middle East in the 1950s, although there is one very large *P. juliflora* tree in Bahrain that is said to be 500 years old (Ahmad et al., 1996). Although not possibly so old, it may show that there was some limited introduction of *Prosopis* by merchant and colonial traders long before the trees were intentionally introduced for other perceived benefits. However, the source of most of the invasions of *P. juliflora* in tropical (Sahelian and eastern) Africa and the Arabian Peninsula is very likely to have come from material planted by or sourced from FAO via their DANIDA-managed seedbank in the 1970s, 1980 and 1990s (some of it also being incorrectly labelled as *P. chilensis*), or planted by NGOs, some of whom sourced seed from commercial suppliers such as Setropa. The escape of *P. juliflora* from trial plots was first noted in the late 1990s (Choge et al., 2012).

Africa

Early introductions of *Prosopis* into Africa are poorly documented, but appear to have begun in 1822 in Richard Toll, in the north of modern-day Senegal at the mouth of the river Senegal This introduction was identified as *P. juliflora* but appears very likely to have been *P. pallida* (Harris et al., 2003). *Prosopis juliflora* had been introduced from Senegal to Mauritania before 1960 (Diagne, 1992) but had certainly been introduced elsewhere in the Sahel before this. It appears that *P. juliflora* was already present in Egypt by the early 1900s, and was introduced into Sudan by RE Massey from the Egyptian Department of Agriculture at Giza and from South Africa both in 1917 (Broun and Massey, 1929; in El Fadl, 1997). The exact origins of *P. juliflora* species and their subsequent introductions in East Africa remain unknown, but they were possibly introduced in the 1930s (Choge et al., 2012) by livestock from Sudan or southern Africa, or by traders from India or southern Africa, and it was also planted along the new railroad from Mombasa to Nairobi and beyond. For details of its recent spread in Kenya and areas at risk of invasion, see Maundu et al. (2009). Probably the source of much of the *Prosopis* to arrive in South Africa was the introduction of 23 seed lots from the USA/Hawaii and Mexico from 1897 to 1916. Although they were all called *P. juliflora*, they almost certainly contained *P. velutina* and all varieties of *P. glandulosa*, and it is unsure whether there is any naturalize *P. juliflora* in South Africa today.

EPPO region

Prosopis juliflora currently has a very limited naturalised distribution in the EPPO region. It is currently reported as naturalized only in low lying areas in Israel, the West Bank and Jordan

(Dufour-Dror and Shmida, 2017), although records of *P. juliflora* outside of the Jordan valley are considered by the Expert Working Group (EWG) to be possible mis-identifications. *Prosopis juliflora* was first confirmed as present in Jordan by Harris et al. (200), in Almeria (two planted trees only: planted in 1988), south-eastern Spain (Pasiecznik and Peñalvo López, 2016), and naturalised in a very limited area in Gran Canaria (Canary Islands) Verloove, 2013, 2017). Here the species has been known since 2011 as an escape from cultivation in the drier, southernmost parts of Gran Canaria. In 2015 it was recorded in several additional localities, all in *barrancos*. In one of these, in the estuary of barranco del Polvo in Arinaga, it is present in relative abundance and in various stages of development, in a natural coastal vegetation. At least in this locality it can be considered naturalized.
The species was reported from Cyprus in 1915 (Bovill, Rep. Plant. Work, 14; 1915) and in 1923 (G. Frangos in Cyprus Agric. Journ., 18: 86; 1923), both reports referenced in Meikle (1977), but has not been detected in recent years. According to Maniero (2000) *P. juliflora* was introduced into Italy in 1813 as an ornamental species. It is likely that all of these reports refer to species other than *P. juliflora* (sensu strictu). For example, Bovill (1915) notes that seeds of *P. juliflora* were received from southerm California where *P. juliflora* does not exist, and the material was almost certainly *P. glandulosa* var. *torreyana*. However, at the time of introduction, this taxa was also referred to as *P. julifora* var. *torreyana*, from where the confusion would have arisen. In addition, Bovill (1915) also noted that "The following [taxa] have been tried, but without any marked success, some of them are alive but that is all." Frangos (1923) merely notes the species as being present in another nursery. As such, it is considered that *P. juliflora* was probably never introduced to Cyprus and probably not to Italy, and in the absence of any subsequent reports, is certainly not present in either country (pers. comm. EWG, 2018).

7. Habitats and where they occur in the PRA area

At present, *P. juliflora* is only present in arid, semi-arid regions of the Jordan Valley (Dufour-Dror and Shmida, 2017). Throughout its introduced range, *P. juliflora* has a broad ecological amplitude, and is adapted to a very wide range of soils and habitat types from sand dunes to cracking clays. It is generally found in areas where water and soil fertility are the principal agents limiting plant growth, and is able to survive, and even thrive, on some of the poorest land, unsuitable for any other tree species. *Prosopis juliflora* dominates in dry, or seasonally dry, watercourses or depressions, and is often found in coastal flats and dunes. Importantly, however, it is frost sensitive, thus in areas at its temperature limits, it will tend to inhabit more protected sites.

The table below, however, contains only those habitat types from EUNIS where *P. juliflora* is known to occur (e.g. Pasiecznik et al., 2001), outside of the PRA area but has the potential of invading within. Other habitat types are not included, as they do not occur (or are very rare) in the EU/EPPO region. These are, notably, warm and hot deserts, savannah, and xerophytic woodlands ('scrub' and shrublands).

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***
Coastal habitats	B1: Coastal dunes and sandy shores (Partly threatened)	European Red List: B1.4b, B1.6c, B1.3b, B1.6b Annex 1. H. Directive: 2130, 2210, 2220, 2230, 2240,	No	Major	Janssen et al., (2016)
Grasslands	E1: Dry grasslands, E6: Inland salt steppes, E7: Sparsely wooded grasslands	European Red List: Annex 1. H, Directive: E1.3 6220	No	Major	Janssen et al., (2016)
Habitat complexes	X02: Saline coastal lagoons X18: Wooded steppe X35: Inland sand dunes	X13, X14, X15	No	Major	Janssen et al., (2016)
Heathland Scrub and Tundra	F5 (Maquis, arborescent matorral and thermo-Mediterranean brushes), F6 (Garrigue), F7 (Spiny Mediterranean heaths), F8 (Thermo-Atlantic xerophytic scrub)	European Red List: F8.1 F8.2	No	Major	Janssen et al., (2016)
Arable land	I1. Arable land and market gardens	European Red List: I1.3	No	Major	Janssen et al., (2016)
Desert	Not listed in EUNIS	Not present in Europe	Yes	Moderate	(Dufour-Dror and Shmida, 2017).

8. Pathways for entry

Possible pathway	**Pathway: Plants for planting (horticulture) (CBD terminology: Escape from confinement – horticulture)**
Short description explaining why it is considered as a pathway	*P. juliflora* seeds are widely available via numerous online global mail order suppliers. For example www.sunshine-seeds.de; http://www.treeseedsindia.com/prosopis-juliflora.htm and Amazon.com. *P. juliflora* is available from 4 suppliers according to the PPP-Index which lists plant species available for sale in Europe.
Is the pathway prohibited in the PRA area?	Neither the pathway or the species are prohibited into the PRA area.
Has the pest already been intercepted on the pathway?	*P. juliflora* is the commodity
What is the most likely stage associated with the pathway?	Seeds are the most likely stage associated with the pathway
What are the important factors for association with the pathway?	Seed are widely available by mail order and the species is available from suppliers in the USA, India and other international suppliers.
Is the pest likely to survive transport and storage along this pathway?	Yes seeds can survive for in their pods under sub-optimal conditions for at least 15 years (Pasiecznik and Felker, 1992).
Can the pest transfer from this pathway to a suitable habitat?	Yes, but seeds are unlikely to germinate under natural conditions in most EPPO countries (in particular EU Member States)
Will the volume of movement along the pathway support entry?	The species is already present in the EPPO region and there are a lot of suppliers that will send the seeds of the species to the PRA area.
Will the frequency of movement along the pathway support entry?	It is unlikely that the frequency of movement along this pathway will support entry but this statement is highly uncertain as there are no figures on the volume of movement.
Rating of the likelihood of entry	*Low* X *Moderate* ☐ *High* ☐
Rating of uncertainty	*Low* ☐ *Moderate* X *High* ☐

As the species is imported as a commodity, all European biogeographical regions will have the same likelihood of entry and uncertainty scores.

Possible pathway	**Pathway: Plants for planting (forestry) (CBD terminology: Escape from confinement – forestry)**
Short description explaining why it is considered as a pathway	*P. juliflora* seeds are widely available via numerous online global mail order suppliers. For example www.sunshine-seeds.de; http://www.treeseedsindia.com/prosopis-juliflora.htm and Amazon.com. The two reported introductions into Europe (Pasiecznik and Penalvo-Lopez, 2016; Dufour-Dror and Shmida, 2017), as with most global introductions, have been as seed for reforestation (Pasiecznik et al., 2001). However, this is highly unlikely to happen now.
Is the pathway prohibited in the PRA area?	Neither the pathway or the species are prohibited into the PRA area.
Has the pest already been intercepted on the pathway?	*P. juliflora* is the commodity
What is the most likely stage associated with the pathway?	Seeds are the most likely stage associated with the pathway
What are the important factors for association with the pathway?	Intentional introduction for reforestation. Seed are widely available by mail order and the species is available from suppliers in the USA, India and other international suppliers.
Is the pest likely to survive transport and storage along this pathway?	Yes seeds can survive for in their pods under sub-optimal conditions for at least 15 years (Pasiecznik and Felker, 1992).
Can the pest transfer from this pathway to a suitable habitat?	Yes, but seeds are unlikely to germinate and grow in most EU countries.
Will the volume of movement along the pathway support entry?	The species is already present in the EPPO region and there are a lot of suppliers that will send the seeds of the species to the PRA area.
Will the frequency of movement along the pathway support entry?	It is unlikely that the frequency of movement along this pathway will support entry but this statement is highly uncertain as there are no figures on the volume of movement.
Rating of the likelihood of entry	*Low* X *Moderate* ☐ *High* ☐
Rating of uncertainty	*Low* ☐ *Moderate* X *High* ☐

As the species is imported as a commodity, all European biogeographical regions will have the same likelihood of entry and uncertainty scores.

A moderate rating of uncertainty has been given for both pathways as the species is not a desirable species due to its known invasiveness and much of the EPPO region including EU Member States is climatically unsuitable a low rating for uncertainty is given with moderate uncertainty.

The EWG does not consider entry by transport of seeds by machinery, soil, animals to be viable pathways into the region and therefore these have not been included in the assessment.

Do other pathways need to be considered? NO

if no **Go to 9**

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

As a species that is predominantly found in frost-free tropical areas in its native range, there are only limited areas within the PRA area of the EPPO region that may be considered suitable. And as was seen in Almeria, south-eastern Spain in an area where frosts are mild and seldom, no seedlings were recorded under or near the only two *P. juliflora* trees that had survived in a sheltered terrace site, 25 years after planting (Pasiecznik and Penalvo-Lopez, 2016). However, the species is reported as naturalised in a very limited area in Gran Canaria (Canary Islands – Macaronesian biogeographical region) (Verloove, 2013, 2017). In the Jordan valley (Israel, West Bank and Jordan) where there is no recorded frost, *P. julflora* is known to naturalize, including "in wadi beds on limestone outcrops as well as in depressions within the loess hilly areas" in Israel, and in canyons of southern Jordan and has formed a savanna like stand in wadis and flood plains (Dufour-Dror and Shmida, 2017). However, records from the Negev Desert require confirmation (EWG opinion).

Most of the environmental requirements for *P. juliflora* are unconducive with that of the EPPO region, in particular EU Member States. *Prosopis juliflora* thrives in a wide range of rainfall zones, from 100 mm mean annual rainfall or less in dry coastal zones to 1500 mm at higher altitudes, and the ability to tolerate very low annual rainfall is well known. Mean annual air temperature in the shade where *P. juliflora* is found is generally above 20°C, with optimum temperatures for growth in the range 20-30°C. There appears to be no natural upper limit to temperature, with introduced *P. juliflora* known to tolerate day-time shade temperatures of over 50°C (Pasiecznik et al., 2001).

A major limitation to the distribution of *P. juliflora* is mean minimum temperature and the frequency and duration of frosts. Light frosts cause dieback of the branches, harder frosts may cause complete stem mortality, and more severe or longer-lasting frosts can cause complete death of the plant (Felker et al., 1982). Frost damage is more severe on seedlings and younger trees of *P. juliflora* and on trees in inter-dunal or other low lying areas (Muthana, 1974). Hyde et al. (1990) found that *P. juliflora* seedlings were killed by a -2°C frost in Spain, whereas the species was noted to suffer frost damage but survive when temperatures fell below 0°C in India (Muthana, 1974). There is also considerable variation in frost tolerance exhibited by different provenances of the same species, and this would be expected also in land races of *P. juliflora*.

Prosopis juliflora has a broad ecological amplitude, and is adapted to a very wide range of soils and habitat types from sand dunes and coastal flats to cracking clays. It is often found in areas where water, soil fertility and salt are the principal agents limiting plant growth, and it is able to survive and even thrive on some of the poorest land unsuitable for any other plant species. *P. juliflora* can become dominant in dry, or seasonally dry, watercourses or depressions, around wells or water points, and commonly, along canal sides, irrigation ditches and around lakes and other water bodies. It is also salt tolerant, so can also be found on beaches growing right up to the shoreline, as well as salt flats and coastal areas where the water table is saline, and is even seen growing a few metres from mangroves in Sri Lanka (Pasiecznik and Weerawardane, 2011). However, whereas it will survive periods of flooding, it tends to suffer dieback or plant mortality when areas are waterlogged for extended periods of time.

A score of moderate has been given as the species is known to have established in the natural environment in a limited area of the EPPO region (Jordan Valley). However, the bio-climatic conditions of the Jordan Valley are not representative of most areas of the EPPO region. A moderate score is further supported by the modelling output, where limited areas have been identified for establishment, include areas in the Mediterranean and Macaronesian biogeographical region. Largely frost-free coastal and low-lying inland areas are suitable, including parts of Cyprus, Greece (and the islands), Italy (including Sardinia and Sicily), Malta, Portugal (including Madeira and the Azores), Spain (including Gran Canaria (Canary Islands)) and Turkey, North African countries (Algeria, Morocco and Tunisia), and Israel, the West Bank and Jordan (see appendix 1 and 2). The EWG consider the moderate rating will apply to both EU and non-EU countries within the EPPO region but uncertainty will raise to high for EU countries.

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

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

Prosopis juliflora has been planted along roadsides in Jordan since the 1980s and the first observed naturalisation of the species in this region were close to roadsides (Dufour-Dror and Shmida, 2017). Since the 1960s in Israel, it was planted in arid and semi-arid regions by the Forestry Department, where it has since naturalised. In Jordan and Israel, it has also established in irrigated agricultural fields (Dufour-Dror and Shmida, 2017). In Gran Canaria, *P. juliflora* is planted as an ornamental tree at the interchange of motorway GC 1 near Bahía Feliz. Young, self-sown plants were seen on several occasions in 2011 and 2012 in the vicinity of these plantations (Verloove, 2013).

A score of moderate has been given as the species is known to have established in these areas in a limited part of the EPPO region (Jordan Valley). However, the conditions of the Jordan Valley are not representative of most areas of the EPPO region. The EWG consider the moderate rating will apply to both EU and non-EU countries within the EPPO region but uncertainty will raise to high for EU countries.

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

11. Spread in the PRA area

Natural spread

The only mode of spread is by seed. There is the possible of spread of seeds from established, fruiting trees, either down dry valleys (e.g. wadis, barrancos) after rains, or along coastlines (Pasiecznik et al., 2001). Pods float, and seeds can survive if pods spend extended periods in seawater (Pasiecznik et al., 2001). More likely, however, would be spread via animals, as the sweet and nutritious pods are highly sought after by wild and domestic mammals (Pasiecznik et al., 2001). This is the main cause of rapid expansion of prosopis as an invasive species elsewhere in the world, and may be the main reason for spread in the Jordan valley.

Each pod can produce up to 25 seeds, but commonly 6 – 12 seeds are produced (Pasiecznik et al., 2001). Each tree can produce 300-420 kg of pods per year (Pasiecznik et al., 2001), with an estimate of 2000 seeds per kilo of pods (Pasiecznik et al.,2012). Felker (1979) and Harding (1988) estimate that each tree can produce between 630 000 and 980 000 seeds per year. As an indication of spread, in India, spread have been recorded using satellite imagery from 378 to 684km ^{2} (an increase of 81 %) from 1980-1990 in Banni grassland and expanding at a rate of about 25km^2 per year (Pasha et al., 2014). In India, the species is also reported as dominating wastelands, grazing land, around river beds, roads, railway lines, canals and other fallow lands (Tewari et al., 2001).

Spread via livestock is likely with seeds passing through the digestive tract having enhanced germination (Pasiecznik et al., 2001).

Human assisted spread

Human assisted spread has been the main reason for the spread of *P. juliflora* around the world over the past 200 years, as a fuel and fodder species able to tolerate the most arid sites and the poorest soils, where little else will grow. There have been two main periods of introduction. The first was by Europeans to their colonies in the late 1800s and early 1900s, and the second was by aid agencies as part of tree planting programmes in the 1980s and early 1990s. Seed stock is available from online supplier and may be spread throughout the EPPO region along this route, e.g. from www.sunshine-seeds.de and www.treeseedsindia.com/prosopis-juliflora.htm and via large online suppliers such as Amazon.com.

A high rating for spread is given for *P. juliflora* in the EPPO region with moderate uncertainty. However, the EWG consider the rating will decrease for EU Member States to a moderate rating with a high uncertainty.

Rating of the magnitude of spread in the PRA area (EPPO region)	*Low* ☐	*Moderate* X	*High*
Rating of uncertainty	*Low* ☐	*Moderate*	*High* X

12. Impact in the current area of distribution

12.01 Impacts on biodiversity

Prosopis juliflora is a very aggressive invader with the potential to outcompete and replace native vegetation. The species has been noted as invasive in protected areas in South Asia, notably grasslands in Gujarat and native xerophytic woodlands in Rajasthan (Kaur et al., 2012), as well as a national park in Sri Lanka (Pasiecznik and Weerwadane, 2012). The species is also reported as dominating wastelands, grazing land, around river beds, roads, railway lines, canals and other fallow lands (Tewari et al., 2001). Even amongst the protected and undisturbed sites, dominance of late successional species, e.g., *Acacia senegal, Maytenus emarginata, Ziziphus nummularia* and *Acacia nilotica,* was less at sites with *Prosopis juliflora* than at sites without it (Kumar and Mathur 2014). Density of *Commiphora wightii*, an endangered species, decreased with increasing density of *P. juliflora*. Invasion of *P. juliflora* has thus demonstrable adverse impacts on plant communities in arid grazing lands (Kumar and Mathur, 2014).

Some plant species are suppressed when *P. juliflora* forms dense stands and Maundu et al. (2009) showed plant biodiversity was reduced in *P. juliflora* thickets in Kenya compared with areas outside. In India and Hawaii, USA, where *P. juliflora* is an aggressive invader, canopy effects were consistently and strongly negative on species richness (Kaur et al., 2012). In the United Arab Emirates, *Malva parviflora*, attained 600 individuals under compared to 4,289 individuals/100 m2 outside canopies (El-Keblawy and Al-Rawai, 2007).

Observations on the overall effects of the species on mammal species' populations and diversity should consider the negative effects of *P. juliflora* on native forage plants. However, the presence of *P. juliflora* as a readily available source of fuel has drastically reduced the previous over-exploitation and illegal cutting in protected reserves, and as such, whereas biodiversity may be reduced in invaded areas, neighbouring natural forests may be 'saved', and thus the net effects should be assessed on the landscape level, noting clearly marked local variations in environmental effects (Pasiecznik et al., 2001).

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

Prosopis species have large impacts upon water resources, nutrient cycling, successional process, and soil conservation (Shackleton et al., 2014). Negative effects of *Prosopis* invasions also include complete loss of native pasture and rangelands, transforming natural grasslands into thorn woodland (i.e. encroachment). *Prosopis* rapidly form dense thorny thickets that reduce biodiversity and can also block irrigation channels, obstruct roads, and block smaller trails completely affecting access to pasture, croplands, water sources and fishing areas (Weber, 2003). Loss of grass cover under canopies may also promote soil erosion.

Prosopis species are amongst a range of invasive woody plants being eradicated in South Africa under the Work for Water programme, due to their noted effect in exploiting soil water and lowering water tables (Zachariades et al., 2011), where stands of *Prosopis* species were estimated to be using water equivalent to four times mean annual rainfall. *Prosopis* are known to possess very deep roots which will use subterranean water when no surface water is available. However, there is some debate as to the extent of effects of *Prosopis* on water tables. In India, Cape Verde and elsewhere in the Sahel, *Prosopis* species have been blamed by large-scale farmers for the lowering of water tables, while some researchers suggest that this is due to the increase in the number of boreholes and the amounts of water being extracted for irrigation by these very same farmers (Pasiecznik 1998).

Invasion of *P. juliflora* was also blamed to limit transhumance, occupying settlement areas and affecting multipurpose trees/bushes and grass availability. All these effects put pressure on livestock assets, with livestock ill health reported in Kenya (Choge et al., 2002, Mwangi and Swallow, 2005) and Brazil (Tabosa et al., 2006).

Specific examples of negative impacts of *P. juliflora* on ecosystem services are highlighted in the table below.

Ecosystem service	**Does the pest impact on this Ecosystem service?**	**Short description of impact**	**Reference**
Provisioning	Yes	- *P. juliflora* invades pasture land reducing yields. - *P. juliflora* utilises significant amounts of water which have a negative impact on the local resource. - *P. juliflora* can negatively impact on livestock health. Consuming pods have been reported to result in facial contortions, impacted rumen and constipation among livestock. These ill effects may sometimes result in death. - Conflicts over resources due to limiting resources as an effect of invasion.	Pasiecznik et al. (2001), Kaur et al., 2012; Weber 2003.Kaur et al., 2014, Shackleton et al., 2014
Regulating	Yes	*P. juliflora* decreases the flow of water in natural habitats in Ethiopia and South Africa. *P. juliflora* has large impacts upon nutrient cycling, successional process, and soil conservation.	Ayanu et al., 2014; Ntshidi et al., 2015; Zachariades et al., 2011; Pasiecznik et al. (2001)
Cultural	Yes	*P. juliflora* invades communities and impacts on local livelihoods. The species can reduce the area available to make a living and even displace people due to the degradation of land through infestation.	Mwangi and Swallow, 2005.

Ecosystem service	Does the pest impact on this Ecosystem service?	Short description of impact	Reference

A high magnitude of impact on ecosystem services has been with a low uncertainty to reflect the scientific studies that have evaluated these impacts.

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

12.03. Socio-economic impact

The principal cause for concern arises from the strong and often profuse thorns of *P. juliflora*, which are able to pierce tyres and all but the toughest of shoes or hooves. The scratches are said in some parts to cause infection by themselves and even lead to amputations (e.g. Choge et al., 2002), though there is no actual poison in the *P. juliflora* thorns. On the contrary, many plant extracts are used in local medicines as fungicides and bactericides, and a poultice of damp leaves is recommended by some to cure infections.

In the USA, Mexico, Saudi Arabia, Kuwait, United Arab Emirates, India and South Africa the pollen has been identified as a major allergen (e.g. Killian and McMichael, 2004), and Dhyani et al. (2008) described *P. juliflora* as an 'important source of respiratory allergens in tropical countries'. Killian and McMichael (2004) identified at least 13 human allergens in the pollen. *Prosopis juliflora* has a close allergenic relationship with *Ailanthus excelsa*, *Cassia siamea* and *Salvadora persica* and the lima bean *Phaseolus lunatus* (Dhyani et al., 2008). As it is a major cause of allergenic disease and has close allergenic relationships with other species, further planting of *P. juliflora* in urban areas is not recommended.

Weedy invasions can become an obstruction on roads or even block smaller trails completely. An additional and unusual negative social affect was noted by Choge et al. (2002) in 12% of respondents in Kenya, who identified *P. juliflora* stands as a 'refuge for thieves', notably livestock poachers and rustlers. However, an increasing issue regarding social impacts is where invasions are particularly dense, the availability of traditional grass fodder is reduced, and some pastoralists have chosen to move to other areas. This has been the case in part of Gujarat, India, especially the Rann of Katchh. In Baringo, Kenya, demands to be relocated have been made by some local people, using invasion of *P. juliflora* as a reason.

Controlling *P. juliflora* is labour intensive and costly. In South Africa, clearing dense populations of *Prosopis* spp. was estimated to cost US$534 per ha (Zacharaides et al., 2011). In Kenya, costs for clearing *P. juliflora* were estimated to be US$2,270 per hectare (Maundu et al. 2009). In Western Australia, almost 120,000 ha are infested with *Prosopis* species (Dodd and Martin 1986), with most infestations occurring on pastoral land in the Pilbara and Kimberley regions. The infestation at Mardie station is believed to be a hybrid species, possibly *P. pallida x P. glandulosa* *x P. laevigata* and the cost of aerially spraying has been estimated at US$1-1.5 million (Csurhes et al., 1996). In 2005, the Kassala state government in Sudan made contracts with private companies to eradicate *P. juliflora* from 6,300 hectares in the Gash area. The cost of mechanical clearing was 350 Sudanese pounds (US$50) per feddan (0.42 hectare), compared to the cost for manual removal which was 150 Sudanese pounds (US$21) per feddan (Kool et al. 2014).

Notwithstanding the high cost, control may be economically feasible. Wakie et al. (2015) found that conversion to irrigated cotton is economically profitable, with Net Present Value (NPV) of US$5234 per hectare over 10 years and at an interest rate of 10% per year. Conversion greatly reduces the spread of *Prosopis* species on farmlands. Managing infested lands for charcoal production with a four-year harvest cycle is profitable, with an NPV of US$805 hectare. However, the production process needs vigilant regulation to protect native plants from exploitation and caution should be taken to prevent charcoal production sites from becoming potential seed sources.

Control methods

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

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

13. Potential impact in the PRA area

To date, there have been no studies on the impact of *Prosopis juliflora* in the limited areas where it is present in the EPPO region. Dufour-Dror and Shmida (2017) suggests that the establishment of *Prosopis* species along streams with a permanent water flow in the Dead Sea Valley will impact on biodiversity, displacing native plant species like *Acacia raddiana*, *Salvadora persica* or *Moringa peregrina* and goes on to suggest that the potential impacts in Jordan will be greater than Israel.

In addition to impacts on biodiversity, impacts on ecosystem services will potentially be similar to those impacts seen in the current area of distribution, with the exception, potentially, of significant impacts on communities and local livelihoods. The potential establishment of *Prosopis* species along protected stream systems around the Dead Sea may have significant impacts on water flow and of course water availability (Dufour-Dror and Shmida, 2017).

What is clear is that the impacts will be restricted to a small area of the EPPO region where the species can establish (the endangered area, see section 14).

In the absence of specific data on impacts in the PRA area the rating of magnitude of impacts remains high for impacts on biodiversity, ecosystem services and socio-economic impacts, however, uncertainty is raised to high for all categories, as it is not clear if these impacts will be realised throughout areas of potential establishment in the PRA area (EWG opinion).

To date there are no impacts recorded on Red List species or species listed in the Birds and Habitats Directives.

The text within this section does not relate equally to EU Member States and non-EU Member States in the EPPO region (see section 13.04).

Will impacts be largely the same as in the current area of distribution? **Yes (In part)**

13.01. Potential impacts on biodiversity in the PRA area (EPPO region)

Rating of magnitude of impact on biodiversity in the area of potential establishment (EPPO region)	*Low* ☐	*Moderate* ☐	*High* **X**
Rating of uncertainty	*Low* ☐	*Moderate* ☐	*High* **X**

13.02. Potential impact on ecosystem services in the PRA area

Rating of magnitude of impact on ecosystem services in the area of potential establishment (EPPO region)	*Low* ☐	*Moderate* ☐	*High* **X**
Rating of uncertainty	*Low* ☐	*Moderate* ☐	*High* **X**

13.03 Potential socio-economic impact in the PRA area

Rating of magnitude of socio-economic impact in the area of potential establishment (EPPO region)	*Low* ☐	*Moderate* ☐	*High* **X**
Rating of uncertainty	*Low* ☐	*Moderate* ☐	*High* **X**

13.04 Potential impacts in the EU

In frost-free coastal and low-lying inland areas of Cyprus, Greece, Italy, Malta, Portugal, Spain impacts on biodiversity, impacts on ecosystem services could be similar to those impacts seen in the current area of distribution and the isolated areas of establishment in the EPPO region, with the exception, potentially, of significant impacts on communities and local livelihoods (EWG opinion). However, for this to be realised extensive populations of the species would need to occur and this would be more uncertainty of occurring compared to areas in Israel and Jordan. In addition, even though the species has been sold as an ornamental species and as a forestry species globally, this is unlikely to be a significant pathway into the EU in future.

Therefore, based on this information new ratings have been given for impacts in the EU.

Rating of magnitude of impact on biodiversity in EU Member States	*Low*	*Moderate* **X**	*High*
Rating of uncertainty	*Low* ☐	*Moderate* ☐	*High* **X**

Rating of magnitude of impact on ecosystem services in EU Member States	*Low*	*Moderate* **X**	*High*
Rating of uncertainty	*Low* ☐	*Moderate* ☐	*High* **X**

Rating of magnitude of socio-economic impact in EU Member States	*Low*	*Moderate* **X**	*High*
Rating of uncertainty	*Low* ☐	*Moderate* ☐	*High* **X**

14. Identification of the endangered area

Based on the current environmental conditions, species distribution modeling identified suitable areas for establishment of *P. juliflora* in the Mediterranean and Macaronesian biogeographical region. Largely frost-free coastal and low-lying inland areas are suitable, including parts of Cyprus, Greece (and the islands), Italy (including Sardinia and Sicily), Malta, Portugal (including Madeira and the Azores), Spain (Canary Islands) and Turkey, North African countries (Algeria, Morocco and Tunisia), and Israel, the West Bank and Jordan (see appendix 1 and 2).

Habitats at risk in the endangered area are arid or semi-arid regions. The main limiting factor preventing further predicted suitability appears to be low winter temperatures.

15. Climate change

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

Climate projection RCP.8.5 2070

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

Temperature **(yes)**	Precipitation **(yes)**	$C0_2$ levels **(minor)**
Sea level rise **(no)**	Salinity **(yes)**	Nitrogen deposition **(minor)**
Acidification **(no)**	Land use change **(yes)**	Other (please specify)

The identified 'components' are relevant for establishment and spread of *P. juliflora*, but all may be minor. The key factor limiting spread in the EPPO region is considered to be the severity and frequency of frosts. Certain changes would favour *Prosopis* species, including mean annual temperatures increase, rainfall decrease and salinity increase. However, if frosts are still likely to occur, or increase in severity and frequency, then this will more than counter any positive effects.

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.

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 via plants for planting (horticulture and forestry) is unlikely to change as a result of climate change. As shown in Appendix 1, the areas suitable for the species will increase but not sustainably, and thus the demand for the species in horticulture is unlikely to increase. The overall rating for introduction pathways will not change.	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**
By 2070s, under IPPC 5 climate projections for RCP8.5, the suitability region in Europe is predicted to increase somewhat, but still be restricted to the same regions (Figure 7, Appendix 1). The Biogeographical Regions most suitable for *P. juliflora* establishment are predicted to be Macaronesia and the Mediterranean, with both projected to become more suitable under the climate change scenario evaluated (Figure 8). The establishment of *Prosopis juliflora* as an ecological process is likely to be higher in both managed and natural environments. The overall rating for establishment will increase to high with a high uncertainty.	Species distribution modelling (Appendix 1) and EWG opinion
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 due to extreme weather events such as flooding. The overall ratings for spread will not change.	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, ecosystem services and socio-economic in	Species distribution modelling and EWG opinion

the PRA area, along with high uncertainty will remain the same for the future 2070 projection. The overall rating and uncertainty for impacts will not change as the current scores are high.	

16. Overall assessment of risk

The results of the PRA show that *Prosopis juliflora* poses a moderate risk to the PRA area. The EWG consider this the case as, notwithstanding the high score for impact, indisputable in the current area and considered high for the endangered area, the risk of introduction and the potential area for establishment are both perceived as low, leading the EWG to propose an overall phytosanitary risk score of moderate.

Pathways for entry:

Plants for planting (Horticulture)

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

Plants for planting (Forestry)

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

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* **X**	*High*
Rating of uncertainty	*Low*	*Moderate*	*High* X

Magnitude of spread

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

<u>Impacts within the EPPO region:</u>

Impact on biodiversity

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

Negative impact the pest may have on categories of 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* ☐	*High* X

Socio-economic impact of the species

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

<u>Impacts within EU Member States:</u>

Impact on biodiversity

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

Negative impact the pest may have on categories of ecosystem services

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

Socio-economic impact of the species

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

17. Uncertainty

Noting the taxonomic difficulties in distinguishing *P. juliflora* from all the other above mentioned species, the EWG recommend careful identification of any prosopis taxa entering the region. This is currently constrained by the lack of confirmed reference material and supporting systematic treatment of all introduced taxa. Further morphological and genetic analysis is recommended.

Uncertainty also relates to the modelling:

There was considerable uncertainty as to the status of the *P. juliflora* distribution records obtained from global databases. We used expert opinion to filter out records that were potentially unreliable, but it is possible that some true *P. juliflora* were lost. The potential effect of this could be to underestimate the range of conditions under which the species could establish.
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 0.48, slightly increasing the region predicted to be suitable.
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.

The naturalised reports in Gran Canaria (Canary Islands) were identified following the completion of the PRA and hence the modelling of the species and although the EWG does not consider this will change the output of the modelling it is noted here.

18. Remarks

This PRA was conducted specifically for *Prosopis juliflora* as the species was identified through horizon scanning studies. However, as highlighted during the work of the EWG and noted in the text, several other *Prosopis* species are also a potential threat to the EU and the EPPO region. These are *P. chilensis* and *P. velutina* that have both been observed fruiting and the latter naturally reseeding in Almeria, south-eastern Spain (first report, Pasiecznik and Penalvo Lopes, 2016), and the closely related *P. glandulosa*. All these three species are also recorded as having very similar ecological and socio-economic impacts compared to *P. juliflora*, and the latter two are reported as highly invasive in Australia, South Africa and the USA. But being more frost tolerant than *P. juliflora*, they are also considered to pose an even greater threat to the PRA area. It was not possible to expand the PRA to cover these additional species in the current project, but it recommended that these be considered for future PRAs.

Noting the taxonomic difficulties in distinguishing *P. juliflora* from all the other above mentioned species, the EWG recommend careful identification of any prosopis taxa entering the region. This is currently constrained by the lack of confirmed reference material and supporting systematic treatment of all introduced taxa. Further morphological and genetic analysis is recommended.

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Appendix 1: Projection of climatic suitability for *Prosopis juliflora* establishment

Aim

To project the suitability for potential establishment of *Prosopis juliflora* 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 0.25 x 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. Reports suggests that *P. juliflora* is highly sensitive to frost and restricted to largely frost-free areas (CABI, 2015). This is likely to be a key limit on its invasive distribution.
- Mean temperature of the warmest quarter (Bio10 °C) reflecting the growing season thermal regime. Low temperatures are likely to limit *P. juliflora*'s invasive distribution in Europe through effects on seed germination (Pasiecznik, 2001) and growth, which are both optimal between 20 and 30 °C (CABI, 2015).
- Climatic moisture index (CMI, ratio of mean annual precipitation, Bio12, to potential evapotranspiration) reflecting drought regimes. *P. juliflora* can occupy a range of rainfall regimes but is principally a species of arid environments so may be restricted from extremely wet environments (CABI, 2015). 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 of the driest quarter (Bio17 mm, ln+1 transformed) based on *P. juliflora*'s preference for arid climates (CABI, 2015).

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.

We also included a habitat variable:

- Percentage tree cover (ln+1 transformed) as *P. juliflora* does not generally occur in dense forest habitats (CABI, 2015). Tree cover was estimated from the MODIS Vegetation Continuous Fields product, distributed by the Global Land Cover Facility (DiMiceli *et al.*, 2011).

Species occurrence data were obtained from the Global Biodiversity Information Facility (GBIF), USGS Biodiversity Information Serving Our Nation (BISON), Integrated Digitized Biocollections (iDigBio), iNaturalist, literature sources (Van Klinken & Campbell, 2001) and members of the Expert Working Group conducting its Pest risk assessment. 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). In the opinion of the Expert Working Group, apparent *P. juliflora* records held in these global databases are actually other *Prosopis* species or hybrid swarms . Therefore, we filtered out records from regions where this was likely to be the case (Figure 1). The remaining records were gridded at a 0.25 x 0.25 degree resolution for modelling (Figure 1). There were 221 grid cells with established occurrence records available for the modelling (Figure 1)

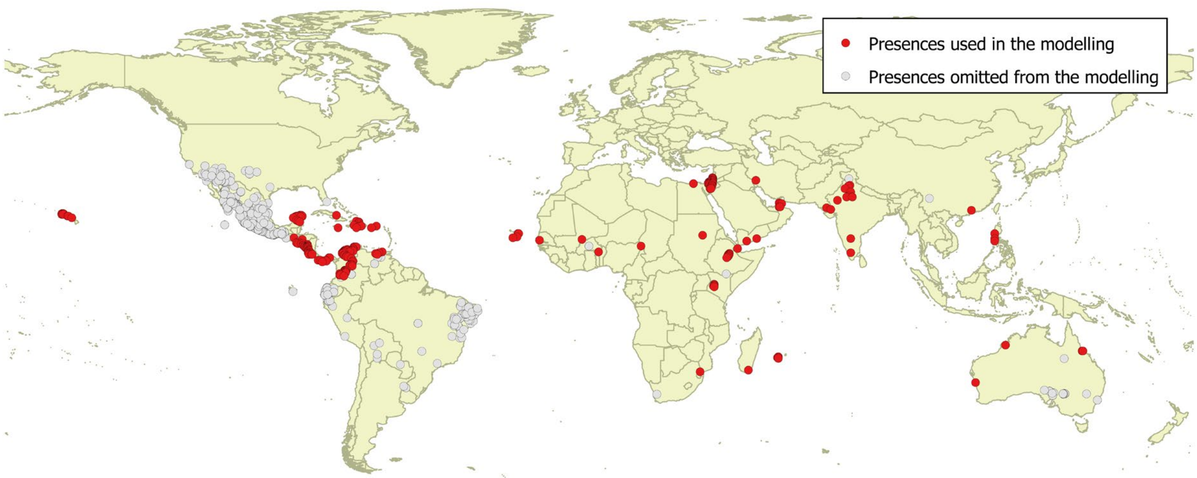

Figure 1. Occurrence records obtained for *Prosopis juliflora*. Points show the records used in the modelling and those considered unreliable and therefore not used in the modelling.

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 *P. juliflora* populations, in which the species is likely to have had sufficient time to disperse to all locations. For the model we assumed the native range to be a 300 km buffer around the minimum convex polygon bounding all occurrences from Central America (including the Carribbean islands, Colombia and Venezuela); AND

- A relatively small 30 km buffer around all non-native occurrences, 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 the region expected to be highly unsuitable for *P. juliflora* at the spatial scale of the model:
    - Mean minimum temperature of the coldest month (Bio6) < 5 °C (CABI, 2015). *P. juliflora* is highly insensitive to frosts and the coldest occurrence has Bio6 = 5.0 °C suggesting this is its minimum tolerance.
    - Mean temperature of the warmest quarter (Bio10) < 14 °C. We assumed areas colder than this would be unable to support growth and reproduction of the species, since the coldest occurrence had Bio10 = 14.1 °C.
    - Climatic moisture index (CMI) > 1.5. Although it tolerates a range of precipitation regimes, *P. juliflora* is adapted to arid environments (CABI, 2015), so we assumed that regions where precipitation is more than 1.5 times potential evapotranspiration would be too wet. In fact six occurrences (2.7%) were at wetter CMI values, but these were outliers from the main distribution.
    - Precipitation of the driest quarter (Bio17) > 275 mm, also reflecting a preference for arid environments with prolonged dry periods. Four outlying occurrences (1.8%) had higher Bio17 than this.
    - Tree cover > 50%, since *P. juliflora* is mostly found in open habitats. Four outlying occurrences (1.8%) were in more tree-covered grid cells than this.

In total, 11 occurrence grid cells (5%) were in regions classified as highly unsuitable for the species.

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).

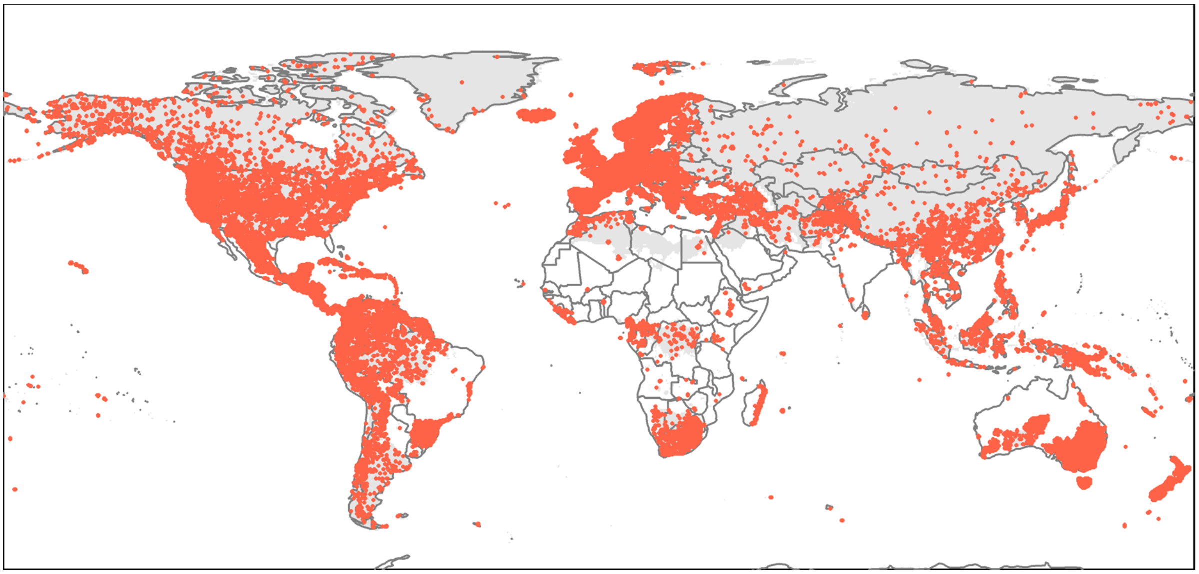

Figure 2. Randomly selected background grid cells used in the modelling of *Prosopis juliflora*, mapped as red points. Points are sampled from the native range, a small buffer around non-native occurrences and from areas expected to be highly unsuitable for the species (grey background region), and weighted 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 *P. juliflora* was most strongly determined by the minimum temperature of the coldest month but with substantial effects of the other variables included in the model (Table 1). From Figure 3, the ensemble model estimated suitable conditions for occurrence (>50% suitability) with:

- Minimum temperature of the coldest month > 6.7 °C
- Low climatic moisture index
- Low tree cover
- Low precipitation of the driest quarter
- High mean temperature of the warmest quarter

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 suitability (Figure 4). Interestingly, several regions with unreliable records of *P. juliflora* (see Figure 1) were also modelled as potentially suitable, including the coasts of Mexico and Ecuador, and northeast Brazil. Elsewhere, large areas of Africa, the Middle East, India, southeast Asia and western Australia were projected as being potentially climatically suitable for *P. juliflora* invasion (Figure 4).

The projection of suitability in Europe and the Mediterranean region suggests that *P. juliflora* may be capable of establishing around parts of the coastline of the Mediterranean, especially in North Africa and the Middle East, but also in Greece, Cyprus, Italy (Sicily) and Spain (Figure 6). South Portugal and Macaronesia may also have potential for *P. juliflora* to establish (Figure 6). The main limiting factor preventing further predicted suitability appeared to be low winter temperatures.

By the 2070s, under climate change scenario RCP8.5, the suitability region in Europe is predicted to increase somewhat, but still be restricted to the same regions (Figure 7). The Biogeographical Regions (Bundesamt fur Naturschutz (BfN), 2003) most suitable for *P. juliflora* establishment are predicted to be Macaronesia and the Mediterranean, with the latter projected to become more suitable under the climate change scenario we evaluated (Figure 8).

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 algorithms). Results are the average from models fitted to five 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 of the driest quarter	Climatic moisture index	Tree cover
MARS	0.9850	yes	67%	3%	4%	12%	13%
GAM	0.9846	yes	63%	8%	4%	13%	13%
GLM	0.9831	yes	59%	13%	5%	12%	11%
GBM	0.9831	yes	60%	4%	7%	12%	17%
ANN	0.9829	yes	49%	10%	11%	16%	15%
RF	0.9756	yes	52%	6%	8%	22%	11%
FDA	0.9754	yes	59%	14%	20%	3%	4%
Maxent	0.9714	yes	64%	4%	4%	18%	10%
MEMLR	0.9660	yes	57%	4%	7%	27%	4%
CTA	0.9606	no	57%	2%	9%	16%	16%
Ensemble	0.9860	no	59%	7%	8%	15%	11%

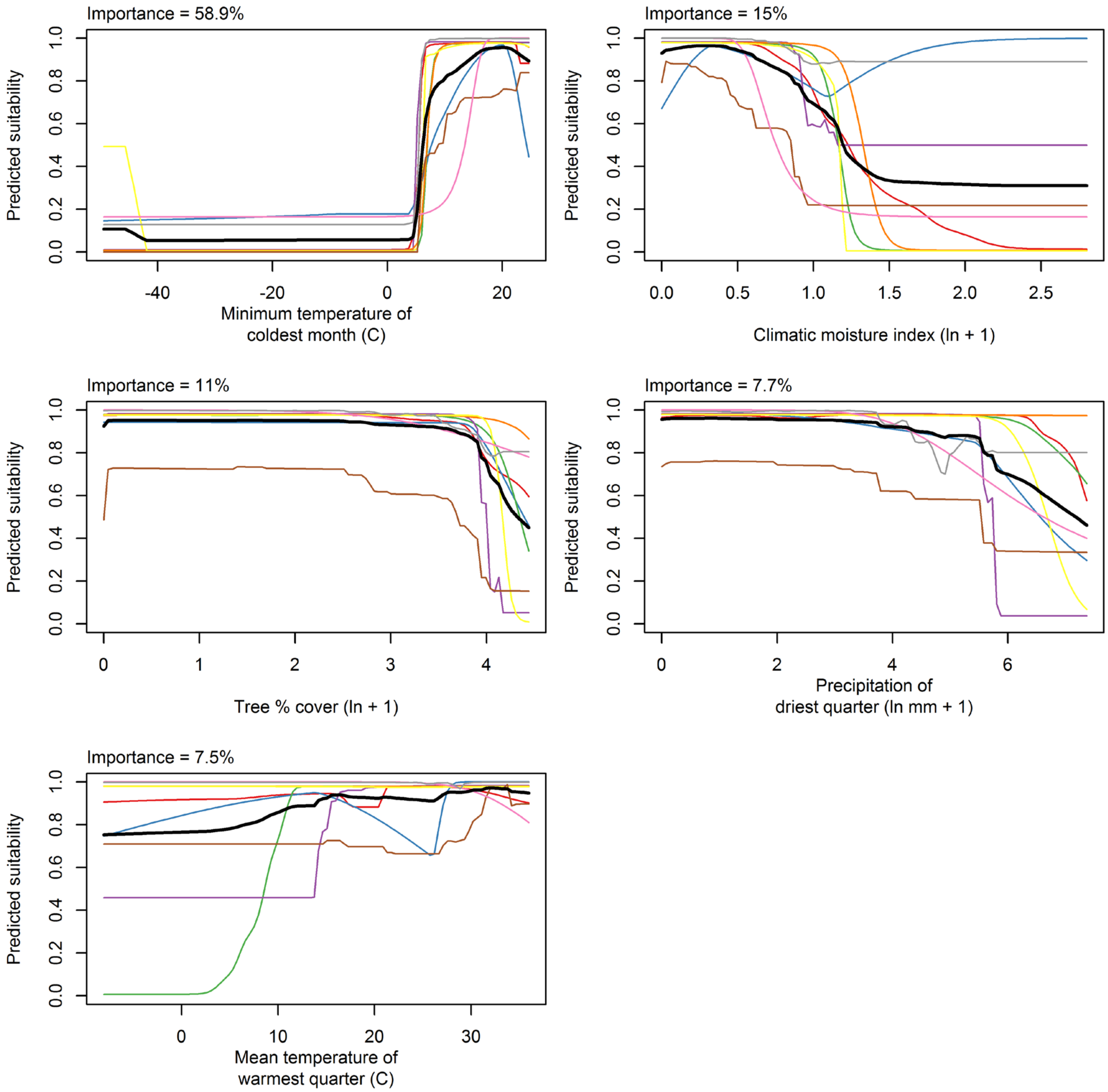

Figure 3. Partial response plots from the fitted models, ordered from most to least important. Thin coloured lines show responses from the algorithms in the ensemble, while the thick black line is their ensemble. In each plot, other model variables are held at their median value in the training data.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

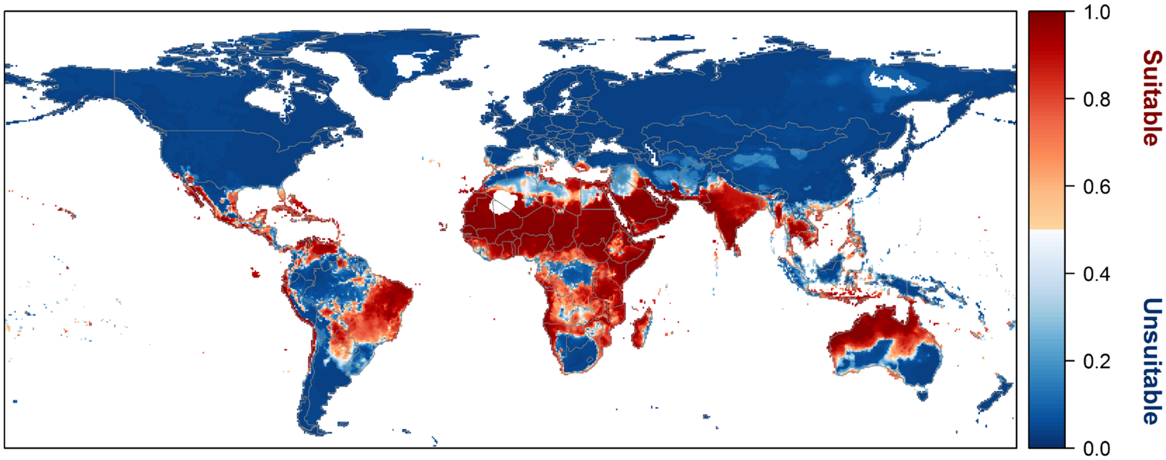

Figure 4. Projected global suitability for *Prosopis juliflora* establishment in the current climate. For visualisation, the projection has been aggregated to a 0.5 x 0.5 degree resolution, by taking the maximum suitability of constituent higher resolution grid cells. Values > 0.5 may be suitable for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

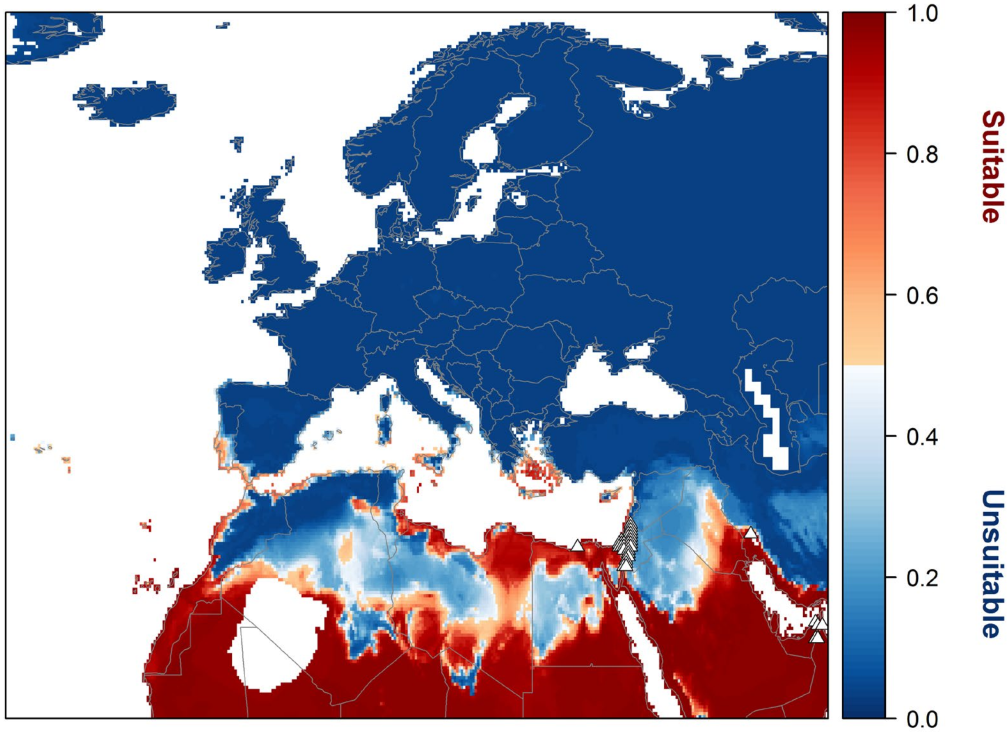

Figure 5. Projected current suitability for *Prosopis juliflora* establishment in Europe and the Mediterranean region. The white areas have climatic conditions outside the range of the training data so were excluded from the projection.

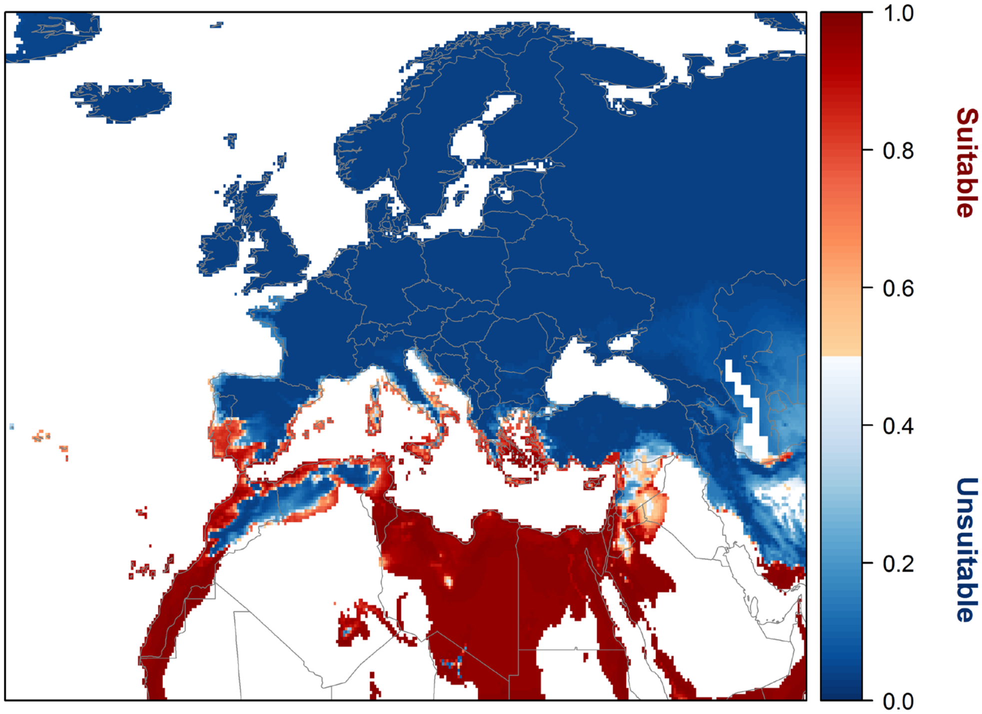

Figure 6. Projected suitability for *Prosopis juliflora* establishment in Europe and the Mediterranean region in the 2070s under climate change scenario RCP8.5, equivalent to Figure 5.

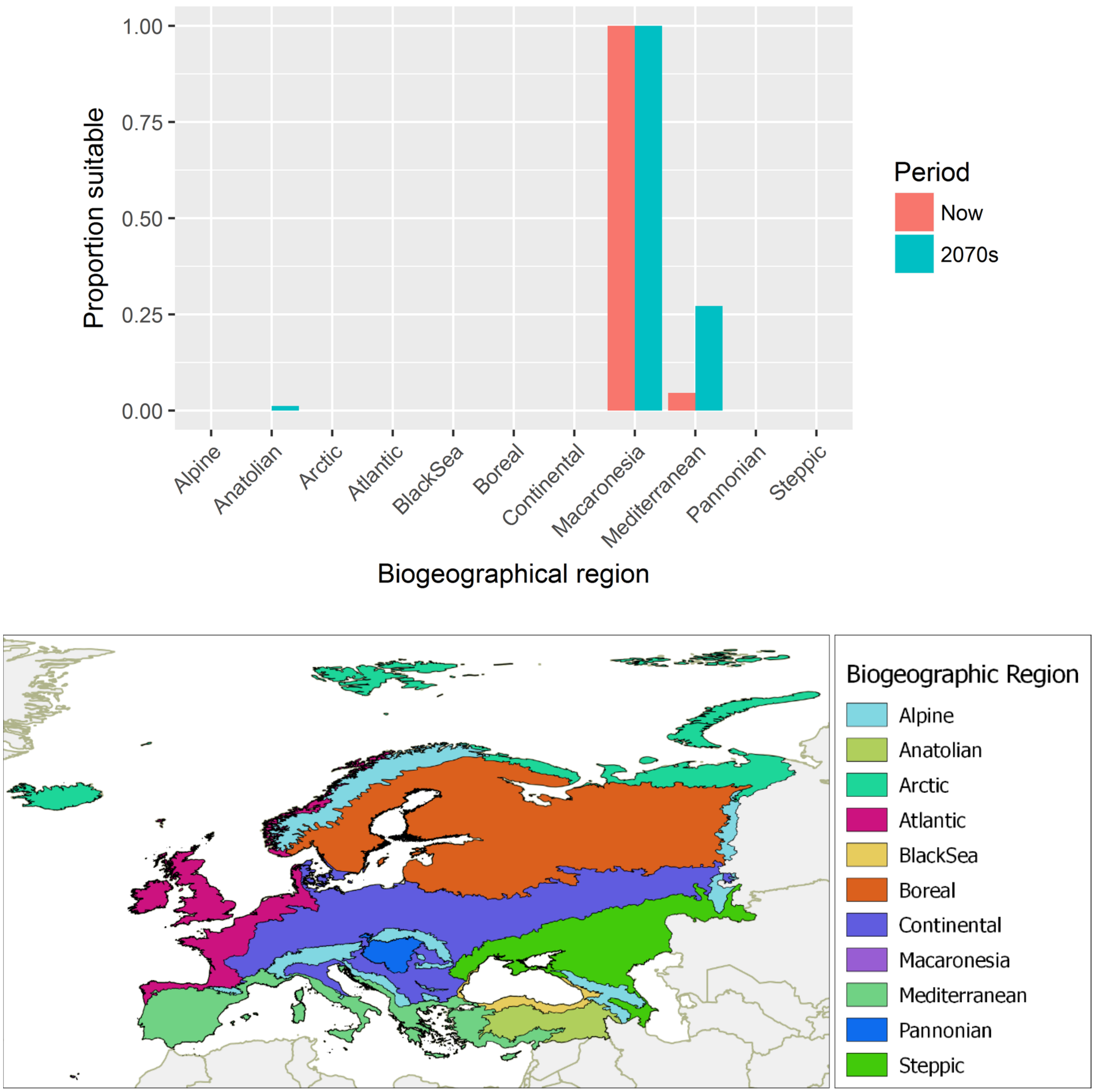

Figure 8. Variation in projected suitability among Biogeographical regions of Europe (Bundesamt fur Naturschutz (BfN), 2003). The bar plots show the proportion of grid cells in each region classified as suitable in the current climate and projected climate for the 2070s under emissions scenario RCP8.5. The coverage of each region is shown in the map below.

Caveats to the modelling

There was considerable uncertainty as to the status of the *P. juliflora* distribution records obtained from global databases. We used expert opinion to filter out records that were potentially unreliable, but it is possible that some true *P. juliflora* were lost. The potential effect of this could be to underestimate the range of conditions under which the species could establish.

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 0.48, slightly increasing the region predicted to be suitable.

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.

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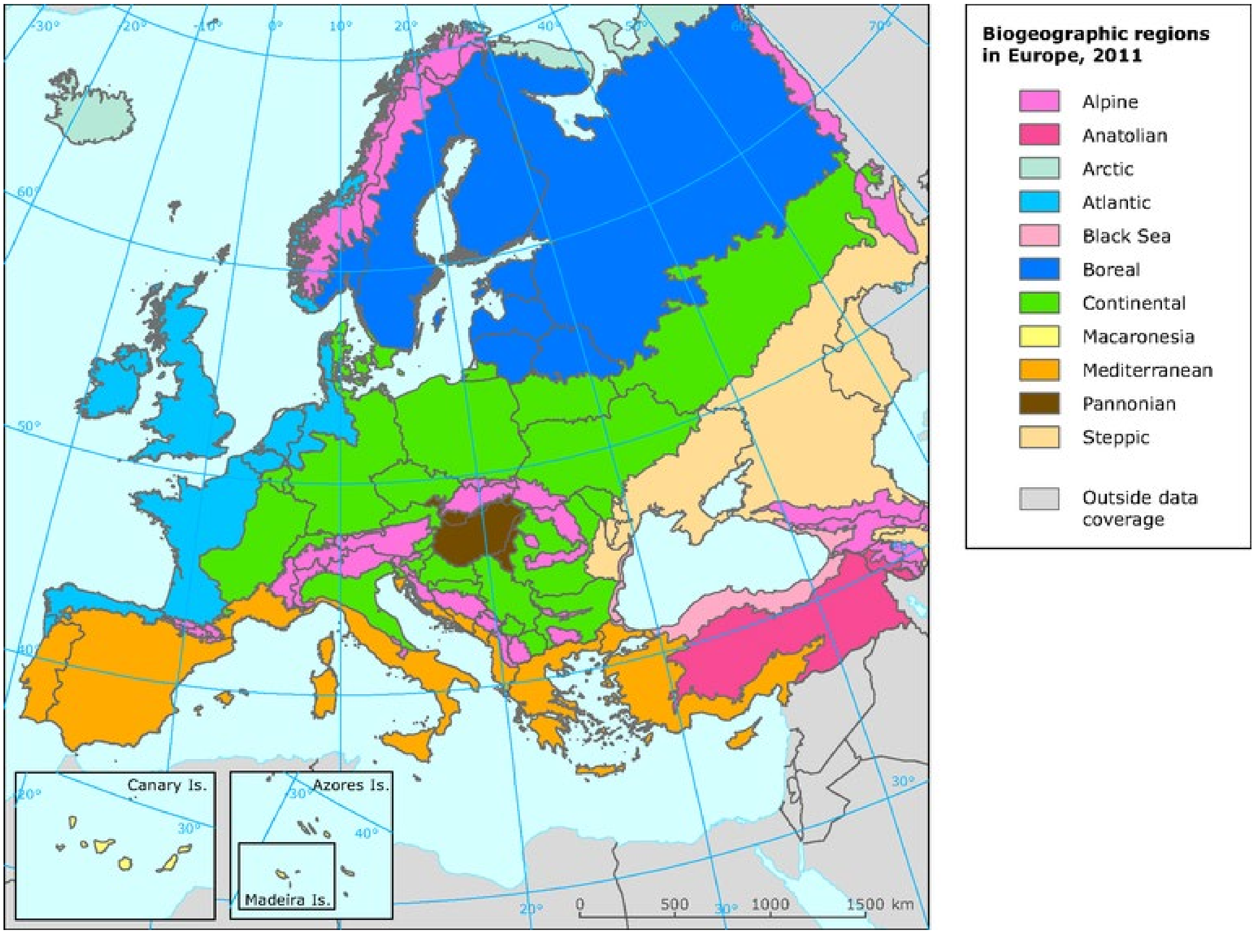
Appendix 2: Biogeographical regions



Appendix 3: Supplementary information

Additional common names:
Brazil: algarobeira; algarobia; algarobo; algaroba; Cape Verde: espinheiro; spinho; Colombia: algarrobo; algarrobo forragero; anchipia guaiva; aroma; cují; cují negro; cují yaque; manca-caballo; trupi; trupillo; Costa Rica: arómo; Cuba: algarrobo del Brasil; algarrobo exótico; cambrón; chachaca; guatapaná; pluma de oro; Curaçao: cojí wawalú; cuida; indjoe; indju; kuigi; qui; wawahi; Djibouti: Dat caxa; garan-wa; Dominican Republic: bayahon; bayahonda; bayahonda blanca; bayahonde; bohahunda; cambrón; mezquite; vallahonda; Ecuador: algarrobo; El Salvador: carbon; Germany: Mesquitbaum; Mesquitebaum; Guatemala: campeche; nacascol; nacasol; palo de Campeche; Haiti: baron; bayahonde; bayahonde française; bayarone; bayawon; bayawonn; bayawonn française; bayohon; chambron; guatapaná; Hawaii: algaroba; kiawe; mesquite; Honduras: algarrobo; espino real; espino ruco; India: angrezi bavaliya; belari jali; ganda babul; ganda-babool; gando baval; vilayati babool; vilayati babul; vilayati khejra; vilayati kikar; karuvelam; Iraq: shouk shami; Jamaica: cashaw; cashew; Kenya: eterai; mathenge; prosopis; Mali: gaudi maaka; Marquesas: carobier; Mexico: algarroba; catzimec; chachaca; mareño; mesquite; Middle East: ghaf; Nicaragua: acacia de Catarina; aquijote negro; espino negro; Niger: mugun kawa; shejain kawa; Pakistan: vilayati babul; vilayati jand; vilayati kikar; Panama: aromo; manca-caballo; Peru: algarrobo; huarango; Philippines: aroma; Puerto Rico: algarroba; Algarroba del Hawaii; algarrobo americano; aroma; aroma americana; bayahonde; cambrón; mesquite; Senegal: dakkar toubab; Somalia: garan-wa; lebi; Sudan: mesquite; Trinidad and Tobago: mesquit-tree; Venezuela: caóbano gateado; cuji; cují amarillo; cuji negro; cují yague; cují yaque; cujicarora; maíz criollo; yaque; yaque blanco; yaque negro

Notes on distribution:
This following text section has been added, based on discussions between members of the EWG and has formed the basis of the occurrence data used for the model calibration. Data are supported by collections of leaf and plant material that were later analyzed, results being reported in Harris et al. (2003), Pasiecznik et al. (2004), Landeras et al. (2006), Pasiecznik et al. (2006), Trenchard et al. (2008), Sherry et al. (2011). See appendix 6 for the distribution of the species.
P. juliflora is considered the only prosopis species present or naturalized or by far the most dominant, in the following '*P. juliflora* only' list of countries. In these, records for presence of a naturalized specimen of prosopis is considered very likely to be *P. juliflora* (*sensu lato*). The second list ('*P. juliflora* + other species') includes other countries where *P. julilfora* is only one of several naturalized (or native) species, and the situation for each is summarized individually.

Note: This list refers to taxonomic confusion between *P. juliflora* and of any other *Prosopis* species of section Algarobia that includes all of the most commonly introduced species, e.g. *P. alba, P. chilensis, P. glandulosa, P. juliflora, P. pallida, P. velutina*, etc.). It does not include the few 'Old World natives', notably *P. africana* in Africa and *P. cineraria* and *P. farcta* in Asia, that are not a taxonomic issue, nor have never been, as these species are very distinct in terms of morphology (and uses), etc. (see Pasiecznik et al. (2004).

And as a rule of a 'rule of thumb' from observations in Africa and Asia, it is considered that where *Acacia tortillis* is native, *P. juliflora* can survive, and as such, is a good indicator species (Personal communication; N. Pasiecznik, 2017).

***P. juliflora* only**

Americas

Caribbean islands (all) + Atlantic islands (Ascension, St Helena)

Colombia

- with the exception of, perhaps, the very south, near the Ecuador border where the range limits with *P. pallida* are not clearly defined, but may be considered as discrete.

Venezuela

Africa

Sahelian Africa and the Horn

- Mali, Burkina Faso, Niger, Chad (except around Lake Chad where *P. chilensis* has been positively identified from scans of leaf sample received, but the frequency and other information is unknown), Sudan (South Sudan likely), Ethiopia, Somalia (including Somaliland and Puntland) (Personal communication, N. Pasiecznik, 2017).

East Africa

- Kenya, and considered very likely in Tanzania and Uganda; and likely in Angola, northern Botswana, Zambia and Zimbabwe (though samples not seen).

Southern Africa

- Mozambique, Madagascar (highly likely)

Asia

Middle East

- Arabian Peninsula countries (all)
- Iran (south coast)

South Asia

- India, Pakistan, Sri Lanka, and whereas plantations of other prosopis species were made and a few scientific trials have been widely published, none are known to have become naturalized (Personal communication, N. Pasiecznik, 2017).

South East Asia

- Myanmar (in the norther, recently identified invasions).
- Philippines (identified as of the Central American race)

Europe

The naturalised reports in Gran Canaria were identified following the completion of the PRA and hence the modelling of the species and although the EWG does not consider this will change the output of the modelling it is noted here.

***P. juliflora* + other species**

Americas

Brazil

- The dominant species in the north east and especially inland areas is certainly *P. pallida*, and not *P. julilfora* as is widely used in the literature even today. However, there are records for *P. juliflora* from coastal areas, and it is likely that it has also naturalized especially in norther coastal areas, adding to the difficulty in resolving the confusion.

Mexico

- The confusion as to the northern native range limit of *P. juliflora* remains unconfirmed, but it appears likely that the latest detailed analysis (Palacios, 2006) may be correct, and that this lies south of the Guatemala-Mexico border, and all Pacific coastal and inland populations north of this were of other species. However, his work did identify a small population of *P. juliflora* in coastal Yucatan and which is probable, related to the Caribbean population.

Central America (mainland)

- *P. juliflora* is certainly the dominant species in Pacific coastal areas, extending up valleys and can be found also on some dry plateau sometime far inland (e.g. in Honduras). It must be noted, however, that away from the coast, there are at least five other native *Prosopis* species recorded, and although they are rarely confused, confirmation by the untrained eye is not guaranteed.

South America (south of Colombia and Venezuela)

- Palacios et al. (2012) finally accepted that Burkart (1976) was wrong - and de facto, that Johnston (1962) was right), in that <u>there is no *P. juliflora* in Peru or Ecuador</u>. Thus, all other records for *P. juliflora* presence the neighbouring countries of Bolivia and Chile must also now be considered as incorrect.

Africa

North Africa

The Mediterranean coast

- The taxonomy of any prosopis material in this region is questioned, including the whole of Tunisia. Many species were planted in early trails, and many have been recorded as 'present' in papers such as those in the FAO State of Knowledge (Habit and Saavedra, 1990), etc. More information is needed.

Egypt

- *P. juliflora* is certainly the common invasive species in the Halaib triangle (south east corner), and is likely elsewhere along the southern border with Sudan, and the Red Sea coast.

Morocco

- It is highly likely that *P. julilfora* may be presence in Western Sahara, especially in coastal areas.

Algeria and Libya, south of the Tropic of Cancer

- It is possible but not certain that *P. juliflora* is present in these areas.

Sahelian Africa and the Horn

Cape Verde

- The dominant species is certainly *P. pallida*, and not *P. juliflora* as is widely used in the literature even today. However, the only records for *P. juliflora* (and other species) are from research trials with no naturalization has observed up to 1995, but sterile triploids and it is likely that it is also naturalized especially in coastal areas, adding to the difficulty in resolving the confusion.

Senegal

- The name *P. juliflora* has and still referred to as the common species. However, earlier work confirmed that *P. pallida* was the dominant species along the coast (see, e.g Harris et al., 2003, Landeras et al., 2006), and was noted also as the main species in central Senegal as far as Kaffrine, though it is likely that *P. juliflora* is also present in other areas (Personal communication, N. Pasiecznik, 2017).

Mauritania

- *P. juliflora* is likely to be the dominant species, widely planted by FAO and other development organizations around Nouakchott and in other parts of the country, but *P. pallida* was also positively identified as naturalized around Aleg and may be more common in the south and coastal areas (Pasiecznik et al., 2006).

Djibouti

- A nationwide survey (Pasiecznik, 2013) found *P. juliflora* the dominant species, making up >95%, with *P. pallida* naturalized in only two areas (Djibouti Ville and Ali Sabieh).

Southern Africa

South Africa (and central and southern Namibia and Botswana).

- The common species are *P. glandulosa* and *P. velutina* and hybrids, though as *P. juliflora* has been identified from around Maputo, Mozambique (pers comm, Pasiecznik) and has been tentatively identified from herbarium samples in Zimbabwe, it is highly likely that it occurs in Limpopo, eastern Mpumalanga, and north coastal Kwazulu Natal.

Asia

Near East

Israel, the West Bank and Jordan

- *P. juliflora* is present in the Jordon Valley (Dufour-Dror and Shmida, 2017). But occurrence data in Israel, the West Bank and Jordan is questioned by the EWG.

South East Asia

- Records for many Asian countries especially those in the east and south east, are often old and with no further details (e.g. Burkart 1976), though many have been repeated in later publications (e.g. Pasiecznik et al. 2001, Shackleton et al. 2014). As such, specimens may only be 'odd' trees and the taxonomy used cannot be verified in any case.

Oceania

Australia

- *P. juliflora* is consider as the least frequent of the four identified invasive species. In southern areas, *P. glandulosa, P. velutina* and hybrids dominate. In northern WA, NT and Qld, *P. pallida* is the dominant invasive, with *P. juliflora* noted in parts of WA and Qld, though records from NSW may well be mis-identifications.

Hawaii

- Both species are present, it seems, though *P. pallida* appears to be dominant.

Galapagos

- *P. juliflora* has been positively identified, but noting the revised classification of Palacios et al. (2012) and the proximity to coastal Peruvian populations, this must be revisited.

Other Pacific Islands

- Both species are apparently present, it seems, though *P. pallida* appears to be dominant.

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

Member States:

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

Biogeographical regions

	Recorded	Established (currently)	Established (future)	Invasive (currently)
Alpine	–	–	–	–
Atlantic	–	–	–	–
Black Sea	–	–	–	–
Boreal	–	–	–	–
Continental	–	–	–	–
Mediterranean	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. Relevant illustrative pictures (for information)

P. juliflora leaves and pods, Somaliland.
Nick Pasiecznik

P. juliflora flowers and leaves, Djibouti.
Nick Pasiecznik

Typical P. juliflora leaves and thorns on an emerging shoot.
Nick Pasiecznik

P. juliflora ‘tree’. Around a hotel compound it may have also been ‘pruned’ Nick pasiecznik

Typical P. juliflora multi-stemmed form. Note also the masses of pods below and around.
Nick Pasiecznik

Some P. juliflora shows a much more prostrate form with some branches growing along the ground. Nick Pasiecznik

P. juliflora invasion between to block a dirt road, Berbera, Somaliland.
Nick Pasiecznik

P. juliflora invading native Acacia tortillis dominated savanna scrub, Djibouti.
Nick Pasiecznik

The start of P. juliflora invasion in coastal Sri Lanka, within metres of the shore and mangroves at Puttalam lagoon.
Nick Pasiecznik

P. julifora invading Lake Baringo shoreline, Kenya, Rains have raised the water level, and waterlogged plants will eventually die, but subrmerged thorned branches are a bane to local people as they tear fishing nets
Nick Pasiecznik

P. julifora invasion, Baringo, Kenya, with cleared land in the foreground.
Nick Pasiecznik

P. juliflora pods attacked by bruchid beetles in Djibouti, assumed to have been introduced accidently from Yemen where they are considered accidentally released by FAO. However, even high levels of infection are not reducing spread, thus showing ineffectualness of bruchids as biocontrol agents.
Nick Pasiecznik

Appendix 6: Distribution maps[4]

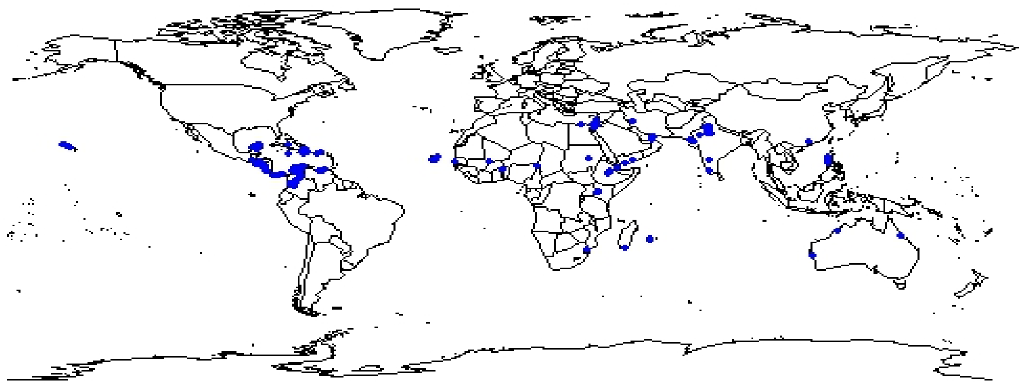


Figure 1: World distribution

[4] Note Maps in appendix 6 may contain records, e.g. herbarium records, that were not considered during the climate modelling stage. Data sources are from literature, GBIF and expert opinion.

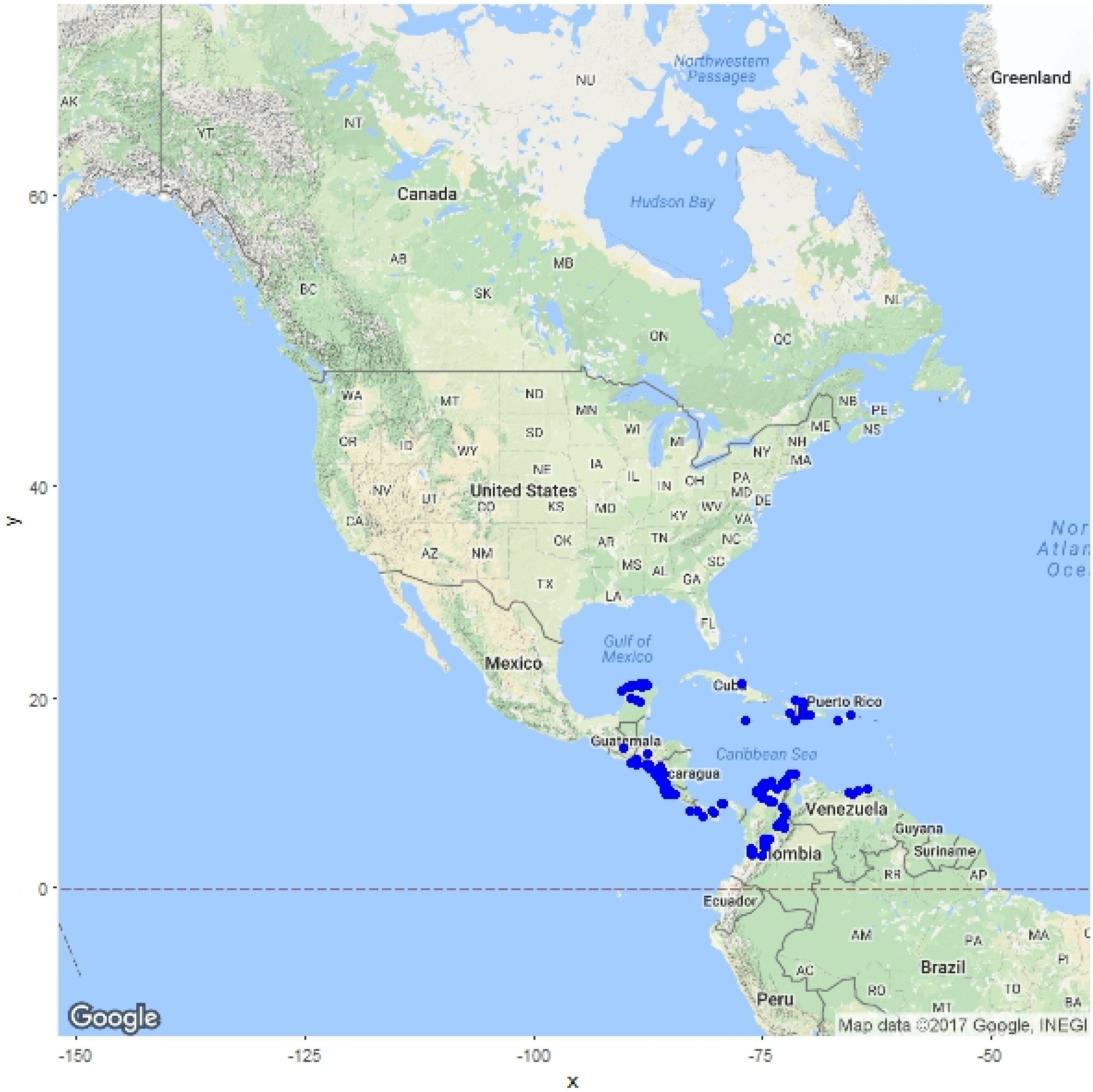


Figure 2: Distribution of *P. juliflora* in central and South America.

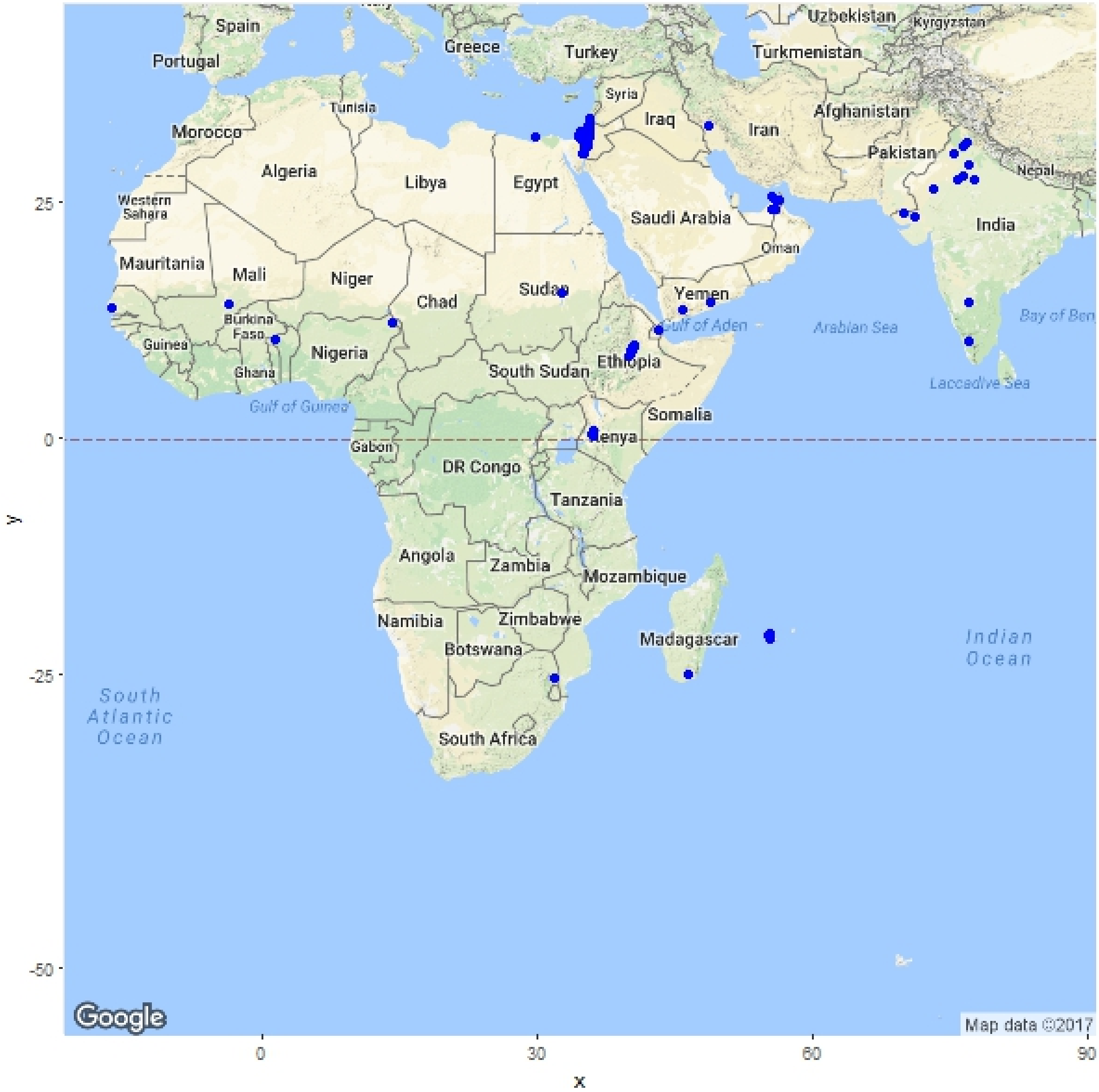


Figure 3: Distribution of *P. juliflora* in Africa and Asia.

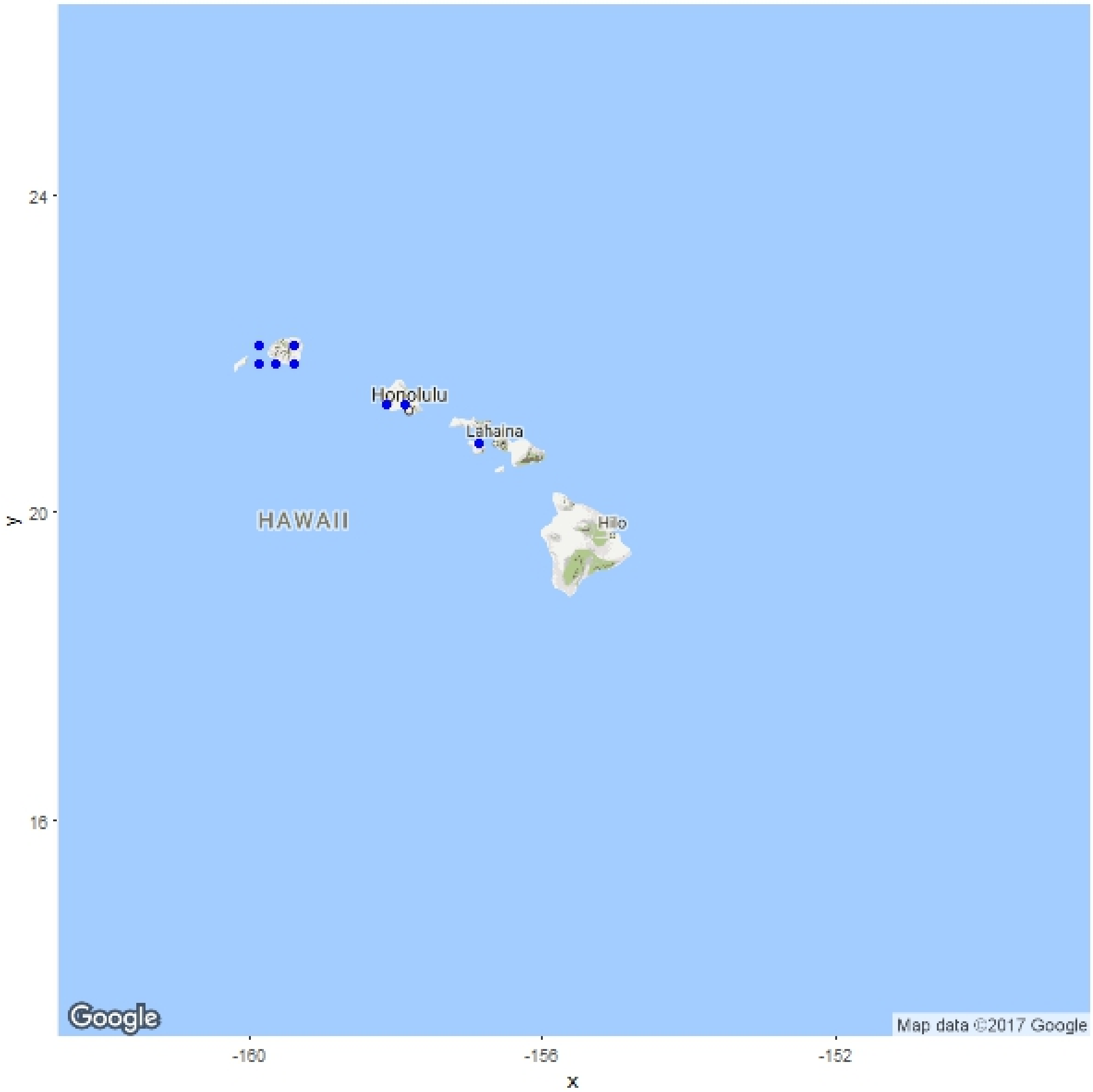


Figure 4: Distribution of *P. juliflora* in Hawaii

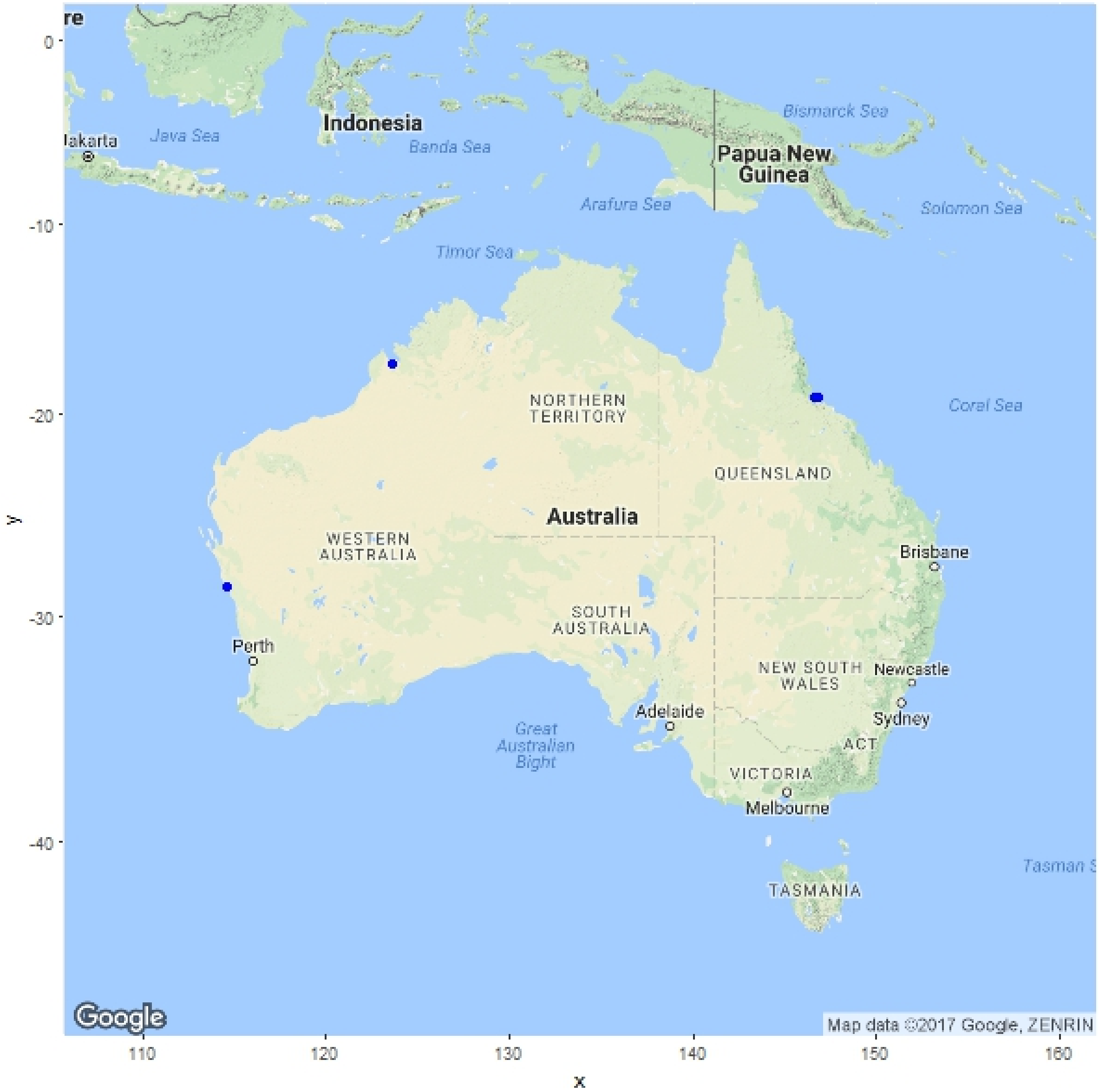


Figure 5: Distribution of *P. juliflora* in Australia