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

18-23438 (17-23243)

Pest risk assessment for *Lespedeza cuneata*

2018
EPPO
21 Boulevard Richard Lenoir
75011 Paris
www.eppo.int hq@eppo.int

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: *Lespedeza cuneata* invasion in North America Leslie J. Mehrhoff, University of Connecticut, Bugwood.org

EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION

Pest risk assessment for *Lespedeza cuneata*

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

Composition of the Expert Working Group

BRUNDU Giuseppe (Mr)	University of Sassari, Department of Agriculture, Viale Italia 39, 07100 Sassari, Italy gbrundu@tin.it
Chapman Daniel (Mr)	Centre for Ecology and Hydrology Bush Estate, Penicuik, Edinburgh , UK, dcha@ceh.ac.uk
FLORY S. Luke (Mr)	Agronomy Department, University of Florida, PO Box 110500, FL 32611 Gainesville, United States flory@ufl.edu
LE ROUX Jaco (Mr)	Department of Botany and Zoology, Stellenbosh University, Private Bag X1, 7602 Matieland, South Africa jleroux@sun.ac.za
PESCOTT Oliver (Mr)	CEH Wallingford, Benson Lane, OX10 8BB Wallingford, Oxfordshire, United Kingdom olipes@nerc.ac.uk
SIEMANN Evan (Mr)	Rice University, 6100 S. Main St, TX 77005 Houston, United States siemann@rice.edu
STARFINGER Uwe (Mr)	Julius Kühn Institut (JKI), Federal Research Centre for Cultivated Plants, Institute for National and International Plant Health, Messeweg 11/12, 38104 Braunschweig, Germany uwe.starfinger@julius-kuehn.de
TANNER Rob (Mr)	OEPP/EPPO, 21 boulevard Richard Lenoir, 75011 Paris, France Tel: +33-145207794 - rt@eppo.int

The pest risk assessment for *Lespedeza cuneata* 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 *Lespedeza cuneata* was first drafted by Dr Oliver L. Pescott, CEH Wallingford, UK,

The PRA has been 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

Contents

Summary[1] of the Express Pest risk assessment for *Lespedeza cuneata*

PRA area: The EPPO region

Describe the endangered area:

The Expert Working Group (EWG) considers that the endangered area is primarily grasslands, open shrublands and forest, and other open or disturbed habitats, within the Continental, Pannonian, Steppic, Mediterranean, Atlantic and Black Sea biogeographic regions. Although there is limited suitability in other regions, e.g. the Boreal region and more western Atlantic areas, the EWG considers that these areas are less likely to be at risk from invasion. The countries within the endangered area include (EU countries): Portugal, France, Germany, Poland, Lithuania, Greece, Croatia, Slovenia, Austria, Hungary and Italy and the wider EPPO region: Belarus, Ukraine, Georgia, Turkey, Albania, Bosnia and Herzegovina and the north coastline of Algeria.

Within Europe and the Mediterranean region, the species distribution model based on current climatic conditions (Appendix 1, Figure 6) predicts a large area of potential suitability for *L. cuneata*. The most suitable regions are predicted to be in continental parts of southern and eastern Europe (e.g. south-east France, northern Italy, Croatia, Serbia, southern Russia). North of this, the model predicts marginal suitability for establishment as far north as the southern Baltic coast (Figure 5). However, the disagreement among algorithms was relatively high in this region (Figure 4b), providing uncertainty as to the exact northern extent of the potentially suitable region. The model predicts that warm winters and arid conditions are the main limiting factors around the Mediterranean coast and in southern Europe, while cool summer temperatures most strongly limit suitability in most of northern Europe.

In terms of Biogeographical Regions, those predicted to be most suitable for *L. cuneata* establishment in the current climate are the Pannonian, Black Sea, Continental, Mediterranean, Steppic and Atlantic.

Main conclusions

The results of this PRA show that *L. cuneata* poses a moderate risk to the endangered area (Pannonian, Black Sea, Continental, Mediterranean, Steppic and Atlantic biogeographical region) with a moderate uncertainty. *Lespedeza cuneata* invades grassland, woodland, forests, edges of wetlands, pastures, and disturbed sites in the United States. The species forms dense stands in areas where it invades, reducing light availability and potentially increasing competition for soil water (Eddy and Moore 1998; Allred *et al.* 2010; Bauman *et al.* 2015). Eddy and Moore (1998) showed that invasions of *L. cuneata* into oak savannas in southeastern Kansas reduced native species richness. *Lespedeza cuneata* can have high socio-economic impacts; for instance, in the USA it can replace more palatable forage species in some systems. High tannin levels in old plants can also have negative impact on cattle and horses (Fechter and Jones 2001).

Entry

Plants for planting (horticulture and agriculture) and contaminant of hay are the main pathway for entry into the EPPO region. The likelihood of entry is low with a moderate rating of uncertainty.

Establishment

The natural areas most at risk of invasion are grasslands, woodlands and forests, the edges of wetlands, pastures, and disturbed areas (Weber 2017). However, variance amongst predictions was relatively high in this region, providing uncertainty as to the exact northern extent of the potentially suitable region. The model predicts that warm winters and arid conditions are the main limiting factors around the Mediterranean coast and in southern Europe, while cool summer temperatures most strongly limit suitability in most of northern Europe.

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

Spread

Reports of range increases and local spread are common in the USA (Gucker 2010). Spread of the species in Kansas showed a 24 % increase in area per year (from 25 000 acres in 1989 to 500 000 acres in 2003) (Gucker, 2010; Duncan *et al.et al.* 2004), however, it's not clear how much of the spread can be attributed to natural or human-mediated spread or intentional planting. Natural spread is likely to be moderately rapid. Quick *et al.* (2017) found that both animals and wind could spread *L. cuneata* seeds. Within their experimental set up, Quick *et al.* (2017) found that wind could move seed up to 3 m, whilst various animals' pelts were demonstrated to pick-up and retain *L. cuneata* seeds within their fur after experimental traverses through a patch of the species. Livestock can also disperse the species in their feces (Cummings *et al.* 2007). At least two studies have also noted an association with horse trails in the USA (Campbell *et al.* 2001; Stroh *et al.* 2009). Various other wildlife has been found to disperse the seed of *L. cuneata*, including deer, birds, and rodents (Eddy *et al.* 2003). In some cases, passage through animals' digestive tracts has been shown to increase germination, as in the case of the northern bobwhite quail, *Colinus virginianus* (Blocksome 2006). Activities associated with the production and distribution of hay can spread *L. cuneata* seed (Ohlenbusch *et al.* 2007). The spread of seed by vehicles is also suspected due to the spread and occurrence of the species in areas associated with high vehicle use in an army training area in Kansas (Althoff *et al.* 2006). Likewise, heavy mechanical disturbance associated with forestry has also been associated with the spread of *L. cuneata* away from seeded areas (Pitman 2006). The species may also be spread through the horticulture industry. The spread of manure between farms/gardens can act to spread the species.

Potential impacts in the EPPO region

As *L. cuneata* is absent from the natural environment in the EPPO region, all data on impacts comes from other regions of the species' invaded range. Thus, all information on impacts can only be used as a proxy to the EPPO region. The attributes that lead to impacts in the current range are not context dependent (for example dense canopies and allelopathy) and therefore the EWG consider that impacts on biodiversity and ecosystem services are likely to be similar in the EPPO region compared to the US. On the contrary, the EPPO region has less rangeland grazing than the US and therefore socio-economic impacts are likely to be lower (EWG opinion). The text within this section relates equally to EU Member States and non-EU Member States in the EPPO region.

Climate change

The climate change projections for Europe in the 2070s cause the model to predict pronounced northwards expansions of the suitable region, accompanied by a lesser contraction of the southern part of the suitable region (Figure 7 and 8). In the more extreme RCP8.5 climate change scenario, the species is predicted capable of establishing as far north as the Arctic coast in Russia. However, some species reports consider that photoperiod affects *L. cuneata* development (Gucker, 2010), which may restrict northwards expansion of the species. The countries within the endangered area include: Portugal, France, Germany, Poland, Lithuania, Belarus, Ukraine, Estonia, Latvia, Georgia, Turkey, Greece, Albania, Bosnia and Herzegovina, Croatia, Slovenia, Austria, Hungary, Italy, and the north coastline of Algeria, Sweden, Finland, Denmark, the Netherlands and Belgium. The influence of projected climate change scenarios has not been taken into account in the overall scoring of the risk assessment based on the high levels of uncertainty with future projections.

The results of this PRA show that *Lespedeza cuneata* poses a moderate risk to the endangered area (Pannonian, Black Sea, Continental, Mediterranean, Steppic and Atlantic biogeographical region biogeographical region) with a moderate uncertainty.

Phytosanitary risk (including impacts on biodiversity and ecosystem services) for the *endangered area* **Pathway for entry**	High	Moderate **X**	Low

Plants for planting: Low/Low Plants for planting (forage) Low/Low Contaminant of hay: Moderate/Low Likelihood of establishment in natural areas: High/High Likelihood of establishment in managed areas: High/High Spread: High/High **Impacts (EPPO region)** Biodiversity: Moderate/Moderate Ecosystem services: Moderate/Moderate Socio-economic: Moderate/Moderate			
Level of uncertainty of assessment **Pathway for entry** Plants for planting: Moderate/High Plants for planting (forage) Moderate/High Contaminant of hay: High/High Likelihood of establishment in natural areas: High/High Likelihood of establishment in managed areas: Low/High Spread: Low/High **Impacts (EPPO region)** Biodiversity: Moderate/High Ecosystem services: High/High Socio-economic: Moderate/High	High	Moderate **X**	Low
Other recommendations:NA			

Express Pest risk assessment:

…………..

***Lespedeza cuneata* (Dum.Cours.) G.Don**

Prepared by: Dr Oliver L. Pescott, CEH Wallingford, UK,

Email: olipes@ceh.ac.uk
Date: 22nd September 2017

Stage 1. Initiation

Reason for performing the PRA:
Lespedeza cuneata is an herbaceous legume native to eastern Asia and eastern Australia. The species has been introduced into other countries and continents. For example, it has naturalised and is invasive in southern and eastern parts of the USA. Reasons for it being considered high priority for a Pest risk assessment (PRA) include its high dispersal potential and the fact that a large area of climatically suitable territory is thought to exist in the EPPO region including Europe (Tanner *et al.* 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). *Lespedeza cuneata* was one of 16 species identified as having a high priority for PRA. Tanner *et al.* (2017) also assessed a suite of 37 non-native plant species using a modified version of the EPPO Prioritisation Process designed to be compliant with the EU Regulation 1143/2014 (Branquart *et al.* 2016); *Lespedeza cuneata* was included in this study's 'EU List of Invasive Alien Plants', and was subsequently ranked as a high priority for PRA given its high potential for spread and the fact that introduction and spread could potentially be reduced by trade restrictions given its current absence from natural habitats in the EPPO region (Tanner *et al.* 2017). Finally, climate modelling has shown that the species has the potential to establish in more regions in the EPPO region and Europe in particular than it currently occurs (Appendix 1). There is further potential for establishment in the Pannonian, Black Sea, Continental, Mediterranean, Steppic and Atlantic biogeographical regions (Appendices 1 and 2).

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

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

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

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

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: *Lespedeza cuneata* (Dum.Cours.) G.Don (Kingdom Plantae; Division Trachaeophyta; Class Magnoliopsida; Order Fabales; Family Fabaceae; Genus *Lespedeza* Michx.

Synonymy: *Lespedeza juncea* var. *sericea* (Thunb.) Lace & Hauech; *Lespedeza sericea* Miq; *Lespedeza juncea* subsp. *sericea* (Thunb.) Steen.; *Anthyllis cuneata* Dum.Cours.; *Aspalathus cuneata* (Dum.Cours.) D.Don; *Hedysarum sericeum* Thunb. non Mill; *Lespedeza argyraea* Siebold & Zucc.; *L. juncea* (L.f.) Pers. var. *sericea* Forbes & Hemsl.; *L. sericea* var. *latifolia* Maxim. (Ohashi *et al.* 2009; Flora of China, 2010; The Plant List, 2017a).

Notes:
(i) Some taxonomic lists and publications give *Lespedeza juncea* var. *sericea* (Thunb.) Lace & Hauech as the accepted name (e.g. The Plant List, 2017a, albeit in this case with a 'Low Confidence' rating); however, some phylogenetic work using both nuclear and plastid loci indicates that *Lespedeza juncea sensu stricto* and *Lespedeza cuneata* are distinct entities (e.g. Han *et al.* 2010; Xu *et al.* 2012); placing one as a variety of the other therefore seems untenable, unless other, currently separate, species are also lumped.

(ii) The names *Lespedeza juncea* var. *sericea* Maxim. and *Lespedeza juncea* subsp. *sericea* (Maxim.) Steen. are confusingly similar to some of the synonyms listed above, but are probably not synonymous with *L. cuneata* (Dum.Cours.) G.Don as currently recognised. For example, Pramanik & Thothathri (1983) give many of Maximovich's names, but do not list *L. juncea* var. *sericea* Maxim. as a synonym of *L. juncea* var. *sericea* (Thunb.) Forbes & Hemsl. The Plant List (2017b) suggests that this name is a synonym of the species *Lespedeza intermixta* Makino (a name accepted with 'High Confidence'). We do not attempt to resolve this here, but merely note that the nomenclatural issues surrounding the use of some of these names may be complex, and that the lists of synonyms presented by some databases may contain errors. Thus, the PRA is for the species *Lespedeza cuneata* (Dum.Cours.) G.Don.

EPPO Code: LESCU

Common names: China: 截叶铁扫帚 jie ye tie sao zhou; English: bush clover, perennial lespedeza, sericea lespedeza, Siberian lespedeza, Chinese lespedeza, Chinese bush clover, silky bush clover; French: lespédéza de Chine, lespédéza soyeux; Georgian: iaponuri samkura; German: Seidenhaar-Buschklee; Italian: lespedeza perenne; Japanese:メドハギ medohagi; Korean: bisuri; Spanish: lespedeza perenne; Russian: lespedeza serebristaya.

Plant type: Erect or sub-erect perennial herbaceous legume. Note that prostrate cultivars also exist (e.g. 'Appalow'; Hoveland & Donnelly 1983). Under the Raunkiaer classification the plant is a hemicryptophyte.

Related species in the EPPO region: *Lespedeza bicolor* Turcz.; *Lespedeza cyrtobotrya* Miq.; *Lespedeza davurica* (Laxm.) Schindl.; *Lespedeza tomentosa* (Thunb.) Maxim.; *Lespedeza juncea* (L.f.) Pers. All these species are listed by Czerepanov (1995) as native for parts of Russia and adjacent states (the former USSR). Note that *L. juncea* here explicitly excludes *L. sericea* Miq. (a synonym of *L. cuneata*), which is listed separately as an alien for the Caucasus (region 2 of Czerepanov 1995).

Lespedeza bicolor, *L. thunbergii*, *L. buergeri, L. capitata, L. japonica, L. tiliifolia* are also all listed as ornamental species within the EPPO region by the Royal Horticultural Society (www.rhs.org.uk).

2. Pest overview

Introduction

Lespedeza cuneata (Fabaceae) is an erect, sub-erect or prostrate, long-lived perennial herbaceous legume native to east Asia and eastern Australia. The species has been introduced to other countries and continents, notably to the USA from Japan in 1896 (Ohlenbusch *et al.* 2007). The species was originally introduced to the USA for fodder and soil conservation, with the subsequent use of improved varieties for hay and pasturage (Hoveland & Donnelly 1985). The species is now considered invasive in the USA, with documented impacts on native biodiversity (Brandon *et al.* 2004). Although the species has not been recorded in natural habitats in the EPPO region, based on its impacts elsewhere and the large area of the EPPO region that is thought to be climatically suitable (Tanner *et al.* 2017), the species has been prioritized for Pest risk assessment.

Reproduction

Lespedeza cuneata flowers are borne on short pedicels in leaf axils along the stem, in colours ranging from cream to purple (Hoveland & Donnelly 1983). In the USA the flowering season is from mid-July to early October (Ohlenbusch *et al.* 2007). Plants are reported to have varying proportions of chasmogamous and cleistogamous flowers (Cope 1966), although cleistogamous flowers may often dominate. For example, across three populations studied by Cope (1966) across two or three years, between 10 and 38% of seed was from chasmogamous flowers. The chasmogamous flowers are often cross-fertilized, whilst cleistogamous flowers are always self-fertilized (Donnelly 1979). Cope (1966) reported an outcrossed percentage of between 16 and 43% for chasmogamous flowers. The proportion of outcrossed chasmogamous flowers is related to the size and activity of pollinator populations (Cope 1966; Woods *et al.* 2009). Woods *et al.* (2009) found that "*L. cuneata* reproduced more consistently and with higher and more stable fecundity through all reproductive modes across sites and years than its native congeneric species [*L. capitata*]", arguing that this "fitness homeostasis" was a contributor to its success. Sundberg *et al.* (2002) found high genetic diversity across 9 populations of *L. cuneata* in Kansas (quantified using RAPD markers), also suggesting a high frequency of outcrossing between sites.

Logan *et al.* (1969) found that the seeds of *L. cuneata* were slow to germinate, and attributed this to the possible presence of a germination inhibitor in the seed coat; correspondingly, agricultural use of the plant typically involves hulling and scarification to improve germination rates (Hoveland & Donnelly 1983). Qiu *et al.* (1995) reported variation in the germination rate of the scarified seed of *L. cuneata* breeding lines and accessions, with the optimum rate between 20 and 30 degrees Celsius given adequate moisture. Germination rate was linked to seed weight in the breeding lines, but not in the accessions, probably reflecting joint selection for seed weight and germinability in the breeding lines. Seedlings are vulnerable to a hard freeze (Hoveland & Donnelly 1983), but the perennating tissues of adult plants have reportedly survived winter temperatures as low as -27 degrees Celsius (Ohlenbusch *et al.* 2007). Ohlenbusch *et al.* (2007) also report that burning can increase seed germination, promoting the establishment of new plants. Wright *et al.* (1978) noted that the seedlings of *L. cuneata* were slow to establish, and were poor competitors with a number of more aggressive species investigated in the context of rapid turf establishment for controlling erosion and vegetating roadsides; Wright *et al.* also concluded that high soil moisture contents and cool temperatures (21 degrees Celsius) were required for good rates of seedling emergence in the (unspecified) *L. cuneata* accessions investigated.

Lespedeza cuneata is a prolific seed producer, with individual stems able to produce in excess of 1 000 seeds, with between 130 and 390 kg of seed produced per acre infested by dense populations; One kg of seed equals around 770 000 actual seeds (Ohlenbusch *et al.* 2007). Seed yields are highest if no biomass is removed from the plant (e.g. from grazing, cutting, or burning) during the year of seed harvest (Adamson & Donnelly 1973). Seeds can be produced in the first year of growth: experiments in Oklahoma demonstrated that plants could set seed as early as 15 weeks (Farris 2006). Seed are expected to survive for more than 20 years in the soil, although

Ohlenbusch *et al.* (2007) note that no direct data were available to confirm this expectation. Inferences have been made about seed banks from field studies, however: Carter and Ungar (2002) found *L. cuneata* seed in 80-90 % of soil samples on restored forest on coal mine spoil, although plants were only present in 2 of 4 plots. Likewise, Honu *et al.* (2009) found over 160 seeds per square metre from a forest plot in Illinois where the plant was not found.

Schutzenhofer *et al.* (2009) developed a population projection matrix based on seed production, germination and plant growth data collected from secondary oak-hickory vegetation near St Louis, Missouri, and estimated that populations were likely to increase at a rate of 20 times per year; the authors noted that density dependence, or the site's carrying capacity, were possibly the only limits to abundance.

Habitat and environmental requirements
Pramanik & Thothathri (1983) state that *L. cuneata* (as *L. juncea* var. *sericea*) is "the only representative of the group occurring in both temperate and tropical climates", although their circumscription of *L. juncea* var. *sericea* includes some taxa that are accepted as distinct species by some other authorities. In the USA, it grows from "Florida to Texas, north to Nebraska, and east to the Atlantic coast, through the states of Michigan and New York" (Ohlenbusch *et al.* 2007). Mosjidis (1990), using growth chamber experiments, found that seedling height, shoot dry weight, leaf dry weight, and stem dry weight of all genotypes tested were very sensitive to both day length and temperature. Increases in temperature and day length above the lowest temperature combination (18/14 °C) and the shortest day length (11 h) brought about large increases in all measurements. Mosjidis (1990) suggests that 26/22 °C or 30/26 °C (day/night) and 13 or 15 h of day length are optimal conditions for screening seedling growth.

Lespedeza cuneata can grow where the annual precipitation exceeds 760 mm. However, the species is also considered to be drought tolerant and is well adapted to clay or loam soils (Hoveland & Donnelly 1985). A deep taproot system, with numerous lateral branches and finer fibrous roots, may penetrate 1.2 m or more into the soil (Guernsey 1977; Ohlenbusch *et al.* 2007), and contributes to the species' drought resistance. Note that the breeding of cultivars adapted to particular soil types is likely to have extended the fundamental niche of the species; for example, Hoveland & Donnelly (1983) report that the cultivar 'Serala 76' is better adapted to light-textured soils than the originally imported accessions.

Lespedeza cuneata can tolerate shallow soils of low productivity with a low pH (< 5), (Cope 1966; Plass & Vogel 1973; Hoveland & Donnelly 1983; Ohlenbusch *et al.* 2007). However, *L. cuneata* reportedly grows best between a pH of 6.0 and 6.5 on deep, well-drained clay or loamy soils (Ohlenbusch *et al.* 2007). Ohlenbush *et al.* (2001) also note that the species tolerates shade reasonably well, and is able to establish in dense shade where sunlight does not reach during the day; however, the best establishment is typically obtained where the competing vegetation is very short, and light is able to reach both the seed and seedlings (Ohlenbusch *et al.* 2007). It has been shown in the USA that the species performs better in soil in which it has been previously grown, although the precise mechanism for this self-facilitation is not known (Coykendall and Houseman 2014). Crawford and Knight (2017) provided evidence that effects on the soil biota were responsible, but also found that the self-facilitation advantage was not realised in competition with communities of native prairie species.

Weber (2017) and Gucker (2010) report that typical invaded habitats include grassland, woodland, forests, edges of wetlands, pastures, and disturbed sites (see Appendix 3, Figure 1).

Identification
Lespedeza cuneata is a long-lived perennial or subshrub, growing to a height of 0.5-1 m. The plant produces trifoliate leaves along the entire stem (Appendix 3, Figure 2), which are more crowded than those of *Lespedeza juncea s.s.* (Pramanik & Thothathri 1983); stems can be coarse or fine,

depending on the cultivar (Hoveland & Donnelly 1983). Leaflets are long, narrow, and indented at the end; one of the key features that has been used to distinguish *L. cuneata* from *L. juncea s.s.* is the length-to-width ratio of the leaflets (Pramanik & Thothathri 1983; Flora of China 2010), with the narrower-leafletted *L. cuneata* showing ratios between 4:1 and 6:1, but *L. juncea s.s.* being between 3:1 and 4:1.

It is perhaps also worth noting the observations of Pramanik & Thothathri (1983) here, that, "[o]f the complex, *L. juncea* (L.f.) Pers. shows much elasticity in its morphological characters within a short range. In general appearance it resembles strikingly any [sic.] of the other members of its immature, and sometimes mature forms as well. Thus, the pertinent question is whether to treat the complex [including *L. cuneata*] as a single species containing several well-defined varieties and forms, or to treat the members of the complex as distinct species." The fact that *L. cuneata* has also been subject to much selection through breeding programs (Hoveland & Donnelly 1983) introduces additional variation. Hoveland & Donnelly (1983) and Ohlenbusch *et al.* (2007) provide brief overviews of some of the key cultivars used throughout the 20th Century. Beaton *et al.* (2011) suggest that, for Illinois, "the *L. cuneata* present in the state today is likely a mixture of the descendants of […] three cultivars ['Arlington', 'Serala', and 'Interstate'], all of which are descendants of the original Japanese plants."

Cummings *et al.* (2007) and other authors (e.g. Gucker 2010) note that *L. cuneata* is probably most easily confused with the native species *L. virginica* (L.) Britton in North America; *L. juncea* is also frequently noted as a very similar species (Ohashi *et al.* 2009).

Symptoms (Impacts)
Lespedeza cuneata can thrive under a variety of conditions, crowding out more palatable forage in pastures and native species in natural areas. The species forms dense stands in areas where it invades, reducing light availability and potentially increasing competition for soil water (Eddy and Moore 1998; Allred *et al.* 2010; Bauman *et al.* 2015). Eddy and Moore (1998) showed that invasions of *L. cuneata* into oak savannas in southeastern Kansas reduced native species richness. For example, the number of native grass species decreased from 12 to four and native forb species declined from 27 to eight. There were also significant impacts on the numbers of invertebrate species found, and on the total biomass of native plant species. "*L. cuneata* has [also] been found growing in ditches, fence rows, or pastures without invading adjacent, well-managed rangeland and pastures", suggesting that land management is also an important determinant of invasion success (Ohlenbusch *et al.* 2007).

Lespedeza cuneata has the potential to disrupt pollination networks as the species has been shown to attract more pollinators than co-occurring native species in the US (Woods *et al.* 2012). Impacts on native plant diversity have also been identified in old fields in the US where Brandon *et al.* (2004) found the species to suppress native plants, possibly through shading effects. Brandon *et al.* (2004) concluded that the species "can subsequently take over grassland communities." *Lespedeza cuneata* may also have impacts on native plant communities through allelopathic effects. Allelopathic chemicals have been found to reduce native grass species' performance by up to 60% (Dudley and Fick 2003). Impacts on small mammal diversity and abundances in response to different *L. cuneata* cover levels have also been reported (Howard 2003).

Existing PRAs
Europe: 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; Roy *et al.* 2015) 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). *Lespedeza cuneata* was one of 16 species identified as having a high priority for PRA. Tanner *et al.* (2017) also assessed a suite of 37 non-native plant species using a modified version of the EPPO Prioritisation Process designed to be compliant with the EU Regulation 1143/2014 (Branquart *et al.* 2016); *Lespedeza*

cuneata was included in this study's 'EU List of Invasive Alien Plants', and was subsequently ranked as a high priority for PRA given its high potential for spread and the fact that introduction and spread could potentially be reduced by trade restrictions given its current absence from natural habitats in the EPPO region (Quick *et al.* 2016).

The current PRA is being conducted under the LIFE project (LIFE15 PRE FR 001) within the context of European Union regulation 1143/2014, which requires that a list of invasive alien species (IAS) be drawn up to support future early warning systems, control and eradication of IAS.

USA: Several states have declared *L. cuneata* a noxious weed (Ohlenbusch *et al.* 2007). Weed Risk Assessments are typically used to support these declarations. The Nebraska WRA found that "sericea lespedeza ranked among [the] top high-risk plants based upon its reported impact and ability to establish and spread" (http://www.neweed.org/NeWeeds/Sericea_Lespedeza.pdf). Wisconsin has conducted a similar process (see http://dnr.wi.gov/topic/Invasives/species.asp?filterBy=Terrestrial&filterVal=Y&catVal=PlantsReg for supporting materials). Weed Risk Assessments supporting other state-level listings (see section **5** below) are not always available.

USA (Hawai'i): Pacific Island Ecosystems at Risk. The risk assessment for Hawai'i scored *L. cuneata* as17, indicating that the species poses a high risk of becoming a problematic invader (PIER 2004).

Socio-economic benefits

Historically, the socio-economic benefits of this species were considered to be high: *Lespedeza cuneata* was originally introduced for the purposes of fodder and soil conservation, with the later development of improved varieties for hay and pasturage (Hoveland & Donnelly 1985). Hoveland & Donnelly (1983) estimated that total hay production was usually 6-11 t ha^{-1}; the plant is still promoted for this purpose in some territories (e.g. Fair 2014). The quality of the forage can be high due to its high levels of crude protein, although the quality is reduced if tannin levels are also high (hence the development of low-tannin varieties). Field drying also decreases tannin concentrations, and livestock will "readily consume" hay containing *L. cuneata* (Ohlenbusch *et al.* 2007). Gucker (2010) provides an overview of a number of variables affecting forage quality. The plant is also considered good for honey production by some authors (e.g. Stubbendiek and Conard 1989).

Positive effects of the species on animal health and milk commercial quality (a reduction in the number of somatic cells in milk) have also been reported (Min *et al.* 2005). Forage containing condensed tannins, such as *L. cuneata*, have shown anthelmintic activity against gastrointestinal nematodes of sheep and goats (Terrill *et al.* 2009). They may play a role in a rotation grazing system and may be included in integrated control plan. These specialized crops, which are bioactive forages, are either grazed or fed after conservation with the main purpose of preventing or curing disease (Grosso, 2014).

The use of *L. cuneata* to provide rapid greening of disturbed sites includes its use for the revegetation of surface coal mine sites in the eastern U.S. (e.g. Carter and Ungar 2002).

It has often been stated that *Lespdeza cuneata* is valuable for wildlife (see Gucker 2010), although some of this information appears to be anecdotal. Schneider *et al.* (2006) found the species to be an important year-round food source for reintroduced elk (*Cervus elaphus*) foraging on restored mine spoil in southeastern Kentucky. *Lespedeza cuneata* has been recommended as a food source for northern bobwhite quail (*Colinus virginianus*), although one study found that birds fed *L. cuneata* experienced "critical" weight losses, and that it would be unlikely to sustain birds during severe winter conditions (Newlon *et al.* 1964). Unger *et al.* (2015) used radio-tracking to determine habitat use by northern bobwhite on a reclaimed coal mining site, and found that *L. cuneata* stands were frequently used; however, these authors still recommended that *L. cuneata* control could be beneficial, partly due the suppressive effect of the species on native plants that are of higher nutritional value to the birds. Many authors agree that, in general, the wildlife value of *L. cuneata* is low (Vogel 1981; Ohlenbusch *et al.* 2007).

Lespedeza cuneata is among the species that may be used as a cover crop to create game habitats for hunting which is increasing in the United States of America and Europe (Lin 2005).

In the native range, the species has various medicinal uses: the whole plant is anthelmintic, depurative and tonic. A decoction is used in the treatment of testicular tuberculosis, hernia, enuresis, dental caries, toothache, infantile marasmus/ascariasis, snake and dog bites, skin ulcers, dysentery and enteritis.

Currently, within the EPPO region (including EU member States), apart from being sold in small numbers as an ornamental species, there are no known socio-economic benefits associated with this species. To our knowledge, the species has not been considered for the benefits shown in the USA in the PRA area. Currently, there is little information available on the value of the species in horticulture. The EWG consider that the species has low value within horticulture within the EPPO region including EU Member States.

Examples of online suppliers within the EPPO region include:

http://b-and-t-world-seeds.com/carth.asp?species=Lespedeza%20cuneata&sref=40202

http://www.omcseeds.com/lespedeza-cuneata-sericea-chinese-lespedeza-100.html

3. Is the pest a vector?	**No**	☑
4. Is a vector needed for pest entry or spread?	**No**	☑

5. Regulatory status of the pest

USA

In the USA, the plant has been declared a noxious weed in Kansas (Ohlenbusch *et al.* 2007), and, more recently, in Nebraska (see http://www.nda.nebraska.gov/plant/noxious_weeds/index.html). In Colorado, the species is also listed as a noxious weed (https://plants.usda.gov/). In addition, the species is listed as a noxious weed in the State of New York (http://www.dec.ny.gov/docs/lands_forests_pdf/islist.pdf).

Spain

Lespedeza cuneata was considered for inclusion in the “black” list of the Real Decreto (Royal Decree) 630/2013. This is a list of potentially invasive species. Inclusion on this list means, among other things, that the introduction of the species listed is prohibited, and that necessary measures should be taken for management, control and eradication. However, the species was not included in the final legislation.

6. Distribution[3]

Continent	***Distribution** (list countries, or provide a general indication , e.g. present in West Africa)*	***Provide comments on the pest status in the different countries where it occurs** (e.g. widespread, native, introduced….)*	*Reference*
Africa	South Africa.	Introduced, with known invasive occurrences.	Henderson (2010); Hoveland & Donnelly (1983)
America	Canada, USA. Brazil, Mexico. Dominican Republic.	Introduced and invasive. Introduced, status unclear. Introduced, possibly locally naturalised (e.g. see location details for http://collections.nmnh.si.edu/search/botany/?ark=ark:/65665/3af065e62c7284365858d372dd50003f3).	Kartesz (1999); Ohlenbusch *et al.* (2007); Hoveland & Donnelly (1983)
Asia	Afghanistan, Bhutan, India, Indonesia, Japan, Korea, Laos, Malaysia, Nepal, Pakistan, Philippines, Thailand, Timor-Leste, Vietnam.	Native.	Flora of China (2010)
Europe	None*	*Not present in the natural environment. Introduced, no evidence of naturalisation known. Only in cultivation.	e.g. Cullen (1995)
Oceania	Australia.	Native.	Harden (2001)

Introduction
Lespedeza cuneata has a wide native geographical range spanning Asia and Australia (see Appendix 5, Figure 1).

Africa
Lespedeza cuneata has been introduced into South Africa but little information is available on its current status (naturalised or invasive) or occurrence.

North America
Lespedeza cuneata is non-native to North America. It was initially planted in the United States in 1896 at the North Carolina Agricultural Experiment Station. In the 1920s and 30s, *Lespedeza cuneata* was grown and planted for erosion control and mine reclamation but was not widely utilized as a pasture species until the 1940s. As of 2009, *Lespedeza cuneata* was known outside of cultivation as far north as New Jersey and Michigan, as far south as Florida and Texas, and as far west as Nebraska and Oklahoma. *Lespedeza cuneata* populations are also reported in Hawaii.

[3] See also appendix 4: Distribution summary for EU Member States and Biogeographical regions

According to the Colorado Weed Management Association, *L. cuneata* is either absent or very limited in their state. The Southeastern Exotic Pest Plant Council reports that *L. cuneata* is especially common in the Piedmont and Coastal Plain regions. *Lespedeza cuneata* var. *serpens* occurs only in Missouri. See Figure 2, Appendix 5.

Asia and Oceania

Lespedeza cuneata has a native distribution range in temperate and tropical Asia and Australasia Harden (2001).

7. Habitats and their distribution in the PRA area

Habitats	EUNIS habitat types	Status of habitat (eg threatened or protected)	Present in PRA area (Yes/No)	Comments (e.g. *major/minor habitats* in the PRA area)	*Reference*
Grassland	E: Grassland and tall forb	Yes, in part	No	Major	Weber (2017) Gucker (2010)
Forest	G: Woodland, forest and other wooded land, (particularly G5 and other open wooded types).	Yes, in part	No	Major	Weber (2017) Gucker (2010)
Cultivated land	I. Regularly or recently cultivated agricultural, horticultural and domestic habitats	In part	No	Major	Weber (2017) Gucker (2010)
Man-made	J: Constructed, industrial and other artificial habitats	No	No	Major	Weber (2017) Gucker (2010)
Heathland	F: Heathland, scrub and tundra e.g. F4 Temperate shrub heathland	Yes, in part	No	Major	Weber (2017) Gucker (2010)
Habitat complexes	X. Particularly open woodland types	Yes, in part	No	Major	Weber (2017) Gucker (2010)

Weber (2017) gives the typically invaded habitats as grassland, woodland, forests, the edges of wetlands, pastures, and disturbed sites. Gucker (2010) summarised the literature available at that time on invaded habitats in America, noting that it “generally occurs on relatively open sites with little or no shrub competition”, although it is also found in “open woodlands, savannas and thickets”. Gucker (2010) also provides a table of the plant communities in which the plant has been recorded in North America; this re-emphasises the association with grasslands and a variety of woodland types, but also includes damper habitats such as stream valleys and the margins of lakes, ponds, and swamps.

8. Pathways for entry *(in order of importance)*

Possible pathways *(in order of importance)*	**Pathway:** Plants for planting **(CBD terminology: Escape from confinement - horticulture)**
Short description explaining why it is considered as a pathway	The species is named in horticultural Floras (e.g. Cullen 1995) for the EPPO region and may be grown on a small scale. *et al.et al.* Examples of online suppliers within the EPPO region include: http://b-and-t-world-seeds.com/carth.asp?species=Lespedeza%20cuneata&sref=40202 http://www.omcseeds.com/lespedeza-cuneata-sericea-chinese-lespedeza-100.html Examples of online suppliers outside the EPPO region include: http://www.pepinieredesavettes.com/pepiniere/lespedeza-cuneata,1697,theme==0,page==1?noclear
Is the pathway prohibited in the PRA area?	No, the pathway is not prohibited within the EPPO region.
Has the pest already been intercepted on the pathway?	No, but is available to purchase (see above) and seed material may be imported into the EPPO region including Europe.
What is the most likely stage associated with the pathway?	Seeds are the most likely stage associated with this pathway.
What are the important factors for association with the pathway?	The important factors associated with this pathway include seed longevity coupled with high seed production at likely sources.
Is the pest likely to survival transport and storage in this pathway?	Yes, the pest likely to survival transport and storage in this pathway
Can the pest transfer from this pathway to a suitable habitat?	Yes, the pest transfer from this pathway to a suitable habitat. The species has the potential of being planted outside close to natural habitats and escape from confinement.
Will the volume of movement along the pathway support entry?	There is no evidence available on the volume of movement into the EPPO region. However, the species is available from multiple sites online in large quantities (greater than 20 kg) and therefore the volume could support entry.
Will the frequency of movement along the pathway support entry?	There is no evidence available on the frequency of movement into the EPPO region. However, the species is available from multiple online distributors and therefore there is potential for frequent imports into the EPPO region.
Likelihood of entry	Low ☑ Moderate ☐ High ☐
Likelihood of uncertainty	Low ☐ Moderate ☑ High ☐

Possible pathways *(in order of importance)*	**Pathway:** Plants for planting **(CBD terminology: Escape from confinement - agriculture)**

Short description explaining why it is considered as a pathway	The species is utilised as a forage species outside of the EPPO region and could be imported into the region for this purpose in the search for new protein plants in the future (Chadd *et al.et al.* 2004). Examples of online suppliers outside the EPPO region include: http://www.pepinieredesavettes.com/pepiniere/lespedeza-cuneata,1697,theme==0,page==1?noclear
Is the pathway prohibited in the PRA area?	No, the pathway is not prohibited within the EPPO region.
Has the pest already been intercepted on the pathway?	No, but is available to purchase (see above) and seed material may be imported into the EPPO region including Europe.
What is the most likely stage associated with the pathway?	Seeds are the most likely stage associated with this pathway.
What are the important factors for association with the pathway?	The important factors associated with this pathway include seed longevity coupled with high seed production at likely sources.
Is the pest likely to survival transport and storage in this pathway?	Yes, the pest likely to survival transport and storage in this pathway
Can the pest transfer from this pathway to a suitable habitat?	Yes, the pest transfer from this pathway to a suitable habitat. The species has the potential of being planted outside close to natural habitats and escape from confinement.
Will the volume of movement along the pathway support entry?	There is no evidence available on the volume of movement into the EPPO region. However, the species is available from multiple sites online in large quantities (greater than 20 kg) and therefore the volume could support entry.
Will the frequency of movement along the pathway support entry?	There is no evidence available on the frequency of movement into the EPPO region. However, the species is available from multiple online distributors and therefore there is potential for frequent imports into the EPPO region.
Likelihood of entry	Low ☑ Moderate ☐ High ☐
Likelihood of uncertainty	Low ☐ Moderate ☑ High ☐

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

Possible pathways *(in order of importance)*	**Pathway: Hay and straw imports** CBD terminology: (Transport – Contaminant)
Short description explaining why it is considered as a pathway	Although there is no published evidence of *L. cuneata* being transported as part of hay material from the USA, there is evidence that hay is imported into the EU (see https://apps.fas.usda.gov/gats/default.aspx) and potentially seed of *L. cuneata* may be included. This is probably related to feed for horses.
Is the pathway prohibited in the PRA area?	Within the EU Member States are able to import under the Regulation 136/2004. Regulations on the import of hay into other EPPO countries is unclear.
Has the pest already been intercepted on the pathway?	The EWG is unaware of any evidence that the species has been intercepted along this pathway.
What is the most likely stage associated with the pathway?	Seeds are the most likely stage associated with this pathway.
What are the important factors for association with the pathway?	*L. cuneata* grows in habitats in the USA from which hay may be harvested for export.
Is the pest likely to survival transport and storage in this pathway?	Yes, seeds are likely to survive storage along this pathway.
Can the pest transfer from this pathway to a suitable habitat?	Yes, via the spreading of hay material and from livestock eating hay material and spreading seed through dung.
Will the volume of movement along the pathway support entry?	Yes. Though the volume of hay import into the EPPO region from the USA varies between years (https://apps.fas.usda.gov/gats/default.aspx).
Will the frequency of movement along the pathway support entry?	Yes. Hay is imported into the EPPO region from the USA regularly over a 5–10-year period, with variation between years (https://apps.fas.usda.gov/gats/default.aspx).
Likelihood of entry	*Low* *Moderate* X *High* ☐
Likelihood of uncertainty	*Low* ☐ *Moderate* *High* X

Do other pathways need to be considered? **NO**

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

To date, the species has not established in natural areas in the PRA area, despite having being present in gardens for some time (Cullen 1995; and see section **6** above).

Lespedeza cuneata can grow where the annual precipitation exceeds 760 mm. However, the species is also considered to be drought tolerant and is well adapted to clay or loam soils (Hoveland & Donnelly 1985). A deep taproot system, with numerous lateral branches and finer fibrous roots, may penetrate 1.2 m or more into the soil (Guernsey 1977; Ohlenbusch *et al.* 2007) traits that contribute to the species' drought resistance. Note that the breeding of cultivars adapted to particular soil types is likely to have extended the fundamental niche of the species; for example, Hoveland & Donnelly (1983) report that the cultivar ‘Serala 76’ is better adapted to light-textured soils than the originally imported accessions.

Lespedeza cuneata can tolerate shallow soils of low productivity with a low pH (< 5)(Cope 1966; Plass & Vogel 1973; Hoveland & Donnelly 1983; Ohlenbusch *et al.* 2007). However, *L. cuneata* reportedly grows best between a pH of 6.0 and 6.5 on deep, well-drained clay or loamy soils (Ohlenbusch *et al.* 2007). Ohlenbush *et al.* (2001) also note that the species tolerates shade reasonably well, and is able to establish in dense shade where sunlight does not reach during the day; however, the best establishment is typically obtained where the competing vegetation is very short, and light is able to reach both the seed and seedlings (Ohlenbusch *et al.* 2007). It has been shown in the USA that the species performs better in soil in which it has been previously grown, although the precise mechanism for this self-facilitation is not known (Coykendall and Houseman 2014). Crawford and Knight (2017) provided evidence that effects on the soil biota were responsible, but also found that the self-facilitation advantage was not realised in competition with communities of native prairie species.

In the USA, in the invasive range, *Lespedeza* species harbour more non-rhizobial symbionts in their root nodules compared to invasive *L. cuneata* (Busby *et al.* 2016). The likelihood of symbiont co-introduction with legumes are generally low, unless plant are introduced with soil material (Le Roux *et al.* 2017). Generalist legume-rhizobial interactions are therefore beneficial for non-native legume establishment. The genus Lespedeza, and indeed *L. cuneata*, appears to be a generalist host plants with regards to rhizobial requirements (Gu *et al.* 2007), with rhizobia from three genera previously isolated from *L. cuneata*, including newly described species (Yao *et al.* 2002).

The natural areas most at risk of invasion are grasslands, woodlands and forests, the edges of wetlands, pastures, and disturbed areas (Weber 2017). Within Europe and the Mediterranean region, the model predicts a broad region of potential suitability for *L. cuneata* (Figure 5). The most suitable regions are predicted to be in continental parts of southern and eastern Europe (e.g. south-east France, northern Italy, Croatia, Serbia, southern Russia). North of this, the model predicts marginal suitability for establishment as far north as the southern Baltic coast (Figure 5). However, variance amongst predictions was relatively high in this region (Figure 4b), providing uncertainty as to the exact northern extent of the potentially suitable region. The model predicts that warm winters and arid conditions are the main limiting factors around the Mediterranean coast and in southern Europe, while cool summer temperatures most strongly limit suitability in most of northern Europe (Figure 6).

In terms of Biogeographical Regions, those predicted to be most suitable for *L. cuneata* establishment in the current climate are the Pannonian, Black Sea, Continental, Mediterranean, Steppic and Atlantic (Figure 9). In the evaluated climate change scenarios, predicted suitability was stable in the Black Sea and Steppic regions, increased in Atlantic and Continental and decreased in Mediterranean and Pannonian. Other biogeographic regions predicted to strongly increase in suitability are Boreal and Alpine (Figure 9).

Based on the information detailed in this section a high likelihood of establishment has been given but as the species has not been recorded in the natural environment in the PRA area a high rating of uncertainty has been scored. The high rating for establishment reflects the broad climatic suitability for the species and the high uncertainty reflects the lack of establishment in the natural environment in the PRA area despite introductions.

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

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

Lespedeza cuneata is frequently observed in disturbed habitats in its invaded range in the USA (e.g. Althoff *et al.* 2006; Pitman 2006), therefore it is very likely that managed environments would also be subject to invasion in the PRA area. Mowing has also been found to promote the dominance of the species in some systems (Brandon *et al.* 2004).

In the USA, *L. cuneata* can establish in pastures where it is considered a crop or a weed depending on the system Gucker (2010). In South Africa, the species is a weed of disturbed areas and roadsides (Henderson 2010).

A high rating of likelihood of establishment in the PRA area in the managed environment with moderate uncertainty has been given as the species, although not yet established in the PRA, has been shown to establish in these situations in similar climatic conditions to the EPPO region including EU Member States (EWG opinion). In addition, the species grows well in gardens throughout the EPPO region (Cullen, 1995).

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

11. Spread in the PRA area

Reports of range increases and local spread are common in the USA (Gucker 2010). Spread of the species in Kansas showed a 24 % increase in area per year (25 000 acre in 1989 to 500 000 acres in 2003) (Gucker, 2010; Duncan *et al.et al.* 2004), however, it's not clear how much of the spread can be attributed to natural or human mediated spread or intentional planting.

The following mechanisms are likely to be important for this process:

Natural spread

Natural spread is likely to be moderately rapid. Quick *et al.* (2017) found that both animals and wind could spread *L. cuneata* seeds. Within their experimental set up, Quick *et al.* (2017) found that wind could move seed up to 3 m, whilst various animals' pelts were demonstrated to pick-up and retain *L. cuneata* seeds within their fur after experimental traverses through a patch of the species.

Livestock can also disperse the species in their feces (Cummings *et al.* 2007). At least two studies have also noted an association with horse trails in the USA (Campbell *et al.* 2001; Stroh *et al.* 2009). Various other wildlife has been found to disperse the seed of *L. cuneata*, including deer, birds, and rodents (Eddy *et al.* 2003). In some cases, passage through animals' digestive tracts has been shown to increase germination, as in the case of the northern bobwhite quail, *Colinus virginianus* (Blocksome 2006). There is also the potential that seeds can be transported in contaminated soil.

Natural spread is likely to facilitate transfer to suitable habitats. At present however, the volume of movement will not support spread within the PRA area as the species is not present in the natural environment.

Human assisted spread

Activities associated with the production and distribution of hay can spread *L. cuneata* seed (Ohlenbusch *et al.* 2007). The spread of seed by vehicles is also suspected due to the spread and occurrence of the species in areas associated with high vehicle use in an army training area in Kansas (Althoff *et al.* 2006). Likewise, heavy mechanical disturbance associated with forestry has also been associated with the spread of *L. cuneata* away from seeded areas (Pitman 2006). The species may also be spread through the horticulture industry. The spread of manure between farms/gardens can act to spread the species. Human assisted spread and the likelihood of transfer to a suitable habitat is high within the PRA area, including between EU member States.

A high rating of spread with moderate uncertainty has been given as the species, although not yet established in the PRA, has the potential to be spread by animals and by the movement of vehicles.

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

12. Impact in the current area of distribution

12.01 Impacts on biodiversity

All impacts described have been reported in the USA. *Lespedeza cuneata* can thrive under a variety of conditions, crowding out native species in natural areas. The species forms dense stands in areas where it invades, reducing light availability and potentially increasing competition for soil water (Eddy and Moore 1998; Allred *et al.* 2010; Bauman *et al.* 2015). Eddy and Moore (1998) showed that invasions of *L. cuneata* into oak savannas in southeastern Kansas reduced native species richness. For example, the number of native grass species decreased from 12 to four and native forb species declined from 27 to eight. There were also significant impacts on the numbers of invertebrate species found, and on the total biomass of native plant species. Peters *et al.et al.* (2015) highlights that the Bobwhite quail has low summer survival in areas dominated by *L. cuneata*.

Lespedeza cuneata has the potential to disrupt pollination networks as the species has been shown to attract more pollinators than co-occurring native species (Woods *et al.* 2012). Impacts on native plant diversity have also been identified in old fields where Brandon *et al.* (2004) found the species to suppress native plants, possibly through shading effects. Brandon *et al.* (2004) concluded that the species "can subsequently take over grassland communities." *L. cuneata* may also have impacts on native plant communities through allelopathic effects. Allelopathic chemicals have been found to reduce native grass species' performance by up to 60% (Dudley and Fick 2003). Positive and negative effects on small mammal diversity and abundances in response to different *L. cuneata* cover levels have also been reported (Howard 2003). Nitrogen fixing bacteria have been shown to benefit *L. cuneata* enabling its growth in nutrient poor conditions (Brandon et al 2004; Houseman *et al.et al.* 2004), thus an additional impact on ecosystem processes is the potential for of the species to increase soil nitrogen levels in invaded habitats.

In South Africa there are no recorded impacts due to the fact that the species is not a strong invader at present.

Based on the impacts shown in the current area of distribution, a high rating of impact has been given with a moderate uncertainty.

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

12.02. Impacts on ecosystem services

Ecosystem service	**Does the IAS impact on this Ecosystem service?** Yes/No	**Short description of impact**	**Reference**
Provisioning	Yes	*Lespedeza cuneata* can replace more palatable forage species in some systems. High tannin levels in old plants can have a negative impact on cattle and horses.	Gucker (2010)
Regulating	Yes	*Lespedeza cuneata* has the potential to disrupt pollination networks as the species has been shown to attract more pollinators than co-occurring native species. *Lespedeza cuneata* can alter nutrient cycling and soil microbial communities.	(Woods *et al.* 2012). (Yannarell *et al.et al.* 2011)
Cultural	No	NA	NA

The potential negative impacts detailed in the table above in relation to ecosystem services are derived from reviews and statements rather than scientific experimentation, with the exception of supporting ecosystem services, therefore a moderate rating of impact has been given but with a high level of uncertainty (EWG opinion).

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

12.03. Describe the adverse socio-economic impact of the species in the current area of distribution

Lespedeza cuneata can replace more palatable forage species in some systems. High tannin levels in senescent plants can have a negative impact on cattle and horses (Fechter and Jones 2001). *L. cuneata* has led to an estimated annual $29 million loss in forage across rangeland in the Flint Hills Kansas, USA (Houseman). *Lespedeza cuneata* has reduced the 30-year net present value of grazing land in Kansas from $726/ha for non-infested lands to $183/ha for infested lands (Fechter and Jones 2001).

In the US, chemical control costs are approximately between $30-40 per acre.

Based on the costs detailed in this section and the fact that the species has been shown to have potential negative impacts on livestock a high rating of socio-economic impact has been given, with low uncertainty.

Control methods

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

Rating of the 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

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

As *L. cuneata* is absent from the natural environment in the EPPO region, all data on impacts comes from other regions of the invaded range. Thus, all information on impacts can only be used as a proxy to the EPPO region. In the USA, in similar climatic zones to the EPPO region, *L. cuneata* can thrive under a variety of conditions, crowding out native species in natural areas.

In terms of Biogeographical Regions, those predicted to be most suitable for *L. cuneata* establishment in the current climate are the Pannonian, Black Sea, Continental, Mediterranean, Steppic and Atlantic. Therefore, impacts may be seen over a large area of the PRA region if the species establishes outside in the natural environment. Here, in grassland, heathland, forests and open wooded habitats, the species has the potential to impact on biodiversity.

The EWG consider that impacts on biodiversity are likely to be moderate in the EPPO region with a moderate uncertainty. This rating is due to the species not being present in the natural environment in the EPPO region. Impacts on ecosystem services are likely to be moderate with a high uncertainty . On the contrary, the EPPO region has less rangeland grazing than the US and therefore socio-economic impacts are likely to be lower with a moderate uncertainty (EWG opinion).

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

13.01 Potential biodiversity impacts

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

13.02 Potential ecosystem service impacts

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

13.02 Potential socio-economic impact of the species

Rating of the magnitude of impact in the area of potential establishment	*Low*	*Moderate* X	*High* ☐
Rating of uncertainty	*Low*	*Moderate* X	*High* ☐

14. Identification of the endangered area

The EWG considers that the endangered area to primarily be grasslands, open shrublands and forest, and other open or disturbed habitats, within the Continental, Pannonian, Steppic, Mediterranean, Atlantic and Black Sea biogeographic regions. Although there is limited suitability in other regions, e.g. the Boreal region and more western Atlantic areas, the EWG considers that these areas are less likely to be at risk from invasion. The countries within the endangered area include (EU countries): Portugal, France, Germany, Poland, Lithuania, Greece, Croatia, Slovenia, Austria, Hungary and Italy and the wider EPPO region: Belarus, Ukraine, Georgia, Turkey, Albania, Bosnia and Herzegovina and the north coastline of Algeria.

Within Europe and the Mediterranean region, the bioclimatic model predicts a large area of potential suitability for *L. cuneata* (Figure 5). The most suitable regions are predicted to be in continental parts of southern and eastern Europe (e.g. south east France, northern Italy, Croatia, Serbia, southern Russia). North of this, the model predicts marginal suitability for establishment as far north as the southern Baltic coast (Figure 5). However, the disagreement among algorithms was relatively high in this region (Figure 4b), providing uncertainty as to the exact northern extent of the potentially suitable region. The model predicts that warm winters and arid conditions are the main limiting factors around the Mediterranean coast and in southern Europe, while cool summer temperatures most strongly limit suitability in most of northern Europe (Figure 6).

In terms of Biogeographical Regions, those predicted to be most suitable for *L. cuneata* establishment in the current climate are the Pannonian, Black Sea, Continental, Mediterranean, Steppic and Atlantic (Figure 9). In the evaluated climate change scenarios, predicted suitability was stable in the Black Sea and Steppic regions, increased in Atlantic and Continental and decreased in Mediterranean and Pannonian. Other biogeographic regions predicted to strongly increase in suitability are Boreal and Alpine (Figure 9).

15. Climate change

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.

The climate change projections for Europe in the 2070s cause the model to predict pronounced northwards expansions of the suitable region, accompanied by a lesser contraction of the southern part of the suitable region (Figure 7 and 8). In the more extreme RCP8.5 scenario, the species is predicted capable of establishing as far north as the Arctic coast in Russia. However, some species reports consider that photoperiod affects *L. cuneata* development (Gucker, 2010), which may restrict northwards expansion of the species. The countries within the endangered area include: all EU countries except Ireland, Cyprus and Malta.

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

Climate projection: **2070**

Which component(s) of climate change do you think are the <u>most relevant</u> for this organism? Delete (yes/no) as appropriate

*Temperature **(yes)***	*Precipitation **(yes)***	*CO_2 levels **(yes)***
*Sea level rise **(no)***	*Salinity **(no)***	*Nitrogen deposition **(no)***
*Acidification **(no)***	*Land use change **(yes)***	

Are the **introduction pathways** likely to change due to climate change? **(If yes, provide a new risk and uncertainty score)**	**Reference**
The introduction pathways are unlikely to change as a result of climatic change, although the frequency of movement may be enhanced as a result of climate change (for example, agriculturists may be increasingly interested in drought tolerant fodder). The EWG is not confident to change the scores but consider the uncertainty will increase from moderate to high.	EWG opinion
Is the **risk of establishment** likely to change due to climate change? **(If yes, provide a new risk and uncertainty score)**	**Reference**
Some areas within the endangered area will increase in suitability, and the total area suitable for *L. cuneata* will increase. The EWG is not confident to change the scores but consider the uncertainty will increase to high for both the managed environment and the natural environment.	EWG opinion
Is the **risk of spread** likely to change due to climate change? **(If yes, provide a new risk and uncertainty score)**	**Reference**
Natural spread is unlikely to change however, human assisted spread may increase if the species becomes a popular fodder species in the EPPO region. The EWG is not confident to change the scores but consider the uncertainty will increase from low to high.	EWG opinion
Will **impacts** change due to climate change? **(If yes, provide a new risk and uncertainty score)**	**Reference**
Impacts are likely to increase as a result of climate change with increased area covered. The EWG is not confident to change the scores but consider the uncertainty will increase to high.	EWG opinion

16. Overall assessment of risk

The results of this PRA show that *L. cuneata* poses a moderate risk to the endangered area (Pannonian, Black Sea, Continental, Mediterranean, Steppic and Atlantic biogeographical region) with a moderate uncertainty. *L. cuneata* invades grassland, woodland, forests, edges of wetlands, pastures, and disturbed sites in the United States. The species forms dense stands in areas where it invades, reducing light availability and potentially increasing competition for soil water (Eddy and Moore 1998; Allred *et al.* 2010; Bauman *et al.* 2015). Eddy and Moore (1998) showed that invasions of *L. cuneata* into oak savannas in southeastern Kansas reduced native species richness. *Lespedeza cuneata* can have high socio-economic impacts, where in the US it can replace more palatable forage species in some systems. High tannin levels in old plants can also have negative impact on cattle and horses (Fechter and Jones 2001). Although the EWG consider economic impacts will only be moderate in the EPPO region, as impacts in the current range are not context dependent (for example dense canopies and allelopathy), impacts on biodiversity and ecosystem services will be similar to those seen in the current area of distribution.

Pathways for entry:

Plants for planting

Likelihood of entry	Low X	Moderate	High
Likelihood of uncertainty	Low	Moderate X	High

Plants for planting (forage)

Likelihood of entry	Low X	Moderate	High
Likelihood of uncertainty	Low	Moderate X	High

Contaminant of hay

Likelihood of entry	Low	Moderate X	High
Likelihood of uncertainty	Low	Moderate	High X

Likelihood of establishment in the natural environment in the PRA area

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

Likelihood of establishment in managed environment in the PRA area

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

Spread in the PRA area

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

Impacts
Impacts on biodiversity and the environment

Rating of the magnitude of impact in the current area of distribution	Low	Moderate	High X
Rating of uncertainty	Low	Moderate X	High

Impacts on ecosystem services

Rating of the magnitude of impact in the current area of distribution	Low	Moderate X	High
Rating of uncertainty	Low	Moderate	High X

Socio-economic impacts

Rating of the magnitude of impact in the current area of distribution	Low	Moderate	High X
Rating of uncertainty	Low X	Moderate	High

Impacts in the PRA area

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

13.01 Potential biodiversity impacts

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

13.02 Potential ecosystem service impacts

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

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

13.02 Potential socio-economic impact of the species

Rating of the magnitude of impact in the area of potential establishment	*Low*	*Moderate* X	*High* ☐
Rating of uncertainty	*Low*	*Moderate* X	*High* ☐

17. Uncertainty

See Appendix 1 for uncertainties associated with the species distribution modelling (SDM) performed in support of several parts of this PRA. Linked to this, there are some uncertainties associated with taxonomy, nomenclature and identification of this species, and this may have affected our harvesting of distribution data for the SDM, and the distribution list of countries given in section 6 above. Additionally, the presence of numerous cultivars in parts of the species' introduced range may mean that there is more variation in physiological traits than has been described in this PRA.

Modelling the potential distributions of range-expanding species is always difficult and uncertain. Gaps in the native distribution from tropical regions may have caused the model to erroneously model tropical regions as unsuitable – though this is unlikely to affect the prediction for Europe.

The suitability projections in northern Europe were relatively marginal and uncertain because of variation among modelling algorithms. Furthermore, occurrence at northern latitudes might be affected by photoperiod requirements of the species not included in the model. Both these factors lead to uncertainty in the precise location of its northern potential range margin.

The limiting factors map may have under-estimated the limiting influence of winter temperatures in Europe, since two of the algorithms in the ensemble did not model a strong limitation of suitability at very cold temperatures. However, this may be a true reflection of a lack of cold winter temperatures limiting habitat suitability for Lespedeza. This will have raising the ensemble model suitability response to very cold winter temperatures.

Other variables potentially affecting the distribution of the species, such as edaphic variables, were not included in the model.
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.
- Additional data sources to GBIF were used, which may have been from regions without GBIF records.

18. Remarks

NA.

19. REFERENCES

Adamson, H.C. and Donnelly, E.D. (1973). *Effect of cutting and irrigation on seed yields of interstate sericea lespedeza*. Auburn University Agricultural Experimental Station Leaflet 87.

Allred, B.W., Fuhlendorf, S.D., Monaco, T.A. and Will, R.E. (2010). Morphological and physiological traits in the success of the invasive plant *Lespedeza cuneata*. *Biological Invasions*, 12(4), pp.739-749.

Althoff, D.P., Gipson, P.S., Pontius, J.S. and Woodford, P.B. (2006). Plant community and bare ground trends on Fort Riley, Kansas: implications for monitoring of a highly disturbed landscape. *Transactions of the Kansas Academy of Science*, 109(3/4): 101-119.

Bauman JM, Cochran C, Chapman J, Gilland K (2015) Plant community development following restoration treatments on a legacy reclaimed mine site. Ecological Engineering, 83, 521-528.

Beaton, L.L., Van Zandt, P.A., Esselman, E.J. and Knight, T.M. (2011). Comparison of the herbivore defense and competitive ability of ancestral and modern genotypes of an invasive plant, *Lespedeza cuneata*. *Oikos*, 120(9), 1413-1419.

Blocksome, C.E.B. (2006) *Sericea lespedeza (*Lespedeza cuneata*): seed dispersal, monitoring, and effect on species richness.* Manhattan, KS: Kansas State University. 125 pp. Dissertation.

Brandon, A.L., Gibson, D.J. and Middleton, B.A. (2004). Mechanisms for dominance in an early successional old field by the invasive non-native *Lespedeza cuneata* (Dum. Cours.) G. Don. *Biological Invasions*, 6(4), pp.483-493.

Branquart E, Brundu G, Buholzer S, Ehret P, Fried G, Starfinger U, van Valkenburg J, Tanner R (2016) A prioritisation process for invasive alien plant species compliant with Regulation (EU) No. 1143/2014. *EPPO Bulletin* 46: 603–617. https://doi.org/10.1111/epp.12336

Campbell, J.E. and Gibson, D.J. (2001). The effect of seeds of exotic species transported via horse dung on vegetation along trail corridors. *Plant Ecology*, 157(1), pp.23-35.

Carter, C.T. and Ungar, I.A. (2002). Aboveground vegetation, seed bank and soil analysis of a 31-year-old forest restoration on coal mine spoil in southeastern Ohio. *The American Midland Naturalist*, 147(1), pp.44-59.

Cope, W.A. (1966). Cross-pollination in sericea lespedeza. *Crop Science*, 6(5), pp.469-470.

Coykendall, K.E. and Houseman, G.R. (2014). *Lespedeza cuneata* invasion alters soils facilitating its own growth. *Biological Invasions*, 16(8), pp.1735-1742.

Crawford, K.M. and Knight, T.M. (2017). Competition overwhelms the positive plant–soil feedback generated by an invasive plant. *Oecologia*, 183(1), pp.211-220.

Cullen, J. (1995). Lespedeza. *European Garden Flora Vol. IV.* pp. 494-495.

Czerepanov, S.K. (1995). *Vascular plants of Russia and adjacent states (the former USSR).* Cambridge: Cambridge University Press.

Cummings DC, Fuhlendorf SD, Engle DM (2007) Grazing selectivity of invasive forage species with patch burning more effective than herbicide treatments? *Rangeland Ecol. Manag*. **60**:253–260.

Donnelly, E.D. (1979) Selection for chasmogamy in sericea lespedeza. *Crop Science*, 19(4):528-31.

Dudley DM, Fick WH (2003) Effects of sericea lespedeza residues on selected tallgrass prairie grasses. Transactions of the Kansas Academy of Science 106: 166-170

Duncan, C.A., J.J. Jachetta, M.L. Brown, V.F. Carrithers, J.K. Clark, J.M. DiTomaso, R.G. Lym, K.C. McDaniel, M.J. Renz, P.M. Rice. 2004. Assessing the economic, environmental, and societal losses from invasive plants on rangeland and wildlands. Weed Technology 18:1411-1416.

Eddy T, Moore C (1998) Effects of sericea lespedeza (*Lespedeza cuneata* (Dumont) G. Don) invasion on oak savannas in Kansas. Trans Wis Acad Sci Arts Lett 86:57–62

Eddy, T.A., Davidson, J. and Obermeyer, B. (2003). Invasion dynamics and biological control prospects for sericea lespedeza in Kansas. *Great Plains Research*, pp.217-230.

Farris, R.L. 2006. *Adaptation, biology and control of sericea lespedeza (*Lespedeza cuneata*), an invasive species*. Unpublished dissertation. Oklahoma State University: Stillwater, OK.

Fechter RH, Jones R (2001) Estimated economic impacts of the invasive plant sericea lespedeza on Kansas grazing lands. J Agric Appl Econ 33:630

Flora of China (2010). *Volume 10 Online:* Lespedeza cuneata. http://www.efloras.org/florataxon.aspx?flora_id=2&taxon_id=200012191 [Accessed 27th September 2017]

Gucker, C. (2010). (Revised from Munger, G.T. 2004) Lespedeza cuneata. In Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Stations, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis [Accessed September 2017]

Guernsey, W.J. (1977) *Sericea lespedeza: its use and management.* USDA Farmers' Bulletin 2245.

Han, J.E., Chung, K.H., Nemoto, T. and Choi, B.H. (2010). Phylogenetic analysis of eastern Asian and eastern North American disjunct *Lespedeza* (Fabaceae) inferred from nuclear ribosomal ITS and plastid region sequences. *Botanical Journal of the Linnean Society*, 164(3), pp.221-235.

Harden (2001) Flora of New South Wales. UNSW Press

Honu, Y.A., Chandy, S. and Gibson, D.J. (2009). Occurrence of non-native species deep in natural areas of the Shawnee National Forest, Southern Illinois, USA. *Natural Areas Journal*, 29(2), pp.177-187.

Houseman GR, Foster BL, Brassil CE (2014) Propagule pressure invasibility relationships: testing the influence of soil fertility and disturbance with *Lespedeza cuneata*. *Oecologia* 174:511-520.

Hoveland, C.S. and Anthony, W.B. (1974). Cutting management of sericea lespedeza for forage and seed. *Agronomy Journal*, 66(2), pp.189-191.

Hoveland, C. S. and E. D. Donnelly. 1985. The Lespedezas. Pp. 128-135, in *Forages: The science of grass agriculture* (M. E. Heath *et al.et al.* eds). Fourth ed. Iowa State Univ. Press, Ames, Iowa.

Howard, J.M. (2003) *Sericea lespedeza (*Lespedeza cuneata*) invasion: Implications for a small mammal community and the influence of local fire history*. PhD thesis. Oklahoma State University.

Kartesz, J.T. (1999). A synonymized checklist and atlas with biological attributes for the vascular flora of the United States, Canada, and Greenland. In: *Synthesis of the North American Flora. Version 1.0* (eds Kartesz, J.T. & Meacham, C.A.). North Carolina Botanical Garden, Chapel Hill, NC.

Logan, R.H., Hoveland, C.S. and Donnelly, E.D. (1969). A germination inhibitor in the seedcoat of sericea (*Lespedeza cuneata* (Dumont) G. Don). *Agronomy Journal*, 61(2), pp.265-266.

Min, B.R., Hart, S.P., Miller, D., Tomita, G.M., Loetz, E. and Sahlu, T. (2005). The effect of grazing forage containing condensed tannins on gastro-intestinal parasite infection and milk composition in Angora does. *Veterinary Parasitology*, 130(1), pp.105-113.

Mosjidis, J.A. (1990). Daylength and temperature effects on emergence and early growth of sericea lespedeza. *Agronomy Journal*, 82(5), pp.923-926.

Newlon, C.F., Baskett, T.S., Breitenbach, R.P. and Stanford, J.A. (1964). Sustaining values of emergency foods for bobwhites. *The Journal of Wildlife Management*, pp.532-542.

Ohashi, H., Nemoto, T. and Ohashi, K. (2009). A revision of *Lespedeza* subgenus *Lespedeza* (Leguminosae) of China. *Journal of Japanese Botany*, 84(3), pp.143-166.

Ohlenbusch P. D. *et al.* (2007). *Sericea lespedeza: history, characteristics and identification.* Kansas State Univ. Agric. Exp. Stn Coop. Ext. Serv. MF-2408.

PIER (2004) *Lespedeza cuneata*.
http://www.hear.org/pier/wra/pacific/lespedeza_cuneata_htmlwra.htm [Accessed 5th October 2017]

Peters, D. C., J. M. Brooke, E. P. Tanner, A. M. Unger, P. D. Keyser, C. A. Harper, J. D. Clark, and J. J. Morgan. 2015. Impact of experimental habitat manipulation on northern bobwhite survival. Journal of Wildlife Management 79:605–617

Pitman, W.D. (2006) Stand characteristics of sericea lespedeza on the Louisiana Coastal Plain. *Agriculture, Ecosystems & Environment*. 115(1):295-8.

Plass, W.T. and Vogel, W.G. (1973). *Chemical properties and particle-size distribution of 39 surface-mine spoils in southern West Virginia*. USDA Forest Serv. Res. Pap. NE-276. 8 p

Pramanik, A. and Thothathri, K. (1983). Notes on the taxonomy, distribution and ecology of *Lespedeza juncea* complex with special reference to India. *J. Jap. Bot*, 58(11), pp.331-337.

Qiu, J., Mosjidis, J.A. and Willliams, J.C. (1995). Variability for temperature of germination in sericea lespedeza germplasm. *Crop Science*, 35(1), 237-241.

Quick, Z. I., Houseman, G. R., & Büyüktahtakin, İ. E. (2017). Assessing wind and mammals as seed dispersal vectors in an invasive legume. *Weed Research*, 57(1), 35-43.

Roy, H.E., Adriaens, T., Aldridge, D.C., Bacher, S., Bishop, J.D.D., Blackburn, T.M., Branquart, E., Brodie, J., Carboneras, C., Cook, E.J., Copp, G.H., Dean, H.J., Eilenberg, J., Essl, F., Gallardo, B., Garcia, M., García-Berthou, E., Genovesi, P., Hulme, P.E., Kenis, M., Kerckhof, F., Kettunen, M., Minchin, D., Nentwig, W., Nieto, A., Pergl, J., Pescott, O., Peyton, J., Preda, C., Rabitsch, W., Roques, A., Rorke, S., Scalera, R., Schindler, S., Schönrogge, K., Sewell, J., Solarz, W., Stewart, A., Tricarico, E., Vanderhoeven, S., van der Velde, G., Vilà, M., Wood, C.A., Zenetos, A. (2015). *Invasive Alien Species - Prioritising prevention efforts through horizon scanning* ENV.B.2/ETU/2014/0016. European Commission.

Schneider, J., Maehr, D.S., Alexy, K.J., Cox, J.J., Larkin, J.L. and Reeder, B.C. (2006). Food habits of reintroduced elk in southeastern Kentucky. *Southeastern Naturalist*, 5(3), pp.535-546.

Schutzenhofer, M.R., Valone, T.J. and Knight, T.M. (2009). Herbivory and population dynamics of invasive and native *Lespedeza*. *Oecologia*, 161(1), pp.57-66.

Stroh, E.D. and Struckhoff, M.A. (2009). Exotic plant species associations with horse trails, old roads, and intact native communities in the Missouri Ozarks. *Natural Areas Journal*, 29(1), pp.50-56.

Stubbendiek, J. and Conard, E.C. (1989). *Common legumes of the Great Plains: an illustrated guide*. Lincoln, NE: University of Nebraska Press.

Sundberg, M.I., Slaughter, D.M. and Crupper, S.S. (2002). Application of randomly amplified polymorphic DNA (RAPD) fingerprinting to detect genetic variation in sericea lespedeza (*Lespedeza cuneata*). *Transactions of the Kansas Academy of Science*, 105(1), pp.91-95.

Tanner, R., Branquart, E., Brundu, G., Buholzer, S., Chapman, D., Ehret, P., Fried, G., Starfinger, U. and van Valkenburg, J. (2017). The prioritisation of a short list of alien plants for risk analysis within the framework of the Regulation (EU) No. 1143/2014. *NeoBiota*, 35, p.87.

Terrill, T.H., Dykes, G.S., Shaik, S.A., Miller, J.E., Kouakou, B., Kannan, G., Burke, J.M. and Mosjidis, J.A. (2009). Efficacy of sericea lespedeza hay as a natural dewormer in goats: dose titration study. *Veterinary Parasitology*, 163(1), pp.52-56.

The Plant List (2017a) Lespedeza juncea *var.* sericea *(Thunb.) Lace & Hauech.* http://www.theplantlist.org/tpl1.1/record/ild-32600 [Accessed 27th September 2017]

The Plant List (2017b) Lespedeza juncea *var.* sericea *Maxim.* http://www.theplantlist.org/tpl1.1/record/ild-38832 [Accessed 27th September 2017]

Unger, A.M., Tanner, E.P., Harper, C.A., Keyser, P.D., Van Manen, F.T., Morgan, J.J. and Baxley, D.L. (2015). Northern bobwhite seasonal habitat selection on a reclaimed surface coal mine in Kentucky. *Journal of the Southeastern Association of Fish and Wildlife Agencies*, 2, pp.235-246.

Vogel, W.G. (1981). *A guide for revegetating coal mine soils in the eastern United States. Gen. Tech. Rep. NE-68.* Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station.

Weber, E. (2017). *Invasive plant species of the world: a reference guide to environmental weeds*. CABI.

Woods, T.M., Hartnett, D.C. and Ferguson, C.J. (2009). High propagule production and reproductive fitness homeostasis contribute to the invasiveness of *Lespedeza cuneata* (Fabaceae). *Biological Invasions*, 11(8), pp.1913-1927.

Woods, T.M., Jonas, J.L. and Ferguson, C.J. (2012). The invasive *Lespedeza cuneata* attracts more insect pollinators than native congeners in tallgrass prairie with variable impacts. *Biological Invasions*, 14(5), pp.1045-1059.

Wright, D.L., Blaser, R.E. and Woodruff, J.M. (1978). Seedling emergence as related to temperature and moisture tension. *Agronomy Journal*, 70(5), pp.709-712.

Xu, B., Wu, N., Gao, X.F. and Zhang, L.B., 2012. Analysis of DNA sequences of six chloroplast and nuclear genes suggests incongruence, introgression, and incomplete lineage sorting in the evolution of *Lespedeza* (Fabaceae). *Molecular Phylogenetics and Evolution*, 62(1), pp.346-358.

Yannarell AC, Busby RR, Denight ML, Gebhart DL, Taylor SJ (2011) Soil bacteria and fungi respond on different spatial scales to invasion by the legume *Lespedeza cuneata*. Front Microbiol 2:127. doi:10.3389/fmicb.2011.00127

Appendix 1: Projection of climatic suitability for *Lespedeza cuneata* establishment

Aim

To project the suitability for potential establishment of *Lespedeza cuneata* 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.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. *Lespedeza cuneata* survives freezing winter temperatures, but are reported to suffer mortality in prolonged frosts and be damaged by late spring frost (Global Invasive Species Database, 2017, Gucker, 2010).
- Mean temperature of the warmest quarter (Bio10 °C) reflecting the growing season thermal regime. Germination of *L. cuneata* seeds depends on temperature, with optimal conditions being 20-30 °C and germination failure below 12 °C (Qiu *et al.et al.* 1995). Low temperature also limits seedling growth (Mosjidis, 1990).
- Climatic moisture index (CMI, ratio of mean annual precipitation, Bio12, to potential evapotranspiration) reflecting plant moisture regimes. *Lespedeza cuneata* is reported to grow best in areas receiving more than 760 mm of annual precipitation (Gucker, 2010).

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) 4.5 and 8.5 were also obtained. For both scenarios, 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).

RCP 4.5 is a moderate climate change scenario in which CO_2 concentrations increase to approximately 575 ppm by the 2070s and then stabilise, resulting in a modelled global temperature rise of 1.8 C by 2100. RCP8.5 is the most extreme of the RCP scenarios, and may therefore represent the worst case scenario for reasonably anticipated climate change. In RCP8.5 atmospheric CO_2 concentrations increase to approximately 850 ppm by the 2070s, resulting in a modelled global mean temperature rise of 3.7 °C by 2100.

In the models the following habitat variable was also included:

- Human influence index as *L. cuneata*, like many invasive species, is likely to associate with anthropogenically disturbed habitats (Global Invasive Species Database, 2017, Gucker, 2010). We used the Global Human Influence Index Dataset of the Last of the Wild Project (Wildlife Conservation Society - WCS & Center for International Earth Science Information Network - CIESIN - Columbia University, 2005), which is developed from nine global data layers covering human population pressure (population density), human land use and infrastructure (built-up areas, nighttime lights, land use/land cover) and human access (coastlines, roads, railroads, navigable rivers). The index ranges between 0 and 1 and was log+1 transformed for the modelling to improve normality.

Species occurrence data were obtained from the Global Biodiversity Information Facility (GBIF), USDA Biodiversity Information Serving Our Nation (BISON) and Eddmaps. Occurrence records were scrutinised to remove those from regions where the species is not known to be well established, those that appeared to be dubious or planted specimens (e.g. plantations, botanic gardens) and those where the georeferencing was too imprecise (e.g. records referenced to a country or island centroid) or outside of the coverage of the predictor layers (e.g. small island or coastal occurrences). The remaining records were gridded at a 0.25 x 0.25 degree resolution for modelling (Figure 1a). In total 1722 grid cells contained records of *L. cuneata*.

Additionally, the recording density of vascular plants (phylum Tracheophyta) on GBIF was obtained as a proxy for spatial recording effort bias (Figure 1b).

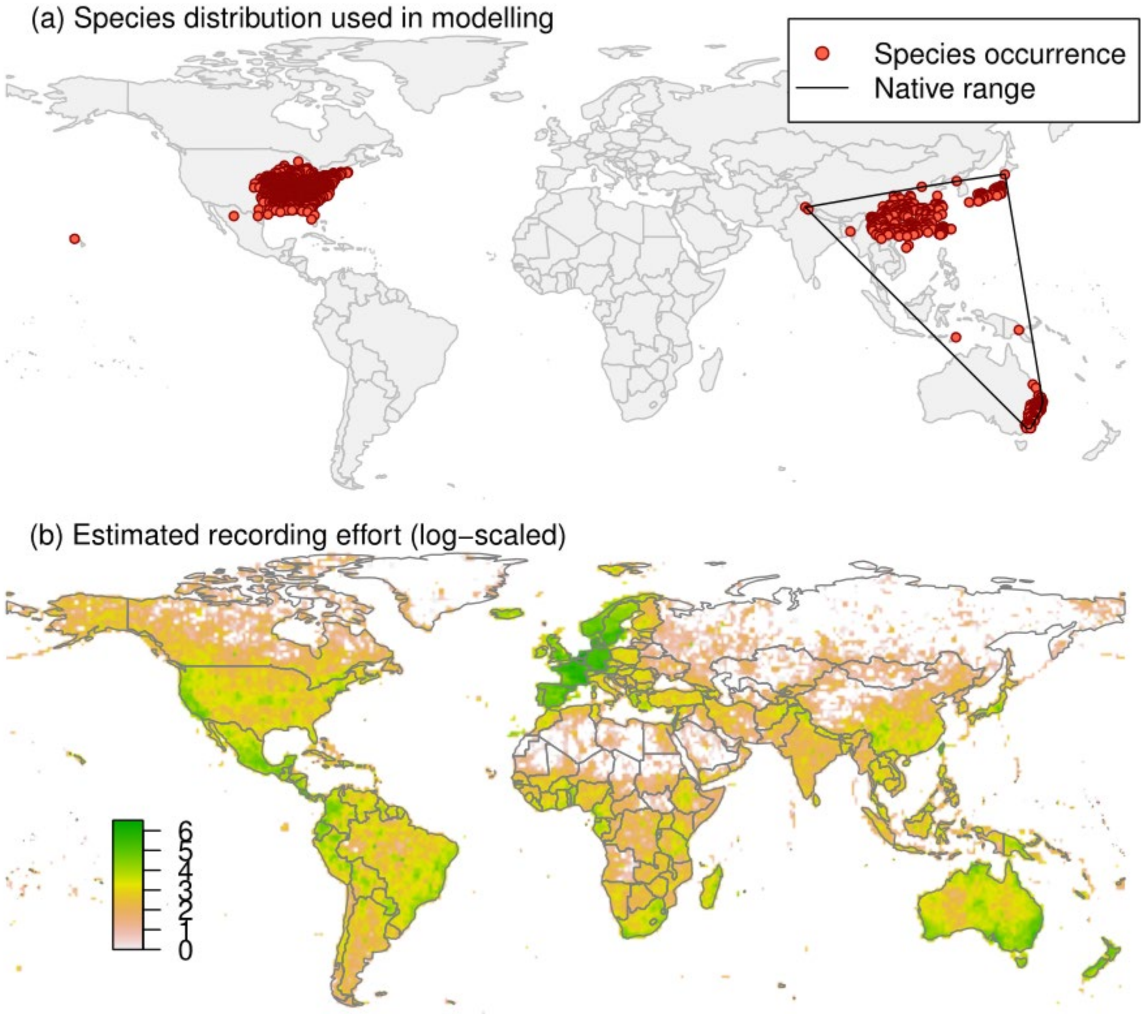


Figure 1. (a) Occurrence records obtained for *Lespedeza cuneata* and used in the modelling, showing the native range and (b) a proxy for recording effort – the number of Tracheophyta records held by the Global Biodiversity Information Facility, displayed on a $\log_{10}$ scale.

Species distribution model
A presence-background (presence-only) ensemble modelling strategy was employed using the BIOMOD2 R package v3.3-7 (Thuiller *et al.et al.* 2014, Thuiller *et al.et al.* 2009). These models contrast the environment at the species' occurrence locations against a random sample of 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 *L. cuneata* populations (see Fig. 1a), in which the species is likely to have had sufficient time to disperse to all locations. The accessible native region was defined as a 300 km buffer around the minimum convex polygon bounding all native occurrences in East Asia and Australia (Global Invasive Species Database, 2017); 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. Based on published ecophysiological information and the extremes of the climatic predictors at the species occurrences the following rules for unsuitability were applied:
    - Mean minimum temperature of the coldest month (Bio6) < -12 °C.
    - Mean temperature of the warmest quarter (Bio10) < 13 °C.
    - Climatic moisture index (CMI) < 0.45.

Fewer than 1% of occurrence grid cells exceeded each individual threshold and 1.3 % exceeded any one threshold. From this background region, ten samples of 10,000 randomly chosen grid cells were obtained (Figure 2). To account for recording effort bias, sampling of background grid cells was weighted in proportion to the Tracheophyte recording density (Figure 1b).

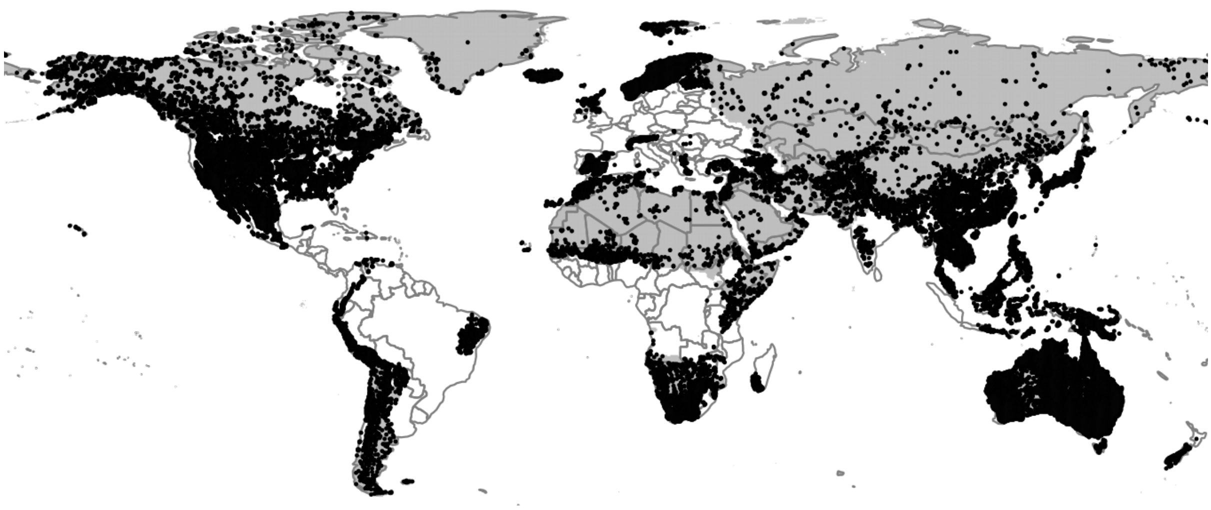


Figure 2. Randomly selected background grid cells used in the modelling of *Lespedeza cuneata*, mapped as black points. Points are sampled from the native range, a small buffer around non-native occurrences and from areas expected to be highly unsuitable for the species (grey background region), and weighted by a proxy for plant recording effort (Figure 1b).

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 (except where specified below) and rescaled using logistic regression:

- Generalised linear model (GLM)
- Generalised boosting model (GBM)
- Generalised additive model (GAM) with a maximum of four degrees of freedom per effect.
- 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. Global model projections were made for the current climate and for the two climate change scenarios, avoiding model extrapolation beyond the ranges of the input variables. The optimal threshold for partitioning the ensemble predictions into suitable and unsuitable regions was determined using the 'minimum ROC distance' method. This finds the threshold where the Receiver-Operator Curve (ROC) is closest to its top left corner, i.e. the point where the false positive rate (one minus specificity) is zero and true positive rate (sensitivity) is one.

Limiting factor maps were produced following Elith *et al.* (2010). For this, projections were made separately with each individual variable fixed at a near-optimal value. These were chosen as the median values at the occurrence grid cells. Then, the most strongly limiting factors were identified as the one resulting in the highest increase in suitability in each grid cell. Partial response plots were also produced by predicting suitability across the range of each predictor, with other variables held at near-optimal values.

Results

The ensemble model suggested that suitability for *L. cuneata* was most strongly determined by moisture availability, summer temperature and winter temperature (Table 1). From Figure 3, suitability was strongly restricted by low moisture, low temperatures and also high temperatures, especially in winter. A weaker preference for human-influenced regions was also modelled. For all predictors, there was substantial variation in the partial response plots between algorithms (Figure 3).

Global projection of the model in current climatic conditions indicates that the main clusters of native and invasive records fell within regions predicted to have high suitability (Figure 4). Tropical regions were modelled as unsuitable for the species, which may represent a lack of records from the tropical parts of its range. Beyond the native range, the model predicts that the species has reached the limits of its climatic tolerance in North America, but with potential for further infilling of this range. Parts of temperate South America, especially Uruguay and the surrounding regions of Brazil and Argentina were predicted as being potentially suitable for invasion by the species.

Within Europe and the Mediterranean region, the model predicts a broad region of potential suitability for *L. cuneata* (Figure 5). The most suitable regions are predicted to be in continental parts of southern and eastern Europe (e.g. south-east France, northern Italy, Croatia, Serbia, southern Russia). North of this, the model predicts marginal suitability for establishment as far north as the southern Baltic coast (Figure 5). However, the disagreement among algorithms was relatively high in this region (Figure 4b), providing uncertainty as to the exact northern extent of the potentially suitable region. The model predicts that warm winters and arid conditions are the main limiting factors around the Mediterranean coast and in southern Europe, while cool summer temperatures most strongly limit suitability in most of northern Europe (Figure 6).

The climate change projections for Europe in the 2070s cause the model to predict pronounced northwards expansions of the suitable region, accompanied by a lesser contraction of the southern part of the suitable region (Figure 7 and 8). In the more extreme RCP8.5 scenario, the species is predicted capable of establishing as far north as the Arctic coast in Russia. However, some species reports consider that photoperiod affects *L. cuneata* development (Gucker, 2010), which may restrict northwards expansion of the species.

In terms of Biogeographical Regions (Bundesamt fur Naturschutz (BfN), 2003), those predicted to be most suitable for *L. cuneata* establishment in the current climate are the Pannonian, Black Sea, Continental, Mediterranean, Steppic and Atlantic (Figure 9). In the evaluated climate change scenarios, predicted suitability was stable in the Black Sea and Steppic regions, increased in Atlantic and Continental and decreased in Mediterranean and Pannonian. Other biogeographic regions predicted to strongly increase in suitability are Boreal and Alpine (Figure 9).

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 ten different background samples of the data.

Algorithm	**Predictive AUC**	**In the ensemble**	**Variable importance**			
			Minimum temperature of coldest month	**Mean temperature of warmest quarter**	**Climatic moisture index**	**Human influence index**
ANN	0.9622	yes	28%	24%	46%	2%
GBM	0.9595	yes	23%	29%	48%	0%
Maxent	0.9589	yes	28%	28%	42%	2%
MARS	0.9586	yes	23%	31%	47%	0%
GAM	0.9580	yes	22%	31%	43%	4%
FDA	0.9545	yes	31%	29%	39%	0%
GLM	0.9483	yes	23%	31%	45%	0%
RF	0.9418	no	23%	30%	42%	5%
CTA	0.9346	no	22%	32%	45%	1%
MEMLR	0.7303	no	2%	63%	31%	4%
Ensemble	0.9628		25%	29%	44%	1%

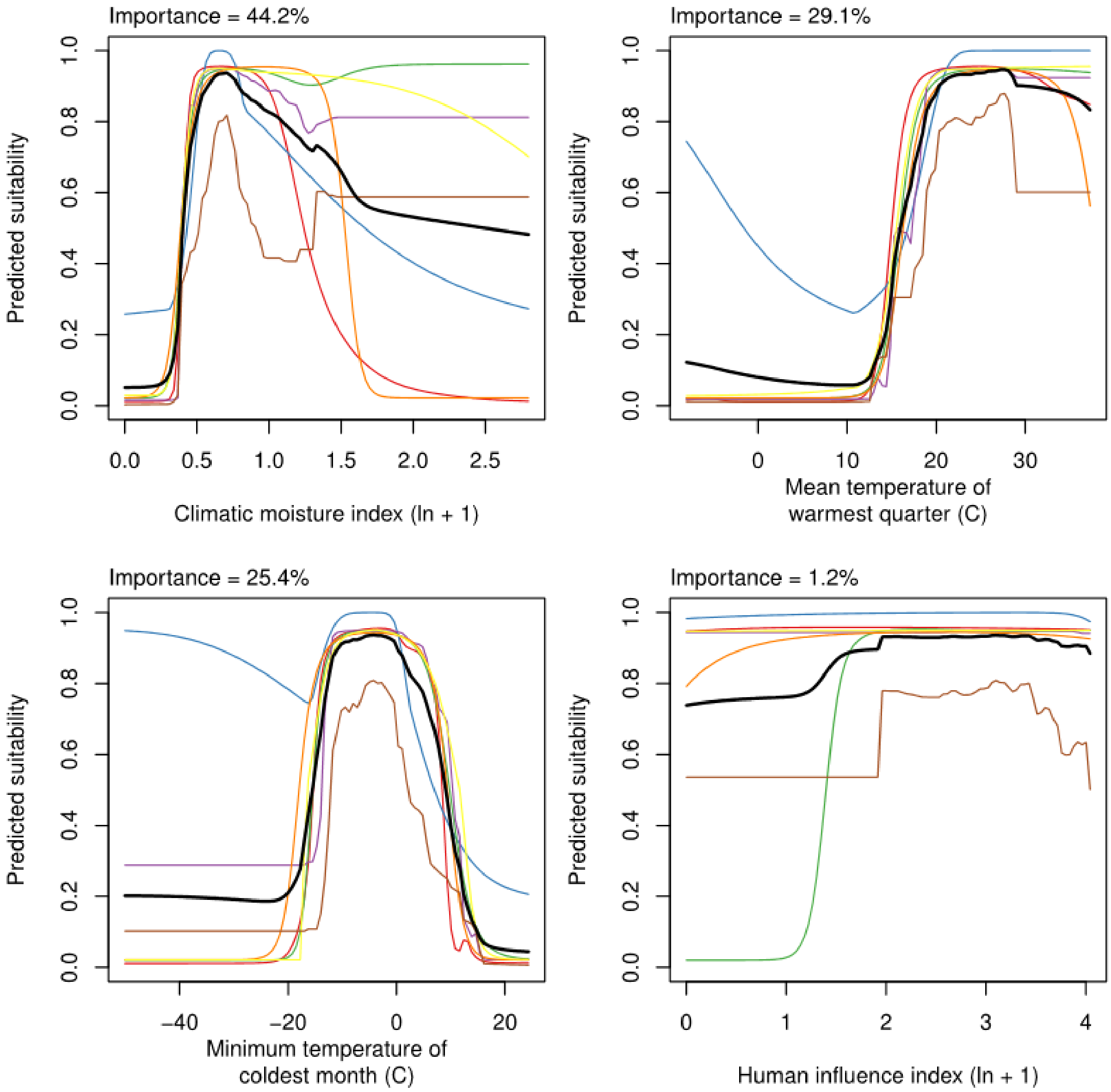


Figure 3. Partial response plots from the fitted models, ordered from most to least important. Thin coloured lines show responses from the algorithms in the ensemble, while the thick black line is their ensemble. In each plot, other model variables are held at their median value in the training data.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

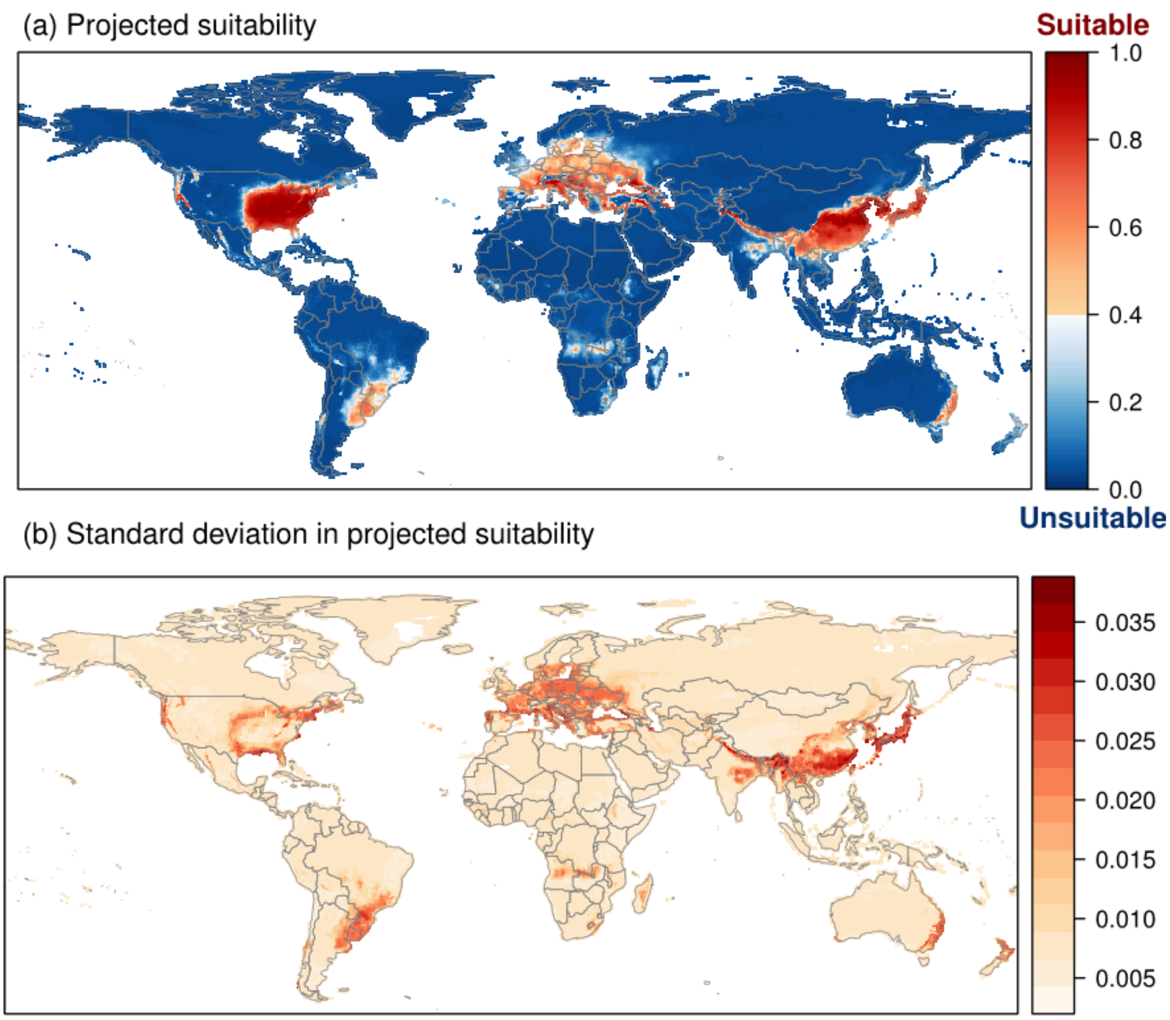


Figure 4. (a) Projected global suitability for *Lespedeza cuneata* establishment in the current climate. For visualisation, the projection has been aggregated to a 0.5 x 0.5 degree resolution, by taking the maximum suitability of constituent higher resolution grid cells. Red shading indicates suitability. White areas have climatic conditions outside the range of the training data so were excluded from the projection. (b) Uncertainty in the suitability projections, expressed as the standard deviation of projections from different algorithms in the ensemble model.

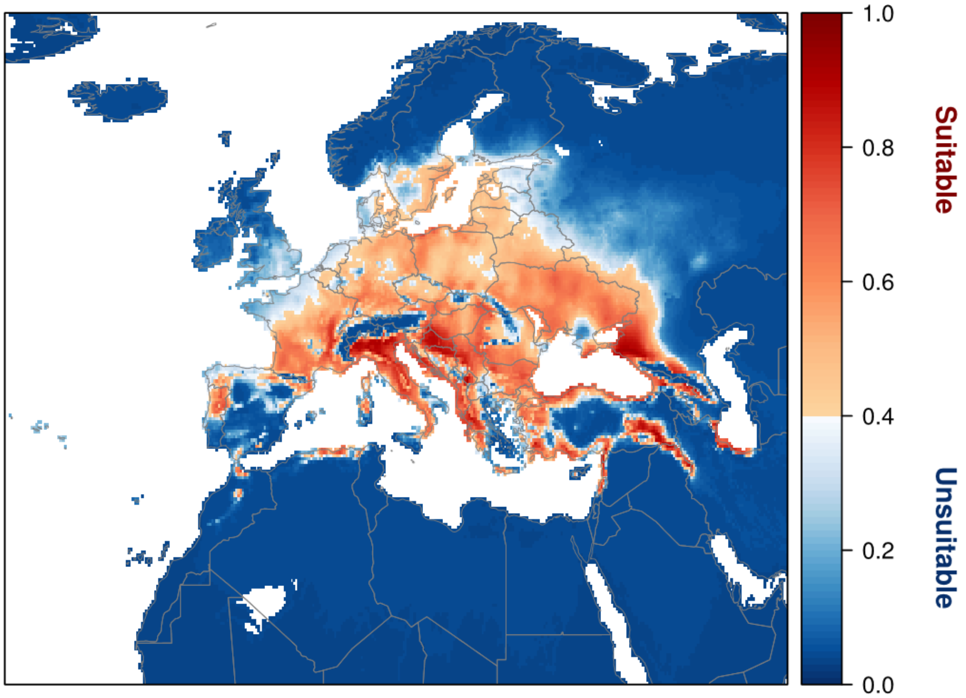


Figure 5. Projected current suitability for *Lespedeza cuneata* establishment in Europe and the Mediterranean region. The white areas have climatic conditions outside the range of the training data so were excluded from the projection.

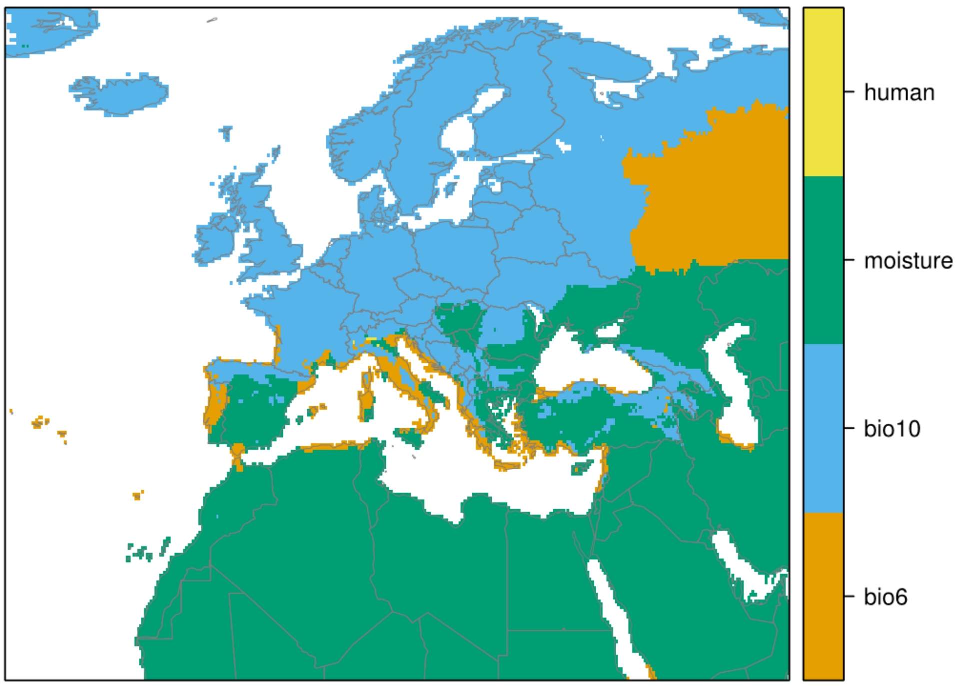


Figure 6. Limiting factor map for *Lespedeza cuneata* establishment in Europe and the Mediterranean region in the current climate. Shading shows the predictor variable most strongly limiting projected suitability.

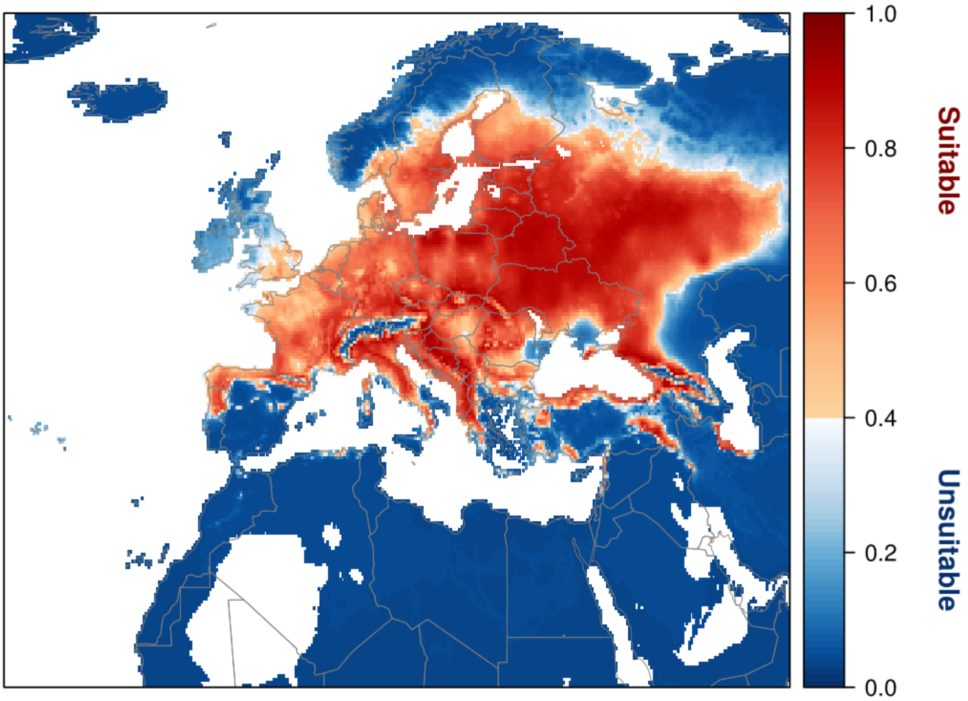


Figure 7. Projected suitability for *Lespedeza cuneata* establishment in Europe and the Mediterranean region in the 2070s under climate change scenario RCP4.5, equivalent to Figure 5.

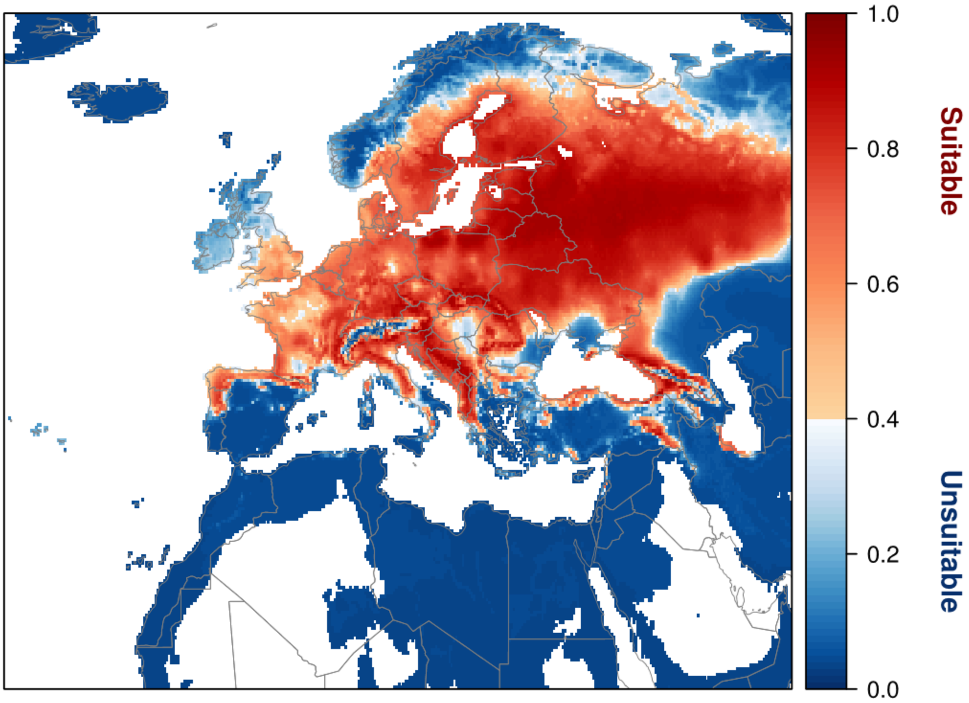
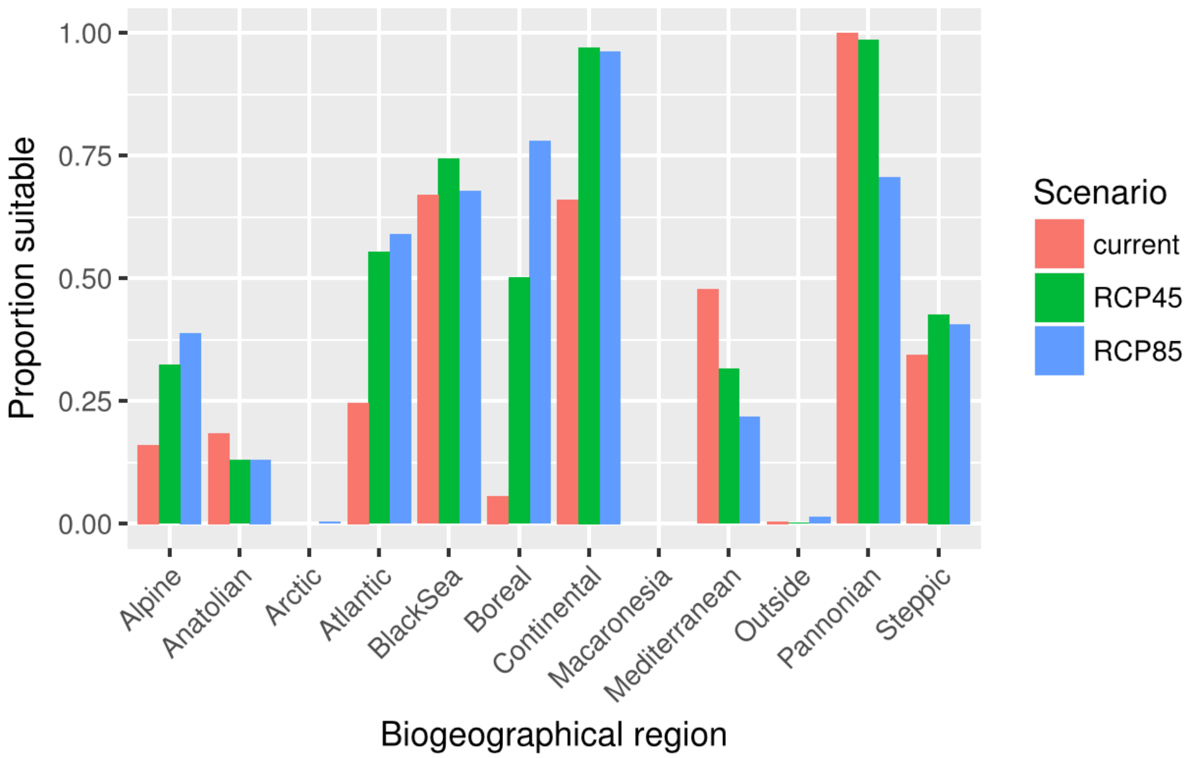


Figure 8. Projected suitability for *Lespedeza cuneata* establishment in Europe and the Mediterranean region in the 2070s under climate change scenario RCP8.5, equivalent to Figure 5.



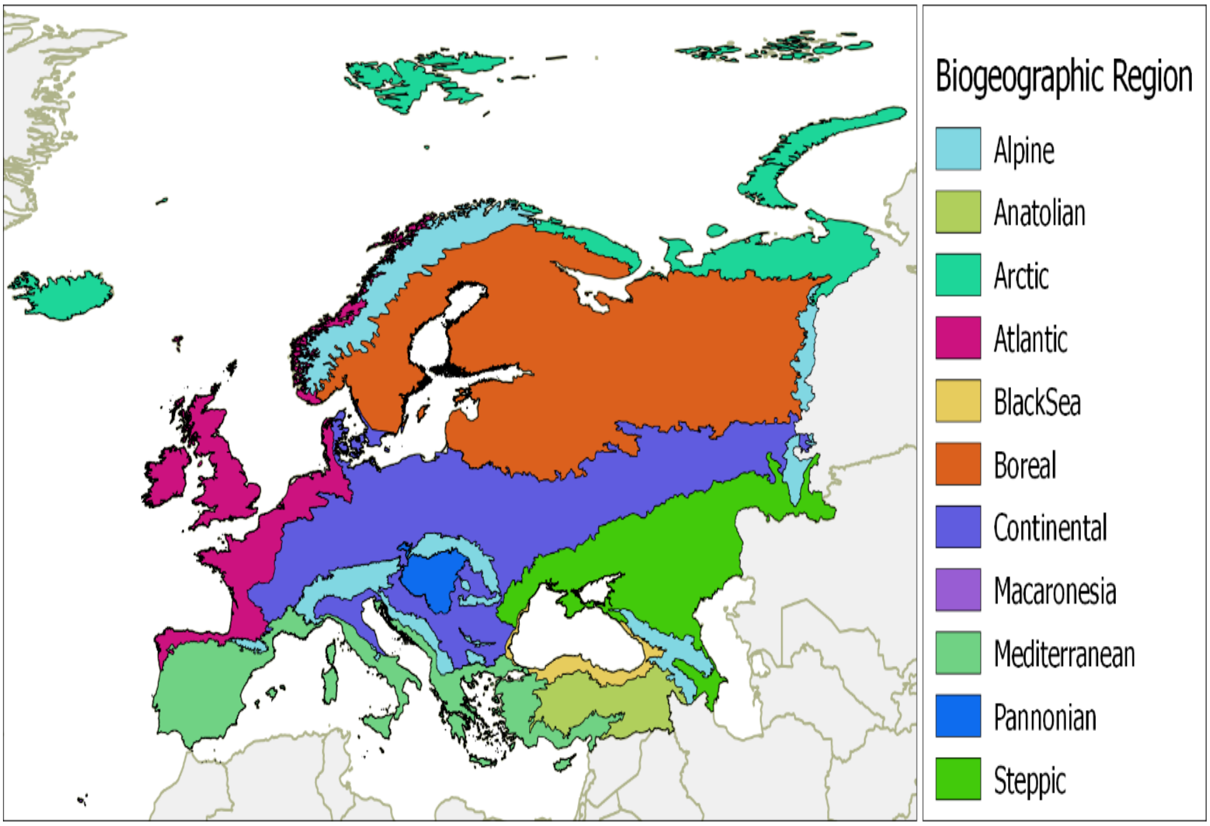


Figure 8. Variation in projected suitability among Biogeographical regions of Europe (Bundesamt fur Naturschutz (BfN), 2003). The bar plots show the proportion of grid cells in each region classified as suitable in the current climate and projected climate for the 2070s under emissions scenarios RCP4.5 and RCP8.5. The coverage of each region is shown in the map below.

Caveats to the modelling
Modelling the potential distributions of range-expanding species is always difficult and uncertain. Gaps in the native distribution from tropical regions may have caused the model to erroneously model tropical regions as unsuitable – though this is unlikely to affect the prediction for Europe.

The suitability projections in northern Europe were relatively marginal and uncertain because of variation among modelling algorithms. Furthermore, occurrence at northern latitudes might be affected by photoperiod requirements of the species not included in the model. Both these factors lead to uncertainty in the precise location of its northern potential range margin.

The limiting factors map may have under-estimated the limiting influence of winter temperatures in Europe, since two of the algorithms in the ensemble did not model a strong limitation of suitability at very cold temperatures. This will have raising the ensemble model suitability response to very cold winter temperatures.

Other variables potentially affecting the distribution of the species, such as edaphic variables, were not included in the model.
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.
- Additional data sources to GBIF were used, which may have been from regions without GBIF records.

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

Global Invasive Species Database (2017) Species profile: *Lespedeza cuneata*.

C. Gucker (2010) *Lespedeza cuneata*. In *Fire Effects Information System, [Online]*. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory.

J. Qiu, J. Mosjidis & J. Willliams (1995) Variability for temperature of germination in sericea lespedeza germplasm. *Crop science* **35**, 237-241.

J. Mosjidis (1990) Daylength and temperature effects on emergence and early growth of sericea lespedeza. *Agronomy journal* **82**, 923-926.

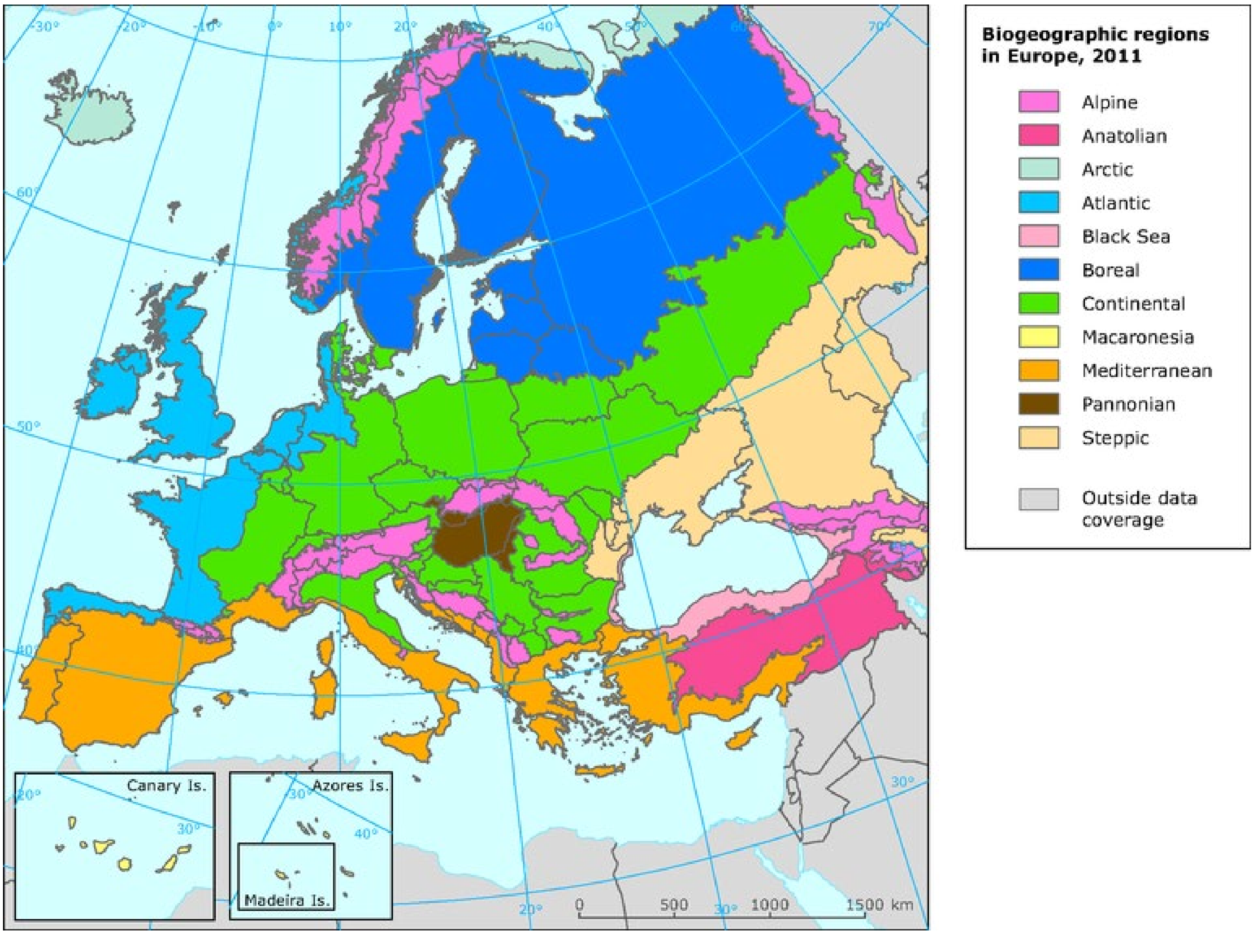
Wildlife Conservation Society - WCS & Center for International Earth Science Information Network - CIESIN - Columbia University (2005) Last of the Wild Project, Version 2, 2005 (LWP-2): Global Human Influence Index (HII) Dataset (Geographic). NASA Socioeconomic Data and Applications Center (SEDAC), Palisades,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

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

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

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

Appendix 2. Biogeographical regions



Appendix 3: Images

Figure 1. *Lespedeza cuneata* invasion into grassland in the North America.

Figure 2. *Lespedeza cuneata* leaf morphology

Figure 3. *Lespedeza cuneata* flowers

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

Member States:

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

Biogeographical regions

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

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

Appendix 5: Maps[4]

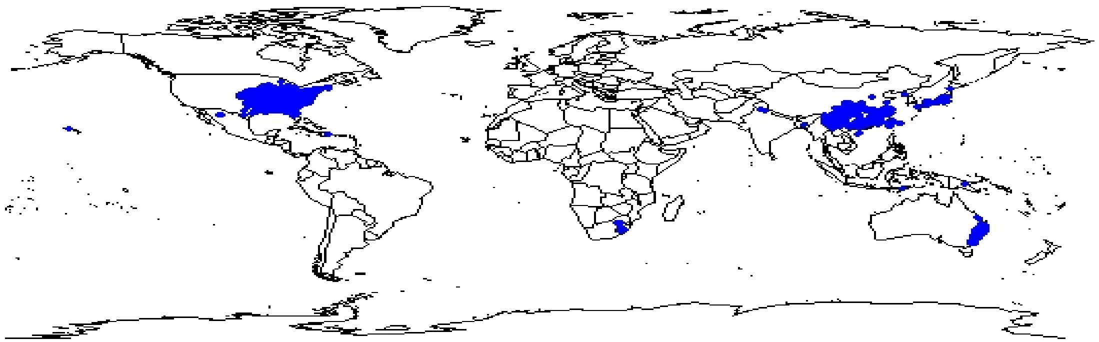


Figure 1. Global distribution of *Lespedeza cuneata*

[4] Note Maps in appendix 5may contain records, e.g. herbarium records, that were not considered during the climate modelling stage. Data sources are from literature, GBIF and expert opinion.

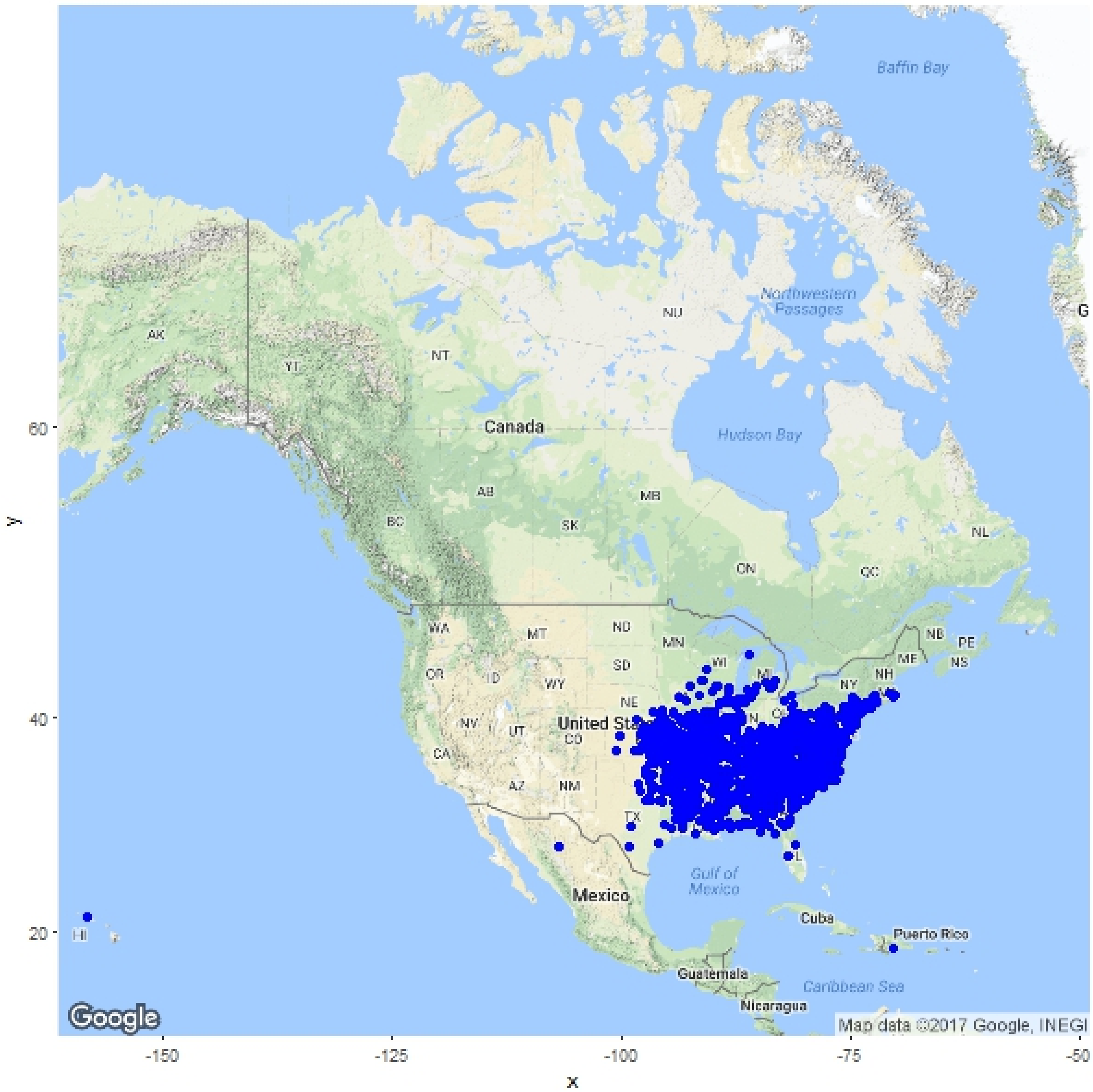


Figure 2. North America distribution of *Lespedeza cuneata*

Figure 3. Asia distribution of *Lespedeza cuneata*

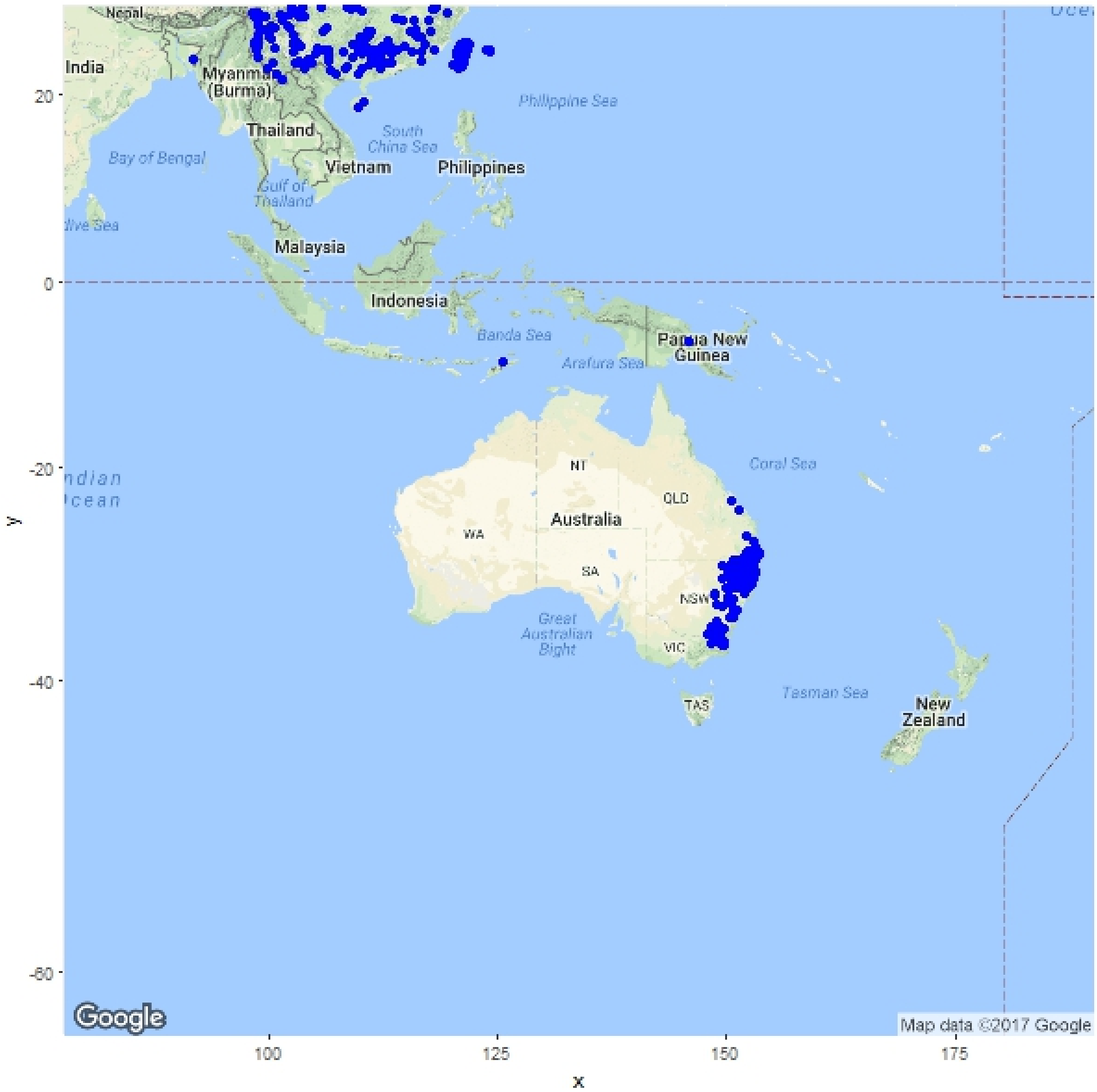


Figure 4. Australia distribution of *Lespedeza cuneata*