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

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Pest risk assessment for *Humulus scandens* (Lour.) Merr.

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

Photo: G. Fried

EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION

Pest risk assessment for *Humulus scandens*

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

PRA area: EPPO region

First draft prepared by: Guillaume Fried

Location and date: Paris (FR), 2017-03-27/31

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In partnership with

EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION

And

NERC CENTRE FOR ECOLOGY AND HYDROLOGY

Review Process

- This PRA on *Humulus scandens* was first drafted by Guillaume Fried

- The PRA was evaluated under an expert working group at the EPPO headquarters between 2017-03-27/31

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

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

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

Contents

Summary of the Express Pest risk assessment for *Humulus scandens*

PRA area: EPPO region

Describe the endangered area:

Climate modelling suggests the endangered area is predicted to be the biogeographic regions: Pannonian, Steppic and Continental, with parts of the Mediterranean and Black Sea regions (see Appendix 1, Fig. 6 and Appendix 2, Fig. 1). The main limiting factors for the species across Europe appears to be low growing season temperatures (warmest quarter) in northern Europe and drought stress (low Climate Moisture Index) around the Mediterranean and Black Sea regions.

Based on the climate modelling, the endangered area concerning climatic suitability include the EU countries: France, Italy, Germany, Austria, Poland, Hungary, Slovakia, Slovenia, Croatia, Greece, Bulgaria, Romania, and in the wider EPPO region: Bosnia-Herzegovina, Serbia, Montenegro, Macedonia, Albania, Turkey, Georgia, Russia, Ukraine. There is only marginally suitable in Portugal, Spain, Morocco and Algeria.

Habitats within the endangered area include riverside, particularly on the loose, bare surfaces of alluvial bars formed by river and stream-sides by temporary floods (Balogh & Dancza, 2008; Fried *et al*., 2017; Zhou & Bartholomew 2003). The species is also found in other habitats in Italy.

Main conclusions

Humulus scandens presents a high phytosanitary risk for the endangered area within the EPPO region with a low uncertainty. Further spread within and between countries is likely.

The overall likelihood of *H. scandens* continuing to enter the EPPO region along the pathway plants for planting is moderate as the species is cultivated and traded within the EPPO region. The risk of the species being introduced into other EPPO countries is considered high as the plant is traded both within the region and to a lesser extent into the EPPO region from outside. In addition, natural spread by river systems will also facilitate its spread between countries (for example the Danube River system).

Entry and establishment

In the EPPO region, *H. scandens* is established and considered naturalized and invasive in France, Hungary and Italy. It is considered naturalised in Serbia. It is recorded as casual in Austria, Belgium, the Czech Republic, Germany, Romania, Slovenia, Switzerland and Ukraine.

The main means of natural dispersal is by water along rivers throughout a catchment. The magnitude of spread within a river catchment is therefore high but the spread into new river catchments is predominantly by human assistance.

The pathway identified is:

Plants for planting (Moderate likelihood of entry)

H. scandens has been introduced in Europe as an ornamental species for growing over trellises, arbours or fences (Tournois, 1914; Chevalier, 1943; Balogh & Dancza, 2008). Currently, the plant is not widely sold in the major garden centre chains. However, for garden amateurs, seeds are widely available in more specialized nurseries and it can be ordered through the Internet.

Impacts

In the current area of distribution, *H. scandens* has a high magnitude of impact on biodiversity, moderate impact on ecosystem services and a moderate impact on socio-economic impact. The

Expert Working Group considers impacts will be the same in the PRA area with the exception of socio-economic activities/factors, where the uncertainty level will rise to high.

In the USA, *H. scandens* forms dense stands that outcompete existing vegetation, especially in moist areas (NatureServe, 2017). It is capable of climbing trees and other nearby vegetation, sometimes resulting in shading, girdling, and occasionally even death if trees are small (saplings). It can become the dominant understory plant (NatureServe, 2017). Throughout its invasive range, *H. scandens* is perceived as predominantly invading open disturbed areas, such as roadsides or disturbed river banks. It has also been found in open woodlands, prairies, floodplain herbaceous wet meadows, and floodplain forest communities, some of which may contain species or communities of conservation concern (NatureServe, 2017).

In Hungary, it has been reported to invade natural environments (Balogh & Dancza, 2008). It can outcompete native species and is considered as a *transformer* species (sensu Richardson *et al*., 2000), that threatens particularly plant communities dominated by *Phragmites* and *Salix* (*Phragmitetea* and *Salicetea* classes) as well as the *Filipendulo-Petasition* alliance (Balogh *et al*., 2004, cited in Balogh & Dancza, 2008).

In France, *H. scandens* has been shown to impact on native plant communities by reducing species richness and modifying species composition (Mahaut, 2014). In particular, *H. scandens* can impact on early emerged spring species, for example, *Atriplex prostata*, *Mentha suaveolens*, *Persicaria hydropiper*, and *Veronica anagallis-aquatica*. Dense mats of the species can persist along riverbanks for several years. Ecosystem functioning (for example, reduced species richness and decrease functional richness) is altered when the species invade riparian habitats. The text within this section relates equally to EU Member States and non-EU Member States in the EPPO region.

Climate change

Under the climatic projection, RCP 8.5, the risk of establishment is likely to increase because of climate change as the plant may be able to produce viable seeds further north because of an extended growing season (Guillaume Fried pers comm., 2017). The model predicts large increases in suitability within the Alpine, Atlantic, Black Sea, Boreal and Continental Biogeographical Regions. However, suitability is predicted to decline in the Pannonian and Steppic regions, which are the two most currently suitable Biogeographical Regions. However, the likelihood scoring will not change as it is already high. Spread is likely to increase with increased risk of flooding events. However, the likelihood scoring will not change as it is already high. The potential area for impacts to be realised may increase with increased establishment and spread. 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.

Phytosanitary measures

The results of this Pest Risk Assessment (PRA) show that *Humulus scandens* poses a high phytosanitary risk to the endangered area (Pannonian, Steppic and Continental, with parts of the Mediterranean and Black Sea region) with a low uncertainty.

Phytosanitary risk (including impacts on biodiversity and ecosystem services) for the *<u>endangered area</u>* (current/future climate) **Pathway for entry:** Plants for planting: Moderate/ Moderate Likelihood of establishment in natural areas: High/ High	High X	Moderate ☐	Low ☐

Likelihood of establishment in managed areas: High/ High Spread: High/ High **Impacts in PRA area:** Impacts on biodiversity: High/High Impacts on ecosystem services: Moderate/High Socio-economic impacts: Moderate/High			
Level of uncertainty of assessment (current/future climate) **Pathway for entry:** Plants for planting: Low/Low Likelihood of establishment in natural areas: Low/Moderate Likelihood of establishment in managed areas: Low/Moderate Spread: Moderate/ High **Impacts in PRA area:** Impacts on biodiversity: Low/ High Impacts on ecosystem services: Moderate/High Socio-economic impacts: High/ High	High □	Moderate □	Low X

Other recommendations:

Inform EPPO or IPPC or EU

- Inform NPPOs that surveys are needed to confirm the distribution of the plant, in the area where it is present, and on the priority to eradicate the species from the invaded area.

Inform industry, other stakeholders

- Encourage industry to assist with public education campaigns associated with the risk of non-native plants. Encourage industry and traders to sell native species as alternatives to non-natives (for example *Clematis* spp.).

Specify if surveys are recommended to confirm the pest status

- Studies should be conducted to evaluate the impact of the species on biodiversity and the impact of the pollen on human health and on nutrient cycling.

Express Pest risk assessment *Humulus scandens* (Lour.) Merr.

Humulus scandens (Lour.) Merr.

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Stage 1. Initiation

Reason for performing the PRA:

Humulus scandens was added to the EPPO Alert List in 2007 and transferred to the EPPO List of Invasive Alien Plants in 2012. 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[1]) 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'. *H. scandens* was one of 16 species identified as having a high priority for PRA. In the EPPO region, *H. scandens* is only established in France, Hungary, Italy and Serbia. Because it locally exhibits an invasive behaviour and its distribution is very limited in Europe, this plant can be considered a new emerging invader (Balogh & Dancza, 2008; Brunel *et al*., 2010).

PRA area: The PRA area is 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 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:

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

Kingdom: Plantae, Subkingdom: Tracheobionta, Superdivision: Spermatophyta, Division: Magnoliophyta, Class: Magnoliopsida, Subclass: Hamamelididae, Order: Urticales, Family: Cannabaceae, Genus: *Humulus* L. Species: *Humulus scandens* (Lour.) Merr.

Synonyms: *Antidesma scandens* Lour. (basionym) - *Humulus japonicus* Siebold & Zucc. - *Humulus japonicus* var. *variegatus* F.Roem. Please note that according to another interpretation (e.g., https://plants.usda.gov/core/profile?symbol=HUJA), the valid name should be *Humulus japonicus* Siebold & Zucc. = *Humulus scandens* auct. non (Lour.) Merrill.

Notes on taxonomy

There are still opposing views on the “correct” name for this species. However, there is no discussion on the proper identity of the species as such. Everyone agrees on what this annual species looks like and how it can be distinguished from the European and Asian native *Humulus lupulus* L. It is all about a contested validity of the description by Loureiro and the omission to nominate a neotype (see for details the note by Valéry Malecot). The expert working group agrees with the scientific view as expressed by Valéry Malecot and also for pragmatic reasons follows the approach as taken by the Flora of China to choose for *H. scandens* as the preferred name for this species (http://www.efloras.org/florataxon.aspx?flora_id=2&taxon_id=242325576)

In addition to the above, the following note was compiled by Dr. Valéry Malecot, botanist at AgroCampus Ouest, France.

The situation of *Antidesma scandens* Lour. (basionym of *Humulus scandens* (Lour.) Merril) is quite specific. It was described when Loureiro was in China. He attributed this species to this genus because it has five stamens, is bifid, and has no corolla (these are the genus characteristics from his work). Authors from the beginning of the 19th century always had doubts concerning the affiliation to the genus *Antidesma* because of the palmate and dentate leaves. Indeed, at this time, these characteristics were not known in other species of the same genus. After year 1850, this name almost disappeared from the literature (in 1851, van Tieghem performed a revision of the genus *Antidesma* and considered this species as doubtful). Moreover, between 1790 and 1850, it seems that no specimen was observed.

In 1930, when Merril decided to work routinely on the Flora cochinchinensis written by Loureiro (in fact he began in 1919), even though he had no specimen, he considered that the only species that could fit should belong to the genus *Humulus* (i.e. a plant with the following characteristics: a vine, with five stamens, with no corolla, and in relation to the place of observation and considering the Chinese name) and proposed the combination *Humulus scandens* (Lour.) Merril. This interpretation was discussed later, and authors, when considering *Humulus japonicus* Siebold & Zucc. as a correct name, very often noted the ambiguity of the name given by Loureiro (and implicitly the priority of the combination proposed by Merril). In 2009, a proposal to reject *Antidesma scandens* was done (Taxon 58(4): 1372-1373). However, this rejection proposal was rejected by the two comities where it was analysed (Nomenclature Committee for Vascular Plants, General Committee).

Because no neotype was designated for *Antidesma scandens*, two options are possible: Either using the name *Humulus japonicus* without considering the name *Humulus scandens* as a synonym (but indicating, as many authors did, that there is incertitude concerning the priority of *Humulus scandens* (Lour.) Merril), or proposing *Humulus scandens* as a correct name.

When analysing more in detail the history of the dispute, it is Merritt L. Fernald who first disagreed with the identification proposed in 1933 by Elmer D. Merril. Fernald wrote: ‘*Possibly* H. scandens

(Lour.) Merr., but that name based upon a plant described as fruticose and with glabrous leaves' (the two terms being in italic in the text because not corresponding to criteria adapted to the species – text available at the following address : https://babel.hathitrust.org/cgi/pt?id=coo.31924077303372;view=1up;seq=624). From a morphological point of view, the 'glabrous' characteristic exists in some Asiatic *Humulus* specimens. Considering the spreading, Loureiro also wrote '*caulis fruticosus, longus, scandens*' which does not necessary mean spreading shrub, but could mean woody plant (Loureiro has often badly described his plants). It should be reminded that Merril had worked a lot on the identification of the names proposed by Loureiro, using a well-documented method (see the following articles: http://www.biodiversitylibrary.org/item/97550#page/47/mode/1up, http://www.jstor.org/stable/984687?seq=1#page_scan_tab_contents, http://www.jstor.org/stable/984687?seq=1#page_scan_tab_contents).

Also, Merril has particularly studied the south-eastern Asian flora (he spent almost 30 years there), whereas Fernald studied first the northern American flora. I had also a look to other names that Merril has re-identified and where the epithet was a priority (*Gaura chinensis* versus *Haloragis scabra* [now in the genus *Gonocarpus*], *Drosera umbellata* versus *Androsace saxifragifolia* [now in the genus *Androsace*]). For these ones, the modification of the naming proposed by Merril has not disturbed later authors. In addition to this, I suspect some competition between Merril and Fernald in Harvard in 1937. This is why I consider that Merril is right and that the correct name is *Humulus scandens* (Lour.) Merril. A neotypification would clarify this finally.

Common name: Japanese hop (English), houblon japonais (French), japanischer Hopfen (German), kanamugura (Japanese), lúpulo (Portuguese (Brazil), Luppolo del Giappone (Italian), japansk humle (Swedish), lü cao (Transcribed Chinese).

Plant type: Herbaceous annual vine

Related species in the EPPO Region: *Humulus lupulus* L. (native)

2. Pest overview

Introduction

Humulus scandens is a dioecious herbaceous annual vine that germinates in early spring. The species is native to Asia (China, Taiwan, Japan, Korea, Russian Far East, and Vietnam) (Germplasm Resources Information Network 2017); Zhou & Bartholomew 2003) and has been introduced as an ornamental in both Europe and North America where it is becoming an invasive alien species in several regions. In both its native range and introduced range, *H. scandens* is a plant of riverside, particularly of the loose, bare surfaces of alluvial bars formed by river and stream-sides by temporary floods.

In the US, *H. scandens* can form dense stands that outcompete existing vegetation, especially in moist areas (NatureServe, 2017). It is capable of climbing trees and other nearby vegetation, sometimes resulting in shading, girdling, and occasionally even death if trees are small (saplings). It can become the dominant understory plant (NatureServe, 2017). In the EPPO region, *H. scandens* has been reported to outcompete native plant species with its smothering habit in France and Hungary (Fried, pers com, 2017). In the EPPO region, this species has no economic importance.

Identification

There are three species in the genus *Humulus*: *Humulus lupulus* L., *Humulus yunnanensis* Hu and *Humulus scandens* (Lour.) Merr., and at least two varieties of *H. lupulus* (*H. lupulus* var. *cordifolius* and *H. lupulus* var. *lupuloides*).

In the native range of *H. scandens*, it is distinguished from *H. yunnannensis* as the latter has leaves with only 3-5 lobes (or sometimes simple), upper leaves usually densely pubescent; longer infructescences 2-9 cm; longer bracts and bracteoles 1.5-3 cm, and absence of spinulose hairs (Zhou & Bartholomew, 2003).

For Europe, Balogh & Dancza (2008) summarized the distinguishing features between the native *Humulus lupulus* and *Humulus scandens* (see Table 1).

Table 1. Distinguishing features of the native (or cultivated) *Humulus lupulus* and the non-native *Humulus scandens*.

Character	***Humulus scandens***	***Humulus lupulus***
Life cycle	Annual	Perennial
Hairs	rigid, spinulose	pubescent, glandular
Leaf colour	light green (see **Photo 1**)	dark green
Leaf shape	5-7(-9)-lobed (see **Photo 1**)	3-5-lobed, the upper and lower entire
Leaf margin	dentate, teeth not aristate	coarsely dentate, teeth aristate
Petiole	longer than the blade (see **Photo 1**)	shorter than the blade
Colour of flowers	pale greenish yellow	yellow
Number of female flowers at maturity	800-1200	4000-6000
Female inflorescences at maturity	not enlarged	significantly enlarged
(Stipular) bracts of the female inflorescence	cordate, significantly mucronate, in number 10-16	short, acute, in number 20-30
Bractlets in female inflorescences ciliate	Yes	No
Number of bractlets and flowers on the base of a stipular bract	1	2
Position of bractlets at fruit ripening and their role in dispersal	not sticking out of the infructescence; no role in dispersal	sticking out of the infructescences, serve as wings for dispersal
Length of cotyledon on the seedlings	4.0-5.0 cm	1.5-2.0 cm

The stem is branched, hexangular, twining clockwise on itself (Balogh & Dancza, 2008) and around objects. Height of plant can range between 0.5 and 5.0 m (Small, 1997; Balogh & Dancza, 2008), but it can grow to heights of 9-11 m (Fried, pers. com.; Panke & Renz, 2013).

Leaves are opposite, blades are light green, cordate, palmately lobed with 5-7(-9) lobes, 5-12 cm long with petioles longer than the blade (Small, 1997; Balogh & Dancza, 2008; see Appendix 3, Fig 1). Leaf margins are dentate with an acuminate apex; the lower leaf surfaces have pubescent veins, with rigid spinulose hairs, with yellow, sessile, discoid glands. The upper margins of younger leaf blades have stiff cystolithic hairs (i.e. mineral concretions of calcium carbonate or calcium oxalate), which are typical in cells of plant leaves from Urticaceae, Moraceae and Acanthaceae.

The male inflorescences form an erected branched panicle, 15-25 cm, flower anthers without glands (see Appendix 3, Fig 2); female inflorescences are ovoid cone-like spikes; bracteole ovate-orbiculate, 7-10 mm, pilose, margins densely ciliate-hairy (see Appendix 3, Fig 3).

Infructescences pendulous, green, conelike, ovoid to oblong, (1-)1.5-3.0(-4) cm; bracteoles without yellow glands. Achenes are yellow-brown, ovoid-orbicular, inflated to lenticular, 4-5 mm, glandless (see Appendix 3, Fig 4).

Humulus lupulus and *H. japonicus* are not cross-compatible (Small 1997. In addition to differences in gross morphology, *H. lupulus* and *H. scandens* have different chromosome numbers, each with a well-developed sex-chromosome system. There are 2n = 20 chromosomes in both male and female plants of *H. lupulus*, while *H. scandens* has 2n = 16 chromosomes in the female and 2n = 17 in the male (Pillay & Kenny 1994 and references therein).

Reproduction and spread of *H. scandens* is exclusively by seeds (achenes). One plant can produce 800 to 1200 seeds (Balogh & Dancza, 2008). A study conducted in the native range trapped a seed rain of 256.0 (± 432.2) seeds of *H. scandens* per m² (Masuda & Washitani, 1990). The seeds of *H. scandens* lack specific adaptations for dispersal so that the plant has no specific means of spread. Mature seeds are primarily dispersed by gravity near parent plants and form a seed bank with ca. 3 years viability (NB: many sources cite wind as a natural mean of dispersion but given the form and the weight of the seeds, it is unexpected that wind plays a significant role in the dispersal of this species).

Life cycle

In the EPPO region, seeds of *H. scandens* germinate in masses in early spring (Appendix 3, Fig 5) starting mid-April in Hungary (Balogh & Dancza, 2008) but as early as February in southern France (Fried, pers. obs. 2017). New seedlings can be observed until early May (Pinston, 2013). This is highly consistent with patterns of germination observed in the native range where emergence occurred from February to early May with a peak in March (Masuda & Washitani, 1990). In a March 2014 study, a mean of 37.9 seedlings/m² (max. = 245.8 seedlings/m²) were measured in 43 plots in the south of France (Fried *et al*., 2017). A study in the native range found a mean of of 32.3 ± 37.0 seedlings/m² (Masuda & Washitani, 1990).

In Europe, flowering time occurs from July to September (Balogh & Dancza, 2008). In a 2013 survey of south France, the first flowers were observed at the end of August, and the first mature fruits were observed at the end of September. Similarly, another survey from France in 2016 detected the first male flowers in mid-August (Maillard, pers. com. CHU Nimes).

In the native range (China and Korea), *H. scandens* flowers from August to October (Park *et al*., 1999). Flowers are mainly wind pollinated but frequently visited by honeybees (Balogh & Dancza, 2008; Fried, pers. obs. 2016). In Hungary, fruits are reported to ripen from the middle of August and seeds remain viable for about three years (Krauss, 1931).

In a controlled greenhouse experiment (Pinston, 2013), the first shoot ramification appeared at 326 degree days. The mean phyllochron (i.e., the intervening period between the sequential emergences of leaves) was 59.7 degree days (which is much faster than another invasive species, *Ambrosia artemisiifolia* 138°C/days). Male flowers were formed at 1293.85 degree days while female flowers appeared later at 1328.6 degree days.

Habitats

In both its native range and its introduced range, *H. scandens* is a plant of riverside, particularly on the loose, bare surfaces of alluvial bars formed by river and stream-sides by temporary floods (Balogh & Dancza, 2008; Fried *et al*., 2017; Zhou & Bartholomew 2003). The plant can also invade ruderal areas under climates with no dry seasons (see Section 7).

Relevant PRAs

There is no existing PRA covering the European Union, except for two countries:

France: using the Weber & Gut (2004) risk assessment protocol, Fried (2010) reported a high risk score of 29 (on a 21-38 scale**).** Using the EPPO Prioritization process, Fried (2010) concluded that *H. scandens* should be considered as a high priority for an EPPO PRA.

Spain: Gassó *et al*. (2010) assessed *H. scandens* with the Australian Weed Risk Assessment adapted to Spain where the species scored 9 indicating a low impact (species rejected). In addition, using the Weber & Gut (2004) method, the species scored 20, indicating a low risk.

USA: several States used different risk assessment protocols**:**

- **New York:** The New York non-native plant invasiveness ranking form was used to assess the risk of *H. scandens.* The species scored 74.0 (0-100 scale) which is considered as high (Jordan *et al*., 2008).
- **Virginia**: The Virginia Department of Conservation and Recreation's Invasive Species Assessment Protocol concluded to a medium risk for *H. scandens* (Hefernan *et al*., 2014).
- **Indiana**: the Indiana Non-native Plant Invasiveness Ranking Form (INPIRF) reported a high risk (Indiana Invasive Species Council (IISC, 2017).
- **Minnesota**: *H. japonicus* was ranked 29th with a score of 70.1 on the top list of 124 terrestrial invasive plants (Minnesota Department of Agriculture, 2011)).

The US Invasive Species Impact Rank (I-Rank) was used to assess the species at a national scale and it was concluded a medium/low ecological impact – due to its limited distribution to the northeastern USA (NatureServe, 2017).

Socio-economic benefits of the species

In the EPPO region, this species does not have any economic importance apart from a limited use as an ornamental and being kept in many botanic gardens (Fried pers comm, 2017). *H. scandens* is sold as an ornamental plant within the EPPO region and there are also sales of the species in North America. Typically, mostly female plants are sold in nurseries.

H. scandens does not have lupulin glands that produces the bitter substance used to flavour beer and which are present in *Humulus lupulus.* Therefore, *H. scandens* has a much less economic value than *Humulus lupulus* (Tournois, 1914).

In the native range, the whole plant is used medicinally and the seed oil is used to make soap (Zhou & Bartholomew, 2003). No other information is known on the plants economic benefit.

Various other uses are currently being studied, for example using the plant to extract cellulose nanocrystals (Jiang *et al*., 2017), or to extend its medicinal use (Park *et al*., 1999). The leaf extracts of *H. scandens* are effective against mosquito larvae (Pavela, 2008) and proved to be superior to various neem extracts, which are reported to be effective with LC_{50} values ranging from 55 to 65 ppm.

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

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

5. Regulatory status of the pest

EPPO
In Europe, *H. scandens* was added to the EPPO Alert List in 2007 and transferred to the List of Invasive Alien Plants in 2012.

In Italy, it is included in the Lombardy region black-list established in 2008 according to the regional Law 31st March 2008, no. 10: "Disposizioni per la conservazione della piccola fauna e della flora spontanea". It is also included in the Piedmont region black-list according to the DGR no. 23-2975 of the 29th February 2016.

USA
H. scandens is considered a noxious weed in Connecticut where it is categorized as “Potentially invasive, banned”, and in Massachusetts where it is prohibited.

6. Distribution[2] (Table 2)

Continent	***Distribution*** *(list countries, or provide a general indication , e.g. present in West Africa)*	***Provide comments on the pest status in the different countries where it occurs*** *(e.g. widespread, native, non-native, established….)*	***Reference***
America	Canada: Quebec, Ontario; United States: Alabama, Delaware, District of Columbia, Georgia, Illinois, Indiana, Kentucky, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Nebraska, New Hampshire, New Jersey, New York, North Carolina, North Dakota, Ohio, Pennsylvania, Rhode Island, South Carolina, South Dakota, Vermont, Virginia, West Virginia, Wisconsin	Canada: Reported as introduced (but unknown) Established and invasive in New England, the mid-Atlantic states, and some areas of the Midwest (OH, IN, IL, MO, IA, eastern NE, and eastern KS). Established in the northern Midwest (MI, WI, MN, ND, SD) and the southeast (KY, AR, TN, NC, SC, GA, AL). Casual in west of the plains or in the most southern states (FL, LA, MS, OK, TX).	Germplasm Resources Information Network, 2017; EWG opinion, 2017.
Asia	China: Anhui, -Zhejiang, - Fujian, - Heilongjiang, -Henan, - Hebei, - Hunan, - Hubei, Jiangxi, - Jiangsu, - Jilin, - Guangdong, - Guizhou, Liaoning, - Shanxi, - Shandong, - Shaanxi, - Sichuan, - Yunnan, - Guangxi, - Xizang, - Hainan, Mongolia: Mongolia Japan: Hokkaido, - Honshu, - Kyushu, - Ryukyu Islands, - Shikoku; Korea, Taiwan, Vietnam, Russian Federation: Primorye, - Amur	Native	Germplasm Resources Information Network, 2017; Zhou & Bartholomew, 2003.

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

Continent	***Distribution*** *(list countries, or provide a general indication , e.g. present in West Africa)*	***Provide comments on the pest status in the different countries where it occurs*** *(e.g. widespread, native, non-native, established….)*	***Reference***
Europe	Austria, Belgium, Bulgaria, Czech Republic, France: Gardon River catchment, Germany, Italy, Hungary, Romania, Poland, Serbia, Slovakia, Slovenia, Switzerland, Ukraine. Biogeographical regions: Pannonian, Steppic, Continental, Mediterranean	It is established and invasive in France, Hungary and Italy. It is considered under naturalization in Serbia. It is recorded as casual in Austria, Belgium, Bulgaria, the Czech Republic, Germany, Poland, Romania, Slovenia, Switzerland and Ukraine. In Czech Republic, it is recorded in the group of species that need continued input of propagules from planted populations but failed to establish.	Balogh & Dancza, 2008; Brunel *et al*., 2010; Celesti-Grapow *et al*., 2009;Carola et al., 2014; FloraWeb, 2017; Fried *et al*., 2017; Morariu 1942; Mosyakin & Fedoronchuk, 1999; Pyšek *et al*., 2012 ; Savić *et al*., 2008 ; Stace & Crawley, 2015;Verloove, 2006; Vladimirov (personal communication)

Introduction

Humulus scandens is native to Asia (China, Taiwan, Japan, Korea, Russian Far East, and Vietnam). It has been introduced as an ornamental in both Europe and North America where it is becoming an invasive alien species in several regions (Table 2 and see Appendix 5, Fig. 1).

Asia

Humulus scandens has a native range within the far East of Asia (China, Taiwan, Japan, Korea, Russian Far East, Vietnam) (Germplasm Resources Information Network, 2017; Zhou & Bartholomew, 2003) (Table 2 and see Appendix 5, Fig. 2).

Europe

Humulus scandens is non-native to Europe. The second edition of Flora Europae (Tutin & Akeroyd, 1993) mentioned the species as an ornamental plant established in northern Italy, western Hungary and possibly elsewhere (Balogh & Dancza, 2008) (Table 2 and see Appendix 5, Fig. 3).

Belgium

Recorded as a casual in 1954 and 1955 (Verloove, 2006).

Bulgaria

The species is established in Bulgaria (Vladimirov, personal communication).

France

According to Tournois (1914), *H. scandens* was introduced in Europe ca. 1880, by Thiébaud-Legendre from Paris for cultivation as an ornamental species. A voucher herbarium specimen (Th. Delacour, s.n., P) dated 10-07-1881 and collected in the Jardin des Plantes (Paris) indicated it flowered for the first time since its introduction two years prior. In 1885, it was presented to the French Horticultural Society by Mr. Cornu who stressed its interest due to its late development offering a nice bed of greenery at a period of the year where most other plant go dormant (however flowering periods and the introduction of exotic plant species have changed these timings now). It is assumed that the company Friedrich Röhmer in Quedlinburg (Swaxe-Anhalt, Germany) launched the variegated form (var. *variegatus* (Siebold & Zucc.) Moldenke) in 1893 (Tournois, 1914) although according to Ascherson & Graebner (1908-1913) it was already cultivated in 1886. According to Chevalier (1943), the variegated form was used since the 1910s for growing over trellises and arbours or sometimes along fences.

The oldest record of the plant in the wild dates back to 1893 when it was found in wastelands along the cours Journu-Aubert in Bordeaux (Neyraut, s.n., CHE). In 1947, the species was recorded on wastelands at Porte de la Villette in Paris (Bouby, n°1454, P) and in similar conditions in south-west France in Royan in 1958 (Bouby, n°4296, P). There are also casual records in Alsace (NE France) where *H. scandens* was collected in a dump site near Modenheim (Rastester, STU). The first established populations were identified in 2004 (Brunel and Tison, 2005) in a disturbed portion of riparian habitat along the Gardon River, near Nîmes in the Mediterranean region (south-east France). Further surveys conducted in 2012, revealed the presence of the species along 40 km of the river between Alès and the confluence of the Gardon River with the Rhône (Pinston, 2013; Mahaut, 2014; Fried *et al*., 2017). Since 2015, *H. scandens* has been recorded in a second catchment in the Huveaune River in the city of Marseille (Fried *et al*., 2017).

Hungary
Very similar to France, the first plant was collected in 1880 by N. Filarszky in the botanical garden of the Budapest University (Balogh & Dancza, 2008). The first occurrence in the wild was confirmed as early as 1894, by an herbarium specimen collected by V. Borbás at Vésztő in county Békés (Balogh & Dancza, 2008). In the early 1900s, the species had spread and became naturalized in some localities of Hungary such as the environs of Lake Balaton (Balogh & Dancza, 2008). Balogh & Dancza (2008) summarized the current distribution in Hungary and indicated there are various new localities in the North Hungarian Mountains, northern Great Hungarian Plain, and southern and western Transdanubia.

Italy
In Italy (according to the Gruppo di Lavoro Specie Esotiche della Regione Piemonte, 2015) it is believed the plant was introduced for ornamental horticulture and nursery purposes in the late nineteenth century (1885). It was recorded as naturalized in Tuscany in 1903 (Saccardo, 1909; Arrigoni, 2011). The first record for Lombardy is dated 1941. Currently, it is considered invasive in Piedmont, Lombardy, Emilia-Romagna (e.g. along the Po river), and naturalized in Veneto and casual in Tuscany. It is not recorded on the islands of Sicily and Sardinia (Celesti-Grapow *et al*., 2009).

Serbia
Humulus scandens was discovered in 1999 in a locality near Novi Sad, in a ruderal humid habitat on the bank of channel Danube-Tisa-Danube (Savić *et al*., 2008). The plant was considered as being under naturalization process with a risk of "becoming a nuisance invasive plant in wetland habitats, similar to *Echinocystis lobata* (Michx.) Torr. et Gray (Savić *et al*., 2008)."

North America
Humulus scandens was first imported to America in the late 1800s for use as a tonic in Asian medicine and as an ornamental vine. It is still sold for these purposes today (Pannil *et al*., 2009). In North America, the earliest records of its escape and naturalization come from eastern Massachusetts in the 19th century (IPANE, 2005). In Delaware, a few escapes from cultivation were observed in the 1900s (Table 2 and see Appendix 5 Fig. 4).

Currently it is most abundantly established in New England, the mid-Atlantic States, and some areas of the Midwest that include Ohio, Indiana, Illinois, Missouri, O, Iowa, eastern Nebraska and Kansas (Natureserve, 2017). The establishment of *H. japonicus* is more scattered in the northern Midwest (Michigan, Wisconsin, Minnesota, North and South Dakota) and the southeast (Kentucky, Arkansas, Tennessee, North and South Carolina, Georgia, and Alabama). It is not yet established in the most southern states (Florida, Louisiana, Mississippi, Oklahoma, and Texas) as well as west of the plains region. In total, it is reported from 31 States of the USA (NatureServe, 2017; Small, 1997). The species has been introduced into Canada (Small, 1997).

7. Habitats and where they occur in the PRA area (Table 3)

Habitat (main)	**EUNIS habitat types**	**Status of habitat (e.g. threatened or protected)**	**Is the pest present in the habitat in the PRA area (Yes/No)**	**Comments (e.g. *major/minor habitats* in the PRA area)**	***Reference***
Lowland meadows	E3. E5.4 and E5.5 Seasonally wet and wet grasslands	Protected pro parte: e.g. Annex 1 6440 Alluvial meadows of river valleys of the *Cnidion dubii*	No	Major habitats within the PRA area	Monsi & Saeki 1953
Forest margins, alluvial woods	G1. Broadleaved deciduous woodland (G1.1., G1.2. and G1.3.)	Protected pro parte: e.g. Annex 1 91E0 * Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicion albae) 92A0 *Salix alba* and *Populus alba* galleries	Yes (but mostly established, non-invasive)	Major habitats within the PRA area	Balogh & Dancza, 2008; Fried *et al.*, 2017; Zhou & Bartholomew 2003
Wetlands, riparian habitats, especially river- and stream-sides	C3. Littoral zone of inland surface waterbodies (C3.1., C3.2., C3.3., C3.4., optimum in C3.5.)	None listed.	Yes (invasive)	Major habitats within the PRA area	Balogh & Dancza, 2008; Fried *et al.*, 2017; Zhou & Bartholomew 2003
Ruderal habitats (roadsides, wastelands, abandoned and disturbed areas)	E5.1. Anthropogenic herb stands	None listed.	Yes (often casual historical records)	Major habitats within the PRA area	Balogh & Dancza, 2008;

The habitats of *H. scandens* are largely similar in its native range and in the PRA area. Alluvia of streams and rivers (*Bidentetalia tripartiti*) are considered as one of the two preferred habitats in the native range. In France, the species is invasive in very similar communities dominated by the native species *Galium aparine*, *Atiplex prostrata*, *Rumex crispus*, *Persicaria lapathifolia*, *Veronica anagallis-aquatica*, *Convolvulus sepium*, and the non-native species *Ambrosia artemisiifolia*, *Artemisia verlotiorum*, *Artemisia annua*, *Bidens frondosa*, *Helianthus tuberosus*, and *Xanthium orientale* subsp. *Italicum* (Fried *et al.*, 2017). In Hungary, it has been described in other communities (*Convolvuletalia sepium*) belonging to the same riparian habitats (Balogh & Dancza, 2008). In Italy, in addition to riparian habitats, it is also present in hydrophilous tall herb fringe communities of plains and of the montane to alpine levels (EUNIS E5.4, E5.5) (see: Habitat Italia, 2010) Other habitats detailed in the table above are also at risk.

8. Pathways for entry (Table 4)

Possible pathway *(in order of importance)*	**Pathway: Plants for planting** **(CBD terminology: Escape from confinement – horticulture)**
Short description explaining why it is considered as a pathway	*H. scandens* has been introduced in Europe as an ornamental species for growing over trellises, arbours or fences (Tournois, 1914; Chevalier, 1943; Balogh & Dancza, 2008). Currently, the plant is not widely sold in the major garden centre chains. However, for garden amateurs, seeds (achenes) of the plant are widely available in more specialized nurseries and it can also be ordered through the Internet. According to gardener forums and websites on Internet, the plant is widely used and exchanged by gardeners and horticulturists, so its presence is very likely in gardens throughout the whole PRA area. It should be noted that there is the possibility of misidentification between *H. scandens* and *H. lupulus.*
Is the pathway prohibited in the PRA area?	Yes in part. *H. scandens* is black listed (trade restrictions) in two Italian regions. However, for the rest of the PRA area this pathway is not prohibited.
Has the pest already been intercepted on the pathway?	*H. scandens* is the commodity.
What is the most likely stage associated with the pathway?	As an annual plant, it is traded mostly as seed.
What are the important factors for association with the pathway?	Plants and seeds are available by mail order and the species is available from suppliers in the USA: https://www.ebay.com/itm/JAPANESE-HOP-18-SEEDS-Humulus-scandens-japonicus-Fast-growing-climber-/221703247529 https://www.amazon.com/Humulus-scandens-1-000-seeds/dp/B01ETYQVP0 The volume produced within EPPO compared with volume imported is unknown.
Is the pest likely to survive transport and storage along this pathway?	Yes, seeds can remain viable for 3 years.
Can the pest transfer from this pathway to a suitable habitat?	All wild populations in Europe and North America are the results of garden escapes. Two processes may be at play. If grown on a fence near a suitable habitat (i.e. a river), passive dispersal may enable the plant to establish in the wild. The second important pathway to suitable habitat is through garden wastes. If aerial parts of the plant are cut at the end of the growing season and the whole plant is thrown in or near a suitable habitat, seeds contained in the infrutescence can enable establishment.
Will the volume of movement along the pathway support entry?	*H. scandens* is cultivated and traded within the EPPO region and therefore the volume of movement from outside of the EPPO region is likely to be low and unlikely to support entry unless production ceases or is reduced within the EPPO region.

Will the frequency of movement along the pathway support entry?	*H. scandens* is cultivated and traded within the EPPO region and therefore the frequency of movement from outside of the EPPO region is likely to be low unless production ceases or is reduced within the EPPO region.
Rating of the likelihood of entry	*Low* ☐ *Moderate* X *High*
Rating of uncertainty	*Low* X *Moderate* ☐ *High* ☐

The EWG does not consider other pathways should be evaluated. Introduction as a contaminant of machinery was considered and although it cannot be excluded it is highly unlikely to occur.

Do other pathways need to be considered? No

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

H. scandens is already established in the PRA area at least in the South of France, Hungary and Northern Italy. Its native distribution occupies part of East Asia ecoregions within the Palearctic realm and extends south to the Indochina bioregion of the Indomalayan realm. According to Köppen-Geiger classification (Kottek *et al*., 2006), its distribution matches that of a warm temperate climate without a dry season but hot summers (Cfa). In its introduced range in North America, it is present in the same climate type (Cfa), plus also cold continental climate without dry season with hot (Dfa) or temperate summer (Dfb). In the PRA area, it is established in temperate climates with dry and hot summers (Csa = Mediterranean climates) and in temperate climates with warm summers but without a dry season (Cfb). The temperate climates (Cfa, Csa) within the PRA area are largely similar and suitable for the establishment of *H. scandens*.

According to the projection of climatic suitability for *Humulus scandens* establishment (Appendix 1), the projection of suitability in Europe and the Mediterranean region suggests that *H. scandens* may be capable of establishing widely in the more continental areas of southern Europe (Northern Italy for example). The biogeographical regions (Appendix 1, Fig. 8)currently most suitable for the establishment of *H. scandens* are predicted to be the Pannonian, Steppic, Continental and Black Sea regions (Appendix 1, Fig. 6 and 7). The main limiting factors for the species across Europe appeared to be low growing season temperatures (warmest quarter) in northern Europe and drought stress (low CMI) around the Mediterranean.

The endangered area concerning climatic suitability includes Portugal, Spain, France, Italy, Germany, Austria, Poland, Hungary, Slovakia, Slovenia, Croatia, Romania, Bosnia-Herzegovina, Serbia, Montenegro, Macedonia, Albania, Greece, Bulgaria, Turkey, Georgia, Russia, Ukraine and Algeria.

The habitats of *H. scandens* are largely similar between its native range and the PRA area. Alluvia of streams and rivers (*Bidentetalia tripartiti*) are considered as one of the two preferred habitats in the native range. In France, the species is invasive in very similar communities dominated by the native species - *Galium aparine*, *Atiplex prostrata*, *Rumex crispus*, *Persicaria lapathifolia*, *Veronica anagallis-aquatica*, *Convolvulus sepium*, and the non-native species *Ambrosia artemisiifolia*, *Artemisia verlotiorum*, *Artemisia annua*, *Bidens frondosa*, *Helianthus tuberosus*, and *Xanthium orientale* subsp. *Italicum* (Fried *et al*., 2017). In Hungary, it has been described in other communities (*Convolvuletalia sepium*) belonging to the same riparian habitats (Balogh & Dancza, 2008). In Italy, in addition to riparian habitats, it is also present in hydrophilous tall herb fringe communities of plains and of the montane to alpine levels (EUNIS E5.4, E5.5) (see: Habitat Italia, 2010).

The establishment of seedlings in riparian habitats along the Gardon River (southern France) was highest in rich soils (N soil content>1.1g/kg), with a low vegetation cover in spring (<25% in March) and full sun exposure where tree canopy is <35% (Fried *et al*. 2017). In this area, establishment can be prevented where resident vegetation forms a dense cover of perennial grasses such as *Agrostis stolonifera* and riparian tree cover limits light availability. However, this does not prevent establishment at a wide landscape level where natural or human-assisted disturbances always exist in vegetation.

Natural enemies

A survey of insects found on *H. scandens* in the south of France in spring 2013 and 2014 highlighted the presence of *Thrips urticae*, *Oxythrips ulmifoliorum*, *Dendrothrips saltator*, *Paratettix meridionalis*, and unidentified species of Aphididae and Collembola. Eggs of *Melanostoma* sp. and larvae of *Altica* sp., *Chromatomyia horticola*, and unidentified species of Carabidae, Chrysomelidae, Cicadellidae, Theridiidae and Thripidae were also found (pers comm. G. Fried, 2017).

Leaves of young seedlings are eaten by snails, including *Cernuella virgata* (da Costa, 1778) and *Oxyloma elegans* (Riso, 1826) (Determination: Bruno Michel (INRA), see Appendix 3, Fig 6). *Cuscuta campestris*, an alien plant parasite frequently observed in riparian habitats has been observed causing foliar damage on *H. scandens* (Appendix 3, Fig 7). At the end of the growing season in southern France, *H. scandens* is attacked by several fungi including *Oidium* and possibly *Fusarium* sp. and *Cladosporium* sp (pers. Comm. G. Fried, 2017, see Appendix 3, Fig 8).

According to studies in Germany, *H. scandens* is a host of the aphid *Phorodon humuli* (Schrank) (Aphididae) (Eppler, 1986).

Despite the identification of these natural enemies in the EPPO region, the establishment of *H. scandens* in new areas is unaffected indicting that the array of invertebrates are generalist species inflicting insignificant damage on the invasive populations.

A high rating of likelihood of establishment in the natural environment within the PRA has been scored with low uncertainty as the species has shown to establish in a number of locations with varying climatic conditions.

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

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

In Hungary, *H. scandens* is associated with ruderal communities (*Onopordetalia acanthii*) such as downtown Keszthely (Dancza, 1994, cited in Balogh & Dancza, 2008). In the USA, *H. scandens* is reported to grow in disturbed areas with moist soils, including roadsides, old fields, and forest edges (Pannill *et al*., 2009).

The second most common community in which *H. scandens* is described in its native range is within a ruderal habitat. The association *Humulo japonicae-Chenopodietum albi* mostly establishes on loamy-sandy ground, disturbed habitats in the outskirts of settlements, roadsides, building areas and waste deposits, though it is seldom found around dumps (Balogh & Dancza, 2008). In its native range, *H. scandens* is also reported to be a weed in pear orchard where it can dominate the community (Chun *et al*., 2000).

In Southern France, where it is restricted to riverbanks, it is estimated that without irrigation it cannot survive the dry season of Mediterranean climates. In a greenhouse experiment, plants watered once a week were one third less in biomass than plants watered every day with a biomass not different from that of *Galium aparine* (Fried *et al.*, in preparation). This provides some evidence that *H. scandens* exhibits poor invasion potential in dry environments. The ability to establish in ruderal habitats depends on seasonal rainfall regimes and seems only possible where there is no dry season during summer.

A high rating of likelihood of establishment in the managed environment has been scored with low uncertainty as the species is grown as an ornamental species and evidence from other invasive regions details the species can grow in disturbed areas including roadsides, old fields, and forest edges and orchards.

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

11. Spread in the PRA area

Natural spread
Reproduction and spread of *H. scandens* is exclusively by seeds (achenes). One plant can produce 800 to 1200 seeds (Balogh & Dancza, 2008). A study conducted in the native range trapped a seed rain of 256.0 (± 432.2) seeds of *H. scandens* per m² (Masuda & Washitani, 1990). The seeds of *H. scandens* lack specific adaptations for dispersal so that the plant has no specific means of spread. Mature seeds are primarily dispersed by gravity near parent plants and form a seed bank with ca. 3 years viability (NB: many sources cite wind as a natural mean of dispersion but given the form and the weight of the seeds, it is unexpected that wind plays a significant role in the dispersal of this species) (Krauss, 1931). *H. scandens* has a very prickly stem, so that part of the plant with the infrutescence can be dispersed accidentally over short distances (i.e. a few dozen of meters) by mammals or humans (Pannill *et al*., 2009). The main natural means of dispersal is by water along river throughout the watershed. The magnitude of spread within a river catchment is therefore high but the translocation into a new river catchment is predominantly by human assistance. Natural spread within any waterbody will facilitate transfer to a suitable habitat.

Human assisted spread
Human assistance spread is important in the dispersal of the species over long distances due to intentional planting in gardens with exchange of seeds between hobbyist's gardeners. Thus, future spread of this species can be expected in the vicinity of gardens, especially in gardens without cover fences close to roadside, forest margins, and river banks.

There is potential that seed can be moved from one catchment to another by boats, dredges and leisurewear. For example, in France, the species has recently been found in a new catchment (Huveaune River in Marseille) more than 100 km south-east of the main invaded catchment (pers com, G. Fried, 2017).

As *H. scandens* produces a high amount of seed which can become incorporated into water bodies and subsequently moved into new habitats, coupled with long distant human assisted spread, a high rate of spread with moderate uncertainty has been given as more research is needed for spread potential for this species.

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

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

12. Impact in the current area of distribution

12.01 Impacts on biodiversity

Impact on plant communities
In its native range in Japan, *H. scandens* is considered a weedy vine in riparian and floodplains habitats rich in nitrogen and lime where it covers neighbouring plants such as *Miscanthus sacchariflorus* and *Phragmites australis* (Ju *et al*., 2006) and decreases the diversity of plant communities (Ohtsuka & Nemoto 1997).

In the USA, *H. scandens* can form dense stands that outcompete existing vegetation, especially in moist areas (NatureServe, 2017). It is capable of climbing trees and other nearby vegetation, sometimes resulting in shading, girdling, and occasionally even the death if trees are small (saplings). It can become the dominant understory plant (NatureServe, 2017). *H. scandens* is perceived as predominantly invading open disturbed areas, such as roadsides or disturbed riverbanks, where it is believed to decrease biodiversity. Conversely, it has also been found in open woodlands, prairies, floodplain herbaceous wet meadows, and floodplain forest communities indicating it has some tolerance to shade (NatureServe, 2017). In the State of New York, the non-native plant invasiveness ranking form scored the impact on community structure and composition 7 out of 10 indicating a moderate to high invasive potential (See New York Invasive Species Information 2018).

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

12.02. Impact on ecosystem services (Table 5)

Ecosystem service	**Does the pest impact on this ecosystem service?** Yes/No	**Short description of impact**	**Reference**
Provisioning	No	Although the species can colonize fields, it is not known as a major weed of agricultural systems in the native or invasive ranges. Currently there is no evidence that the species has impacts on provisioning ecosystem services.	Chun *et al*. 2000
Regulating	Yes	Displacement of native species of *Bidention* communities in the PRA area. Once establish on a river bank, it can become dominant, and by excluding other perennial herbaceous species, it may favour erosion due to absence of vegetation in winter. This could	Mahaut, 2014; Fried *et al.* 2017.; Park *et al*., 1999

Ecosystem service	Does the pest impact on this ecosystem service? Yes/No	Short description of impact	Reference
		act to increase flood risk in invaded areas. If sensitivity to pollen allergens of *H. scandens* is confirmed in European populations, *H. scandens* may decrease air quality by increasing the risk of pollinose. Potentially impacts on nutrient cycling but there is a lack of data for this throughout its invaded range.	
Cultural	Yes	Dense cover of this vine with prickly stems may obstruct river access and recreational activities within the PRA area.	Pannill *et al*., 2009

In the USA, *H. scandens* reduce light levels when it covers existing dominant vegetation (e.g. saplings) (NatureServe, 2017). By smothering tree saplings in riparian areas, it can modify the dynamic of natural vegetation succession (NatureServe, 2017; Fried *et al*., in preparation).

It is difficult to assess the impact on ecosystem services without dedicated studies on the subject. However, by illustrating the variety of ecological roles fulfilled within an ecosystem, functional traits of the resident community can be used as an indirect measure for estimating ecosystem processes (Lavorel & Garnier, 2002). Thus, *H. scandens* not only reduces species richness,but also decreases functional richness and modifies Community Weighted Mean (CWM) of traits (Fried *et al*., 2017). This suggests some impacts on ecosystem functioning.

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

12.03. Socio-economic impact

Pollen allergy

In its native range, many people have an allergic reaction to *H. scandens* pollen. Aerobiological studies in Beijing (China) and Korea showed that *H. scandens* pollen counts are larger than those of both mugwort (*Artemisia vulgaris*) and ragweed (*Ambrosia artemisiifolia*) (two species with very high pollen counts) and account for about 18% of total pollen during the pollination period (Park *et al*., 1999). According to a study conducted in China (Hao *et al*., 2013), the prevalence of positive intradermal responses to pollens of *H. scandens* was 6.6%. Correlations of specific IgE antibodies suggest that pollen allergens from *Artemisia* and *Humulus* are independent sources for primary sensitization.

Skin irritation

In addition, the hooked hairs and prickles on the stems and leaves can cause skin irritation, dermatitis and blistering skin after contact. (http://www.mda.state.mn.us/plants/pestmanagement/weedcontrol/noxiouslist/japanesehops.aspx).

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

In the PRA area, significant impacts on biodiversity and ecosystem services have been recorded. Further impacts similar to those detailed below are expected if the species spreads and establishes in similar habitats. The text within this section relates equally to EU Member States and non-EU Member States in the EPPO region.

13.01. Potential impacts on biodiversity in the PRA area

In Hungary, it has been reported to invade natural environments (Balogh & Dancza, 2008). It can outcompete native species and is considered as a *transformer* species (sensu Richardson *et al*., 2000), that threatens plant communities dominated by *Phragmites* spp. and *Salix* spp. (*Phragmitetea* and *Salicetea* classes) as well as the *Filipendulo-Petasition* alliance (Balogh *et al*., 2004, cited in Balogh & Dancza, 2008).

In Italy, in addition to riparian habitats, it is also present in hydrophilous tall herb fringe communities of plains and of the montane to alpine levels (see: Habitat Italia, 2010)

In Southern France, a removal experiment was set up to measure the impact of *H. scandens* on riparian vegetation dominated by willow, poplar and ash trees and to assess the trajectory of restored communities in which the invader was removed compared to non-invaded reference plots (Fried *et al*., 2017). The comparison of paired invaded plots and removal plots showed that *H. scandens* reduced native species richness by 92 - 98% at the end of the growing season when the vine reached its full development and cover during July and August (see Appendix 3, Fig 9; Fried *et al*., in preparation.). The spring census in April of emerging seedlings indicated *H. scandens* cover at this stage already accounted for a reduced establishment of an average of 5 species (Fried *et al*., 2017.). An estimated 40% decrease in species richness was recorded at the catchment level based on 40 x 1m² plots over 1000 m². At the end of the season, *H. scandens* had formed near monospecific stands over 250 to 700 m² (Fried, pers. com., Appendix 3, Fig 10). The CWM of the traits showed that residual plants persisting in invaded plots at the end of the season differed by a higher proportion of perennials with rhizomes, higher plant size and seed mass. Other plants within the plots are mostly other alien plants such as *Artemisia verlotiorum*, *Helianthus tuberosus* and *Sicyos angulata* (Fried *et al*., in preparation).

After two years, the restored community had the same level of species richness as control plots but functional richness and species composition including less tree saplings was significantly lower (Fried *et al*., 2017). This suggests a negative impact on vegetation succession through preventing the regeneration of native trees.

Impact on particular species

H. scandens reduced species frequency of occurrence from 8.1% to 3.6% and their mean ground cover from 2.3% to 1.1% (Fried *et al*., 2017). However, the relative ranking of species remained similar for species frequency and abundance . Among the native species co-occurring between removal and invaded-plots, *Persicaria lapathifolia* showed the strongest decline in frequency (-42%) while *Ficaria verna* and *Alliaria petiolata* were not affected. *Lythrum salicaria* (-5.4%), *Agrostis stolonifera* (-5.1%) and *Galium aparine* (-4.5%) showed the largest decline in abundance. There was a significant correlation between the decrease in frequency and the functional similarity with *Humulus scandens* , i.e. species that differ from *H. scandens* were less affected. For example, there was a seasonal affect among the plants. Early spring species such as *Ficaria verna* and *Alliaria petiolata* completed their life cycle before *H. scandens* reached its highest cover, while typical spring germinating annual of the *Bidention* communities (*Persicaria* spp., *Veronica anagallis-aquatica*) were more impacted (Fried *et al*., 2017).

As the species has a high rating for establishment in the PRA area, coupled with a high spread, further impacts as described above are likely to be seen as the species spreads and establishes in other areas.

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

13.02. Potential impact on ecosystem services in the PRA area

It has been mentioned that once established on a river bank, *H. scandens* can become dominant, and by excluding other perennial herbaceous species, it may favour erosion due to the absence of vegetation in winter (Table 5) (Mahaut 2014; Fried *et al*. 2017.; Park *et al*., 1999). Further impacts similar to those detailed are expected if the species spreads and establishes in similar habitats within the PRA area.

H. scandens will negatively affect cultural ecosystem services in the PRA area, where dense cover of this vine with prickly stems may obstruct river access and recreational activities within the PRA area (EWG opinion). However, in the absence of any dedicated studies on impacts on ecosystem services, a moderate rating of impacts on ecosystem services is given with a moderate uncertainty.

The species also has the potentially to impact on nutrient cycling but there is a lack of data for this throughout its invaded range.

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

13.03 Potential socio-economic impact in the PRA area

Potential socio-economic impacts may be different in the PRA area. Sensitivity to allergen may differ across different human populations (European versus Asian). A study has started in France to collect pollen and test if people of Nîmes (near the invaded Gardon River) are allergic to *H. scandens* pollen.

Therefore, based on the information detailed, the rating of impact will be similar to the current area of distribution but the uncertainty will raise from low to high.

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

14. Identification of the endangered area

Climate modelling suggests the endangered area is predicted to be the biogeographic regions: Pannonian, Steppic and Continental, with parts of the Mediterranean and Black Sea regions (see Appendix 1, Fig. 6 and Appendix 2, Fig. 1). The main limiting factors for the species across Europe appeared to be low growing season temperatures (warmest quarter) in northern Europe and drought stress (low Climate Moisture Index) around the Mediterranean and Black Sea regions.

Based on the climate modelling, the endangered area concerning climatic suitability include the EU countries: France, Italy, Germany, Austria, Poland, Hungary, Slovakia, Slovenia, Croatia, Greece, Bulgaria, Romania and in the wider EPPO region: Bosnia-Herzegovina, Serbia, Montenegro, Macedonia, Albania, Turkey, Georgia, Russia, Ukraine. There are only marginally suitable areas in Portugal, Spain, Morocco and Algeria.

Habitats within the endangered area include riverside, particularly on the loose, bare surfaces of alluvial bars formed by river and stream-sides by temporary floods (Balogh & Dancza, 2008; Fried *et al*., in preparation; Zhou & Bartholomew 2003). Also the habitats in Italy (Section 7)

15. Climate change

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.

Under the climatic projection, RCP 8.5, the risk of establishment is likely to increase because of climate change as the plant may be able to produce viable seeds further north because of an extended growing season (Fried pers comm. 2017). The model predicts large increases in suitability within the Alpine, Atlantic, Black Sea, Boreal and Continental Biogeographical Regions. However, suitability is predicted to decline in the Pannonian and Steppic regions, which are the two most currently suitable Biogeographical Regions. However, the likelihood scoring will not change as it is already high. Spread is likely to increase with increased risk of flooding events. However, the likelihood scoring will not change as it is already high. The potential area for impacts to be realised may increase with increased establishment and spread.

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

Climate projection RCP 8.5 (2070) (see Appendix 1, Fig. 7).

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

Temperature ***(yes)*** *Precipitation* ***(yes)*** *C0$_2$ levels* ***(yes)***
Sea level rise ***(no)*** *Salinity* ***(no)*** *Nitrogen deposition* ***(yes)***
Acidification ***(no)*** *Land use change* ***(yes)***

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

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

Are the **pathways** likely to change due to climate change? **(If yes, provide a new rating for likelihood and uncertainty)**	**Reference**
The introduction pathways are unlikely to change because of climate change. Rating for plants for planting: moderate with a low uncertainty	EWG opinion
Is the **likelihood of establishment** likely to change due to climate change? **(If yes, provide a new rating for likelihood and uncertainty)**	**Reference**
The risk of establishment is likely to increase because of climate change as the plant may be able to produce viable seeds further north because of an extended growing season (Fried pers comm. 2017). However, the likelihood scoring will not change, as it is already high though uncertainty will raise from low to moderate. (See Appendix 1, Fig 7).	Appendix 1, EWG opinion
Is the magnitude of **spread** likely to change due to climate change? **(If yes, provide a new rating for the magnitude of spread and uncertainty)**	**Reference**
Spread is likely to increase with increased risk of flooding events. However, the likelihood scoring will not change as it is already high. Uncertainty will raise from moderate to high. See Appendix 1, Fig 7).	Appendix 1, EWG opinion
Will **impacts** in the PRA area change due to climate change? **(If yes, provide a new rating of magnitude of impact and uncertainty for biodiversity, ecosystem services and socio-economic impacts separately)**	**Reference**
The potential area for impacts to be realised may increase with increased establishment and spread (see Song, 2017). For impacts on biodiversity the score under future climate change will remain the same (high) and uncertainty will increase from low to high. It should be noted that Song (2017) showed that *H. scandens* had increased performance at elevated temperatures and increased its competitive advantage over native species. For impacts on ecosystem services the score under future climate change will increase from moderate to high and uncertainty will increase from moderate to high. For socio-economic impacts the score under future climate change will increase from moderate to high and uncertainty will increase from low to high.	EWG opinion

16. Overall assessment of risk

Humulus scandens presents a high phytosanitary risk for the endangered area within the EPPO region with a low uncertainty. Further spread within and between countries is likely. The overall likelihood of *Humulus scandens* continuing to enter the EPPO region is moderate because the species is cultivated and informally traded within the EPPO region.

The risk of the species being introduced within the EPPO region (including EU Member States) is considered high as the plant is traded within the PRA area.

Pathways for entry:

Plants for planting

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

Likelihood of establishment in the natural environment in the PRA area

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

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* X	*Moderate* ☐	*High* ☐

Magnitude of Spread

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

Impacts

Biodiversity

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

Ecosystem services

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

Socio-economic impacts

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

Potential impact in the PRA area

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

Except for:
Socio-economic impacts

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

17. Uncertainty

Pathway for entry: Low

Likelihood of establishment in natural areas: Low

Likelihood of establishment in managed areas: Low

Spread: Moderate

Impacts current area of distribution: Low

Potential impacts in PRA area: Moderate

Uncertainties apply to the species distribution modelling where:

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 did not appear to give completely accurate results. For example, in a small number of cases, GBIF indicated no Tracheophyte records in grid cells in which it also yielded records of the focal species.
- We used additional data sources to GBIF, which may have different biases to the GBIF records.

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

18. Remarks

Inform EPPO or IPPC or EU

- Inform NPPOs that surveys are needed to confirm the distribution of the plant in the area where the plant is present, and on the priority to eradicate the species from the invaded area.

Inform industry, other stakeholders, traders

- Encourage industry to assist with public education campaigns associated with the risk of non-native plants. Encourage industry to sell native species as alternatives to non-natives (for example *Clematis* spp.).

Specify if surveys are recommended to confirm the pest status

Studies should be conducted to evaluate the impact of the species on biodiversity and the impact of the pollen on human health.

19. REFERENCES

Arrigoni P. V. & Viegi L., 2011. La flora vascolare esotica spontaneizzata della Toscana. Regione Toscana, Firenze. (Available at: http://www.regione.toscana.it/documents/10180/320308/La+flora+vascolare+esotica+spontaneizzata+della+Toscana/acd32225-2909-4d0b-a1ba-80f89d68a3f7?version=1.0)

Ascherson P, Graebner P (1908-1913) Synopsis der Mitteleuropäischen Flora. Band 4. Verlag von Wilhelm Engelmann, Leipzig.

Balogh L, Dancza I (2008) *Humulus japonicus*, an emerging invader in Hungary. In, Tokarska-Guzi B, Brock JH, Brundu G, Child CC, Daehler C & Pyšek P (eds.), Plant Invasions: Human Perception, Ecological Impacts and Management. pp. 73-91. Editorial???

Brunel S, Tison JM (2005) Compilation of available invasive plant lists in the Mediterranean Basin and comparison with other Mediterranean Regions of the World. Draft 2005 May. UICN, CBNMP.

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

Celesti-Grapow, L, Alessandrini, A, Arrigoni PV, Banfi E, Bernardo L, Bovio M, Brundu G, Cagiotti MR, Camarda I, Carli E, Conti F, Fascetti S, Galasso G, Gubellini L, La Valva V, Lucchese F, Marchiori S, Mazz(ola P, Peccenini S, Pretto F, Poldini L, Prosser F, Siniscalco C, Villani MC, Viegi L, Wilhalm T, Blasi C (2009) Inventory of the non-native flora of Italy. *Plant Biosystems* 143: 386-430.

Chevalier A (1943) Notes sur le Houblon. *Revue de Botanique Appliquée Et D'agriculture Coloniale*, 263-265, 225-242.

Chun JC, Lee SJ, Lim SJ, Kim SE (2000) Change in weed population in pear orchard by sequential applications of non-selective herbicides. *Korean Journal of Weed Science*, 20, 39-45.

Eppler A (1986) Investigations on food-plant selection by *Phorodon humuli* Schrk. I. Colonized species. Anzeiger fur Schadlingskunde, Pflanzenschutz, Umweltschutz 59 (1): 1-8.

EPPO (2006) Guidelines for the management of invasive alien plants or potentially invasive alien plants which are intended or have been intentionally imported. *EPPO Bulletin* 36, 417-418.

EPPO (2014) PM 9/19 (1) Invasive alien aquatic plants. *EPPO Bulletin* 44, 457-471.

FloraWeb (2017) Available http://www.floraweb.de/pflanzenarten/artenhome.xsql?suchnr=2998& (Accessed: March 7, 2017)

Fried G (2010). Prioritization of potential invasive alien species in France. In: Brunel, S., Uludag, A., Fernández-Galiano, E., Brundu, G. (ed.) 2nd International Workshop Invasive Plants in the Mediterranean Type Regions of the World, 2010-08-02/06, Trabzon, Turkey, 120-138.

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

Fried G, Mahaut L, Pinston A, Carboni M (2018) Abiotic constraints and biotic resistance control the establishment success and abundance of invasive *Humulus japonicus* in riparian habitats. *Biological invasions*. 20, 315-331

Fried G, Mahaut L, Carboni M, Violle C (In preparation) Improved understanding of the impact of an invasive plant on resident community diversity and homogenization using a trait-based approach: lessons from a two-years removal experiment.

Gasso, N, Basnou C, Vila M (2010) Predicting plant invaders in the Mediterranean through a weed risk assessment system. *Biological Invasions*, 12, 463–476.

Germplasm Resources Information Network (2017) Beltsville (MD): United States Department of Agriculture, Agricultural Research Service. Available https://npgsweb.ars-grin.gov/gringlobal/taxonomydetail.aspx?id=19414 (Accessed : March 7, 2017)

Gruppo di Lavoro Specie Esotiche della Regione Piemonte (a cura del), 2015. Scheda monografica. *Humulus japonicus*. Regione Piemonte, Torino.

Habitat Italia (2010) Manuale italiano di interpretazione degli habitat (Directtiva 92/43/CCE). Avaliable at: http://vnr.unipg.it/habitat/cerca.do?formato=stampa&idSegnalazione=112

Hao GD, Zheng YW, Gjesing B, Kong XA, Wang JY, Song ZJ, Spangfort MD (2013). Prevalence of sensitization to weed pollens of Humulus scandens, *Artemisia vulgaris,* and *Ambrosia artemisiifolia* in northern China. *Journal of Zhejiang University Science B*, 14, 240-246.

Heffernan, K, ngle E, Richardson C. 2014. Virginia Invasive Plant Species List. Virginia Department of Conservation and Recreation, Division of Natural Heritage. Natural Heritage Technical Document 14-11. Richmond. Available at https://www.reston.org/Portals/3/2016%20ParksRec/nh%20invasive%20plant%20list%202014.pdf (Accessed March 7, 2017).

Indiana Invasive Species Council (IISC) (2017) Official IISC Invasive Plant List; Available at https://www.entm.purdue.edu/iisc/invasiveplants.php) (Accessed March 7, 2017).

IPANE (2005) *Humulus japonicus* (Japanese hops). Invasive plant atlas of New England. Available https://www.invasive.org/weedcd/pdfs/ipane/Humulusjaponicus.pdf (Accessed March 7, 2017).

Jiang Y, Zhou J, Zhang Q, Zhao G, Heng L, Chen D, Liu D (2017) Preparation of cellulose nanocrystals from *Humulus japonicus* stem and the influence of high temperature pretreatments. Carbohydrate Polymers, 164, 284-293.

Jordan MJ, G Moore, Weldy TW (2008). *Invasiveness ranking system for non-native plants of New York*. Unpublished. The Nature Conservancy, Cold Spring Harbor, NY; Brooklyn Botanic Garden, Brooklyn, NY; The Nature Conservancy, Albany, NY.

Ju EJ, Kim JG, Lee YW, Lee BA, Kim H, Nam JM, Kang HJ (2006) Growth rate and nutrient content changes of *Humulus japonicus*. *Journal of Ecology and Field Biology*, 29, 433-440.

Kottek M, Grieser J, Back C, Rudolf B, Rubel F (2006) World map of the Köppen-Geiger climate classification updated. Meterologische Zeitschrift, 15, 259-263.

Krauss O (1931) *Humulus* L., Hopfen. In: Bonstedt, C. (ed.), Pareys Blumengärtnerei. Erster Band,pp. 498-499. Verlag Paul Parey, Berlin

Lavorel S, Garnier E (2002) Predicting changes in community composition and ecosystem functioning from plant traits: revisiting the Holy Grail. *Funct Ecol* 16:545–556

Lu Y, Jiao Z, Wu K (2012) Early season host plants of *Apolygus lucorum* (Heteroptera: Miridae) in northern China. *Journal of Economic Entomology*, 105, 1603-1611.

Mahaut L (2014) Le houblon du Japon (*Humulus japonicus* Siebold. & Zucc., une espèce locomotrice ou une simple passagère du train des changements? Rapport de stage de Master 2. Anses (supervised by G. Fried) Université de Montpellier 2 / Montpellier SupAgro – Master Sciences et technologies, Mention Ecologie Biodiversité , Spécialité Biodiversité Evolution, Parcours Ecosystèmes , 44 p.

Masuda M, Washitani I (1990) A comparative ecology of the seasonal schedules for 'reproduction by seeds' in a moist tall grassland community. *Functional Ecology*, 4,169-182.

Monsi M, Saeki T (1953) Über den Lichtfaktor in der Pflanzengesellschaften und seine Bedeutung für die Stoffproduktion. *Japanese Journal of Botany* 14, 22-52.

Morariu I. (1942): O plantă străină cu tendinţă de încetăţenire în România. (Humulus japonicus Siebold & Zucc.). Revista Şti. V. Adamachi 28(2-3): 189-190

Minnesota Department of Agriculture (2011) Japanese hops assessment worksheet. Available at: https://static1.squarespace.com/static/57539006044262fce01261c5/t/5a8edc7a24a694953abf4ce1/1519311998571/Japanese+Hops+2011_MDARA00002JAHP_11_30_2011.pdf

Mirek Z, Piekos-Mirkowa, Zajac A, Maria Z (2002) Flowering plants and Pteridophytes of Poland. A checklist. W. Szafer Institute of Botany, Polihs Academy of Science, Kraków

New York Invasive Species Information (2018) Available at: http://nyis.info/non-native-plant-assessments/

NatureServe (2017) NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://explorer.natureserve.org. (Accessed: March 2, 2017).

Ohtsuka T, Nemoto M (1997) Effect of soil eutrophication on weedy riparian communities around agricultural areas. *Journal of Weed Science and Technology*, 42, 107-114.

Panke B, Renz M (2013*) Japanese hop (Humulus japonicus)*. A3924-26. Management of Invasive plants in Wisconsin. University of Wisconsin-Extension, Cooperative extension. (Available at https://learningstore.uwex.edu/Assets/pdfs/A3924-26.pdf).

Pannill PD, Cook A, Hairston-Strang A, Swearingen JM (2009) *Fact Sheet Humulus japonicus*. Plant Conservation Alliances Alien Plant Working Group Weeds Gone Wild: Alien Plant Invaders of Natural Areas. Available at http://www.nps.gov/plants/alien/

Park JW, Ko SH, Kim CW, Jeoung BJ, Hong CS (1999). Identification and characterization of the major allergen of the Humulus japonicus pollen. *Clinical and Experimental Allergy*, 29, 1080-1086.

Pavela R (2008) Larvicidal effects of various Euro-Asiatic plants against Culex quinquefasciatus Say larvae (Diptera: Culicidae). *Parasitology Research*, 102, 555.

Pillay M, Kenny ST (1996) Structure and inheritance of ribosomal DNA variants in cultivated and wild hop, *Humulus lupulus* L. *Theoretical and Applied Genetics*. 93, 333-340.

Pinston A (2013) *Étude de la plasticité écologique d'une plante invasive*, *Humulus japonicus*. Rapport de stage de Master 1. Anses (supervised by G. Fried) Université de Bourgogne – Master STS – ETE – Spécialité Biologie des Organismes et des Populations, 15p.

Richardson DM, Pyšek P, Rejmánek M, Barbour MG, Panetta DF, West CJ (2000). Naturalization and invasion of alien plants - concepts and definitions. Diversity and Distributions, 6,93-107.

Saccardo P.A. 1909. Cronologia della flora italiana. Padova, Tipografia del Seminario, Italy.

Sasakawa K (2010) Field observations of climbing behavior and seed predation by adult ground beetles (Coleoptera: Carabidae) in a lowland area of the temperate zone. *Environmental Entomology*, 39, 1554-1560.

Savić D, Anačkov G, Boža P (2008) New chorological data for flora of the Pannonian region of Serbia. *Central European Journal of Biology*, 3, 461-470.

Small E (1997) *Humulus*. In: Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico. 20+ vols. New York and Oxford. Vol. 3, pp. 356-357

Song U (2017) Temperture dependant performance of competitive native and alien invasive plant species. Acta Oecologica, 84, 8-14.

Stace C, Crawley MJ (2015) Alien plants (Collins New Naturalist Series). London: Harper Collins

Tournois J (1914) *Études sur la sexualité du Houblon* (Doctoral dissertation).

Tutin TG, Akeroyd JR (1993) *Humulus* L. In: Tutin, T.G., Burges, N.A., Chater, A.O., Edmondson, J.R., Heywood, V.H., Moore, D.M., Valentine, D.H., Walters, S.M. and Webb, D.A. (eds.), Flora Europaea. Vol. 1, 2nd ed. p. 78. Cambridge University Press, Cambridge.

Verloove, F. (2006) *Catalogue of neophytes in Belgium (1800-2005).* Filip Verloove. – Meise, National Botanic Garden of Belgium, 2006. 89 p.; ill.; 21 cm. – (Scripta Botanica Belgica, vol. 39).

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

Zheng H, Wu Y, Ding J, Binion D, Fu W, Reardon R (2004) *Invasive Plants of Asian Origin Established in the United States and Their Natural Enemies*. Volume 1. United States Department of Agriculture, Forest Service. FHTET-2004-05. Morgantown, WV. September 2004.147 p.

Zhou ZK, Bartholomew B (2003) Cannabaceae. *In*: Flora of China. 5: 74-75.
(Avaiable at http://flora.huh.harvard.edu/china/mss/volume05/Cannabaceae.pdf).

Appendix 1: Projection of climatic suitability for *Humulus scandens* establishment

Aim

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

Data for modelling

Climate data were taken from 'Bioclim' variables contained within the WorldClim database (Hijmans *et al.*, 2005) originally at 5 arcminute resolution (0.083 x 0.083 degrees of longitude/latitude) and aggregated to a 0.25 x 0.25 degree grid for use in the model. We used three climate variables commonly limiting plant distributions at global scale:

- Mean temperature of the warmest quarter (Bio10, °C) reflecting the growing season thermal regime.
- Mean minimum temperature of the coldest month (Bio6, °C) reflecting exposure to frost.
- Climatic moisture index (CMI, ratio of annual precipitation Bio12 to potential evapotranspiration) (ln + 1 transformed). Monthly potential evapotranspiration was estimated from the WorldClim monthly temperature data and solar radiation using the simple method of Zomer *et al.* (2008), based on the Hargreaves evapotranspiration equation (Hargreaves, 1994).

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

In addition, the following habitat variables were obtained and ln+1 transformed for modelling:

- Tree % cover was estimated from the MODerate-resolution Imaging Spectroradiometer (MODIS) satellite continuous tree cover raster product, produced by the Global Land Cover Facility (http://glcf.umd.edu/data/vcf/). The raw product contains the percentage cover by trees in each 0.002083 x 0.002083 degree grid cell. We aggregated this to the mean percent cover in our 0.25 x 0.25 degree grid cells and applied a ln+1 transformation for modelling. As a vine, *H.scandens* colonises trees and occurs in grows in the broadleaved forest zone in the native distribution (Balogh & Dancza, 2008).
- Inland water % cover was estimated from the Global Inland Water layer (Feng *et al.*, 2016), originally at 30 x 30 m resolution, but supplied by the authors for this project at 0.1 x 0.1 degree. This was aggregated to a 0.25 x 0.25 grid and ln+1 transformed for modelling. *H. scandens* is reportedly invasive in riparian habitat and floodplains.
- Lakes and wetlands % cover estimated from the Global Lakes and Wetlands Database: Lakes and Wetlands Grid (Level 3), which was originally in a 0.008333 x 0.008333, aggregated to the 0.25 x 0.25 grid as the percentage of constituent pixels classified as wetlands and ln+1 transformed for modelling. Wetlands include lakes, reservoirs, rivers, marshes and floodplains, swamp forest, flooded forest, coastal wetlands, bogs, fens and mires, intermittent wetlands and mixed pixels with wetlands and other land cover types.Reference?
- Human Influence Index (ln+1 transformed) estimates the relative anthropogenic influence based on 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) (Wildlife Conservation Society -

WCS & Center for International Earth Science Information Network - CIESIN - Columbia University, 2005). *H. scandens* may have a preference for human-disturbed habitats.

Species occurrences were obtained from the Global Biodiversity Information Facility (www.gbif.org), USGS Biodiversity Information Serving Our Nation (BISON), the Integrated Digitized Biocollections (iDigBio), iNaturalist and EDDMaps. We scrutinised occurrence records from regions where the species is not known to be well established and removed any that appear to be casual or planted specimens or where the georeferencing was too imprecise (e.g. records referenced to a country or island centroid). The remaining records were gridded at a 0.25 x 0.25 degree resolution for modelling (Figure 1).

In total, there were 752 grid cells with recorded occurrence of *H. scandens* available for the modelling (Figure 1).

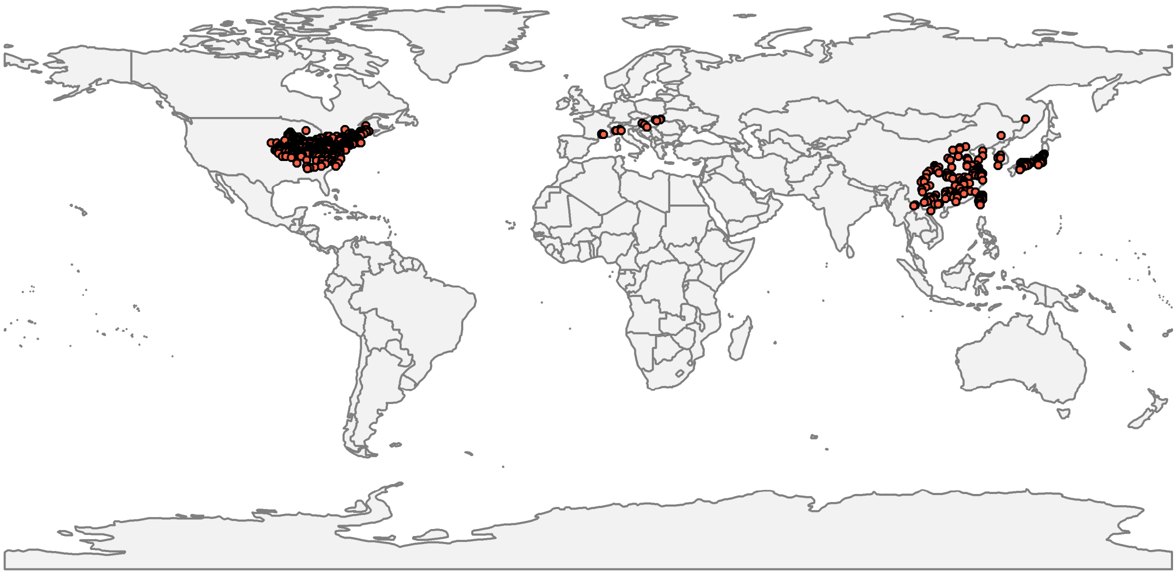


Figure 1. Occurrence records obtained for *Humulus scandens* used in the model, after data cleaning and thinning to the 0.25 x 0.25 degree grid.

Species distribution model

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

- The native distribution of *H. scandens* was assumed to be Asia, excluding Vietnam where the species is introduced (Hassler, 2017), island nations without records of the species (potentially representing dispersal constraints to colonisation of Malaysia, Indonesia, Brunei-Darussalem, Phillipines and Sri Lanka) and North Korea, which is within the native distribution (Hassler, 2017) but yielded no occurrence records; AND
- A relatively small 50 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 Fig. 3). Absence from these regions is considered to be irrespective of dispersal constraints. Although there was limited information on which to base these rules, we specified the following constraints:
    - Mean minimum temperature of the coldest month (Bio6) > 15 °C, since *H. scandens* seeds require cold stratification to germinate (Fried, pers comm, 2017). The warmest location with a presence in our dataset has Bio6 = 15.5 °C but this is an outlier from the rest of the distribution.
    - Mean temperature of the warmest quarter (Bio10 °C) < 15 °C, which we assume would be too cold to sustain growth and life cycle development. In a greenhouse experiment in France, 1329 growing degree days (GDD, base 4 °C) are required for the species to develop mature seed (Guillaume Fried, personal communication). From a global GDD layer (https://nelson.wisc.edu/sage/data-and-models/atlas/data.php?incdataset=Growing%20Degree%20Days) we determined that there was a strong correlation between GDD and Bio10, with 1329 degree days corresponding approximately to Bio10 = 15 °C. Furthermore, the coldest occurrence in our data has Bio10 = 15.5 °C.
    - Climatic moisture index (CMI) < 0.4, reflecting extreme drought. Although we do not have a direct estimate of maximum drought stress, the driest occurrence in the data has CMI = 0.433.

Within this sampling region there will be substantial spatial biases in recording effort, which may interfere with the characterisation of habitat suitability. Specifically, areas with a large amount of recording effort will appear more suitable than those without much recording, regardless of the underlying suitability for occurrence. Therefore, a measure of vascular plant recording effort was made by querying the Global Biodiversity Information Facility application programming interface (API) for the number of phylum Tracheophyta records in each 0.25 x 0.25 degree grid cell (Figure 2). The sampling of background grid cells was then weighted in proportion to the Tracheophyte recording density. Assuming Tracheophyte recording density is proportional to recording effort for the focal species, this is an appropriate null model for the species' occurrence.

To sample as much of the background environment as possible, without overloading the models with too many pseudo-absences, 10 background samples of 10,000 randomly chosen grid cells were obtained (Figure 3).

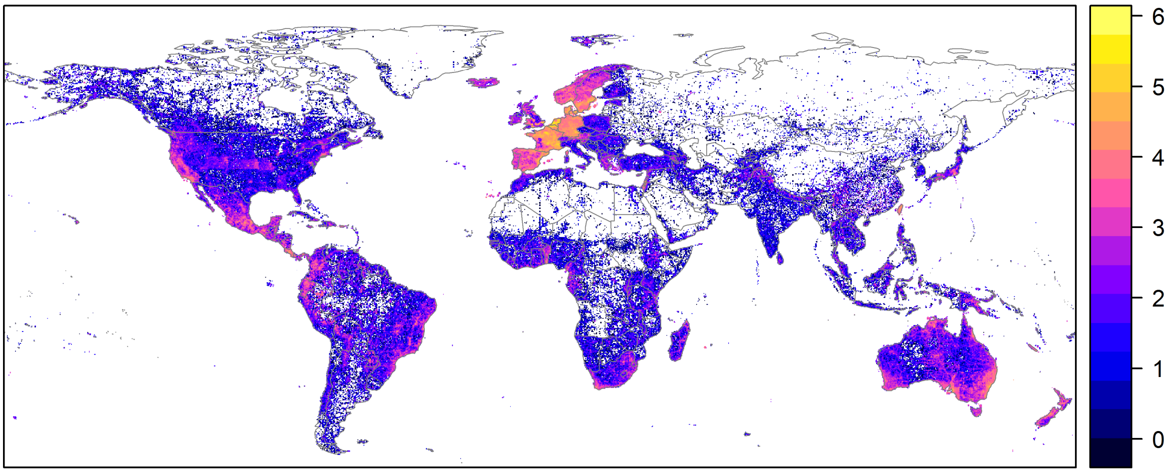


Figure 2. The density of Tracheophyta records per 0.25 x 0.25 degree grid cell held by GBIF, log_{10} transformed. These densities were used to weight the sampling of background locations for modelling to account for recording effort biases.

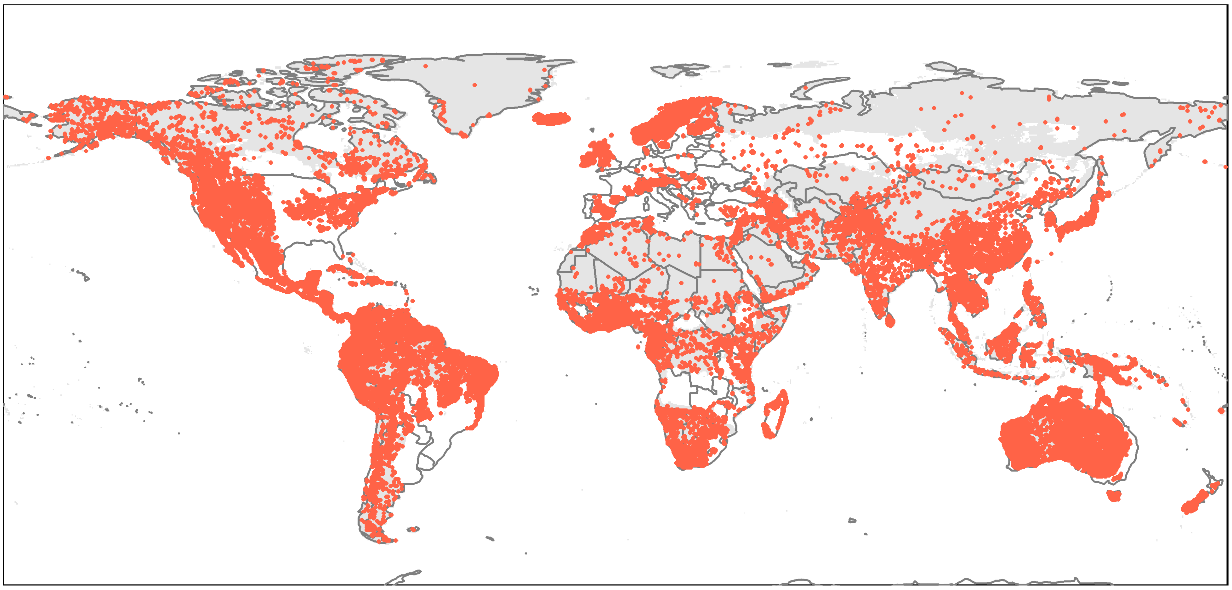


Figure 3. Randomly selected background grid cells used in the modelling of *Humulus scandens*, mapped as red points. Points are sampled from across the native range, a small buffer around non-native occurrences and from areas expected to be highly unsuitable for the species (grey background region), and weighted by a proxy for plant recording effort (see Figure 2).

Each of the 10 datasets (combinations 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:

- Generalised linear model (GLM)
- Generalised boosting model (GBM)
- Generalised additive model (GAM) with a maximum of four degrees of freedom per smoothing spline.
- Classification tree algorithm (CTA)

- Artificial neural network (ANN)
- Flexible discriminant analysis (FDA)
- Multivariate adaptive regression splines (MARS)
- Random forest (RF)
- MaxEnt
- Maximum entropy multinomial logistic regression (MEMLR)

Since the background sample was much larger than the number of occurrences, prevalence fitting weights were applied to give equal overall importance to the occurrences and the background. Variable importances were 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 characteristic Curve (AUC) for model predictions on the evaluation data, which 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. This information was used to combine the predictions of the different algorithms to produce ensemble projections of the model. For this, the three algorithms with the lowest AUC were first rejected and then predictions of the remaining seven algorithms were averaged, weighted by their AUC. Ensemble projections were made for each dataset and then averaged to give an overall suitability.

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.

Results

The ensemble model had a better predictive ability (AUC) than any individual algorithm and suggested that the model for *H. scandens* was most strongly affected by the minimum temperature of the coldest month, mean temperature of the warmest quarter and climatic moisture index (Table 1). As shown in Figure 4 and allowing for variation among the model algorithms, the estimated optimum conditions for occurrence were approximately:

- Minimum temperature of the coldest month = -16.7°C (>50% suitability with < 9.5 °C).
- Mean temperature of the warmest quarter = 26.7 °C (>50% suitability with > 17.6 °C).
- Climatic moisture index > 0.972 (>50% suitability with > 0.444).

There were weaker preferences for anthropogenically impacted habitats and high tree cover, but very little influence of wetland or inland water cover (Figure 4).

These optima and ranges of high suitability described above are conditional on the other predictors being at their median value in the data used in model fitting, which may explain some of the variation in responses among algorithms (Figure 4). The variation in the modelled responses among algorithms also reflect their different treatment of interactions among variables. Since partial plots are made with other variables held at their median, there may be values of a particular variable at which this does not provide a realistic combination of variables to predict from. It also demonstrates the value of an ensemble modelling approach in averaging out the uncertainty between algorithms.

Global projection of the model in current climatic conditions (Figure 5) indicates that the major native distribution area with records in China, Japan, and southeast Asia was well defined and predicted to be climatically suitable. The major cluster of non-native records in North America fell within region modelled with high climatic suitability (Figure 5). The model predicts that the climate may permit some further expansion of the species' distribution in North America. Notably more southern parts of the USA than are currently known to be invaded may be suitable for the species. Non-native regions without records of the species but that are projected to be climatically suitable include the southeast coast of Australia, southern Brazil and Uruguay (Figure 5). The Himalayan foothills regions of Nepal, India and Pakistan are also predicted to be suitable for the species, which may represent a model over-prediction of the native range, or highlight an area potentially capable of being invaded.

The projection of suitability in Europe and the Mediterranean region (Figure 6) suggests that *H. scandens* may be capable of establishing widely in the more continental parts of southern Europe. The Biogeographical Regions (Bundesamt fur Naturschutz (BfN), 2003) currently most suitable for *H. scandens* establishment are predicted to be the Pannonian, Steppic, Continental and Black Sea regions (Figure 8). The main limiting factor for the species across Europe appeared to be low growing season temperatures (warmest quarter) in northern Europe and drought stress (low CMI) around the Mediterranean.

By the 2070s, under climate change scenario RCP8.5, the suitability for *H. scandens* is predicted to increase substantially across Europe (Figure 7). The model predicts large increases in suitability within the Alpine, Atlantic, Black Sea, Boreal and Continental Biogeographical Regions (Figure 8). However, suitability is predicted to decline in the Pannonian and Steppic regions, which are the two most currently suitable Biogeographical Regions.

Table 1. Summary of the cross-validation predictive performance (AUC) and variables importance of the fitted model algorithms and the ensemble (AUC-weighted average of the best performing seven algorithms). Results are the average from models fitted to 10 different background samples of the data.

Algorithm	**Predictive AUC**	**Variable importance**						
		Minimum temperature of coldest month	**Mean temperature of warmest quarter**	**Climatic moisture index**	**Human influence index**	**Tree cover**	**Wetland cover**	**Inland water cover**
GBM	0.9759	32.0%	31.7%	22.8%	13.1%	0.5%	0.0%	0.0%
ANN	0.9757	37.1%	35.2%	18.2%	2.3%	4.7%	1.3%	1.1%
GAM	0.9737	34.2%	37.9%	23.4%	2.5%	1.8%	0.0%	0.1%
MARS	0.9735	33.6%	35.7%	29.2%	1.5%	0.0%	0.0%	0.0%
FDA	0.9734	46.2%	37.9%	13.1%	2.4%	0.2%	0.2%	0.0%
MaxEnt	0.9728	32.1%	31.7%	24.3%	3.9%	4.2%	1.1%	2.6%
GLM	0.9695	37.8%	38.8%	19.4%	2.6%	1.4%	0.0%	0.1%
RF	0.9686	36.5%	31.1%	17.7%	8.6%	2.9%	1.3%	1.8%
CTA	0.9446	30.1%	26.5%	21.5%	20.8%	1.0%	0.0%	0.0%
MEMLR	0.5499	1.9%	50.1%	33.9%	4.3%	2.5%	4.8%	2.4%
Ensemble	0.9780	36.1%	35.5%	21.5%	4.0%	1.8%	0.4%	0.6%

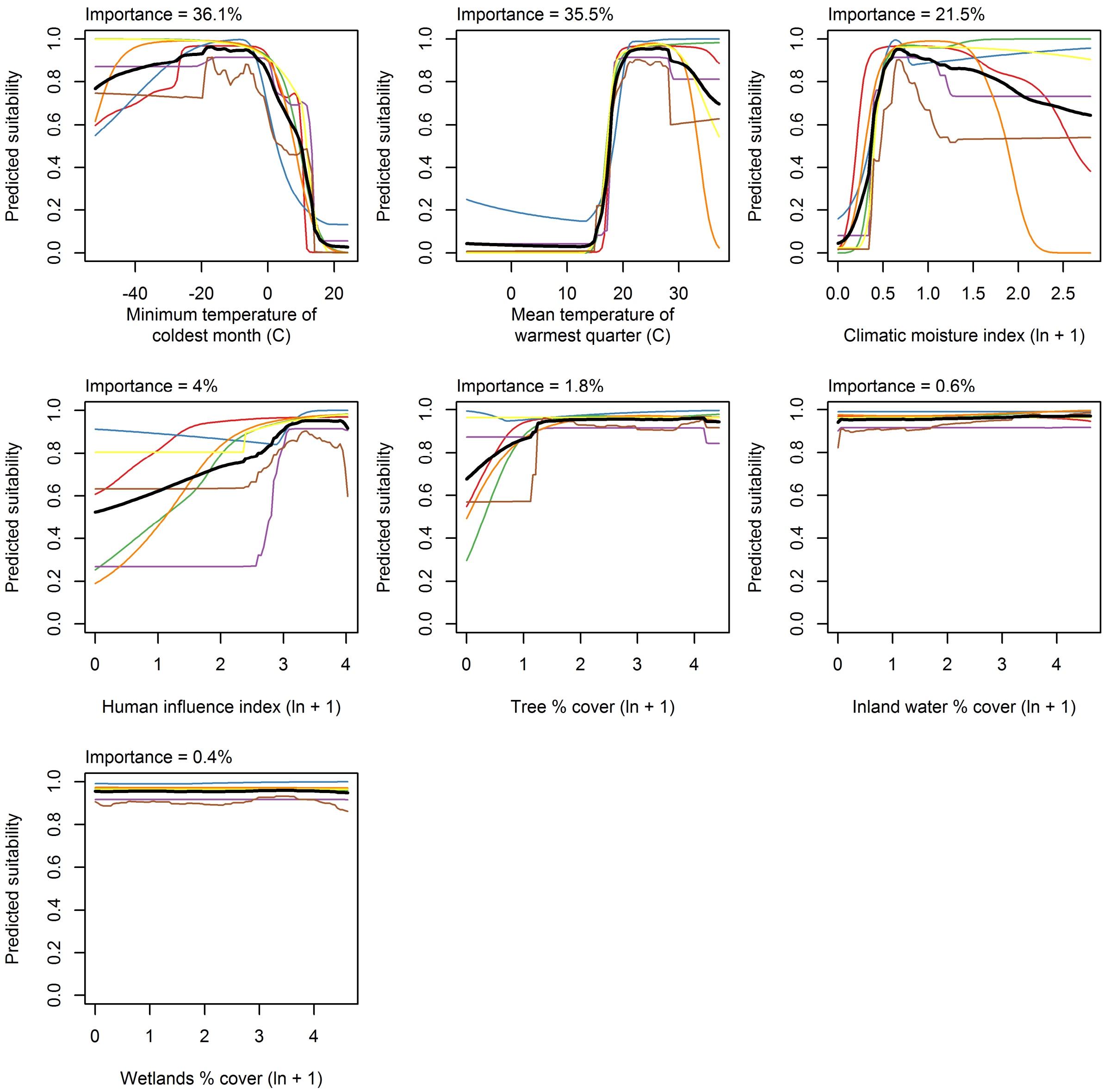


Figure 4. Partial response plots from the fitted models, ordered from most to least important. Thin coloured lines show responses from the seven algorithms, while the thick black line is their ensemble. In each plot, other model variables are held at their median value in the training data. Some of the divergence among algorithms is because of their different treatment of interactions among variables.

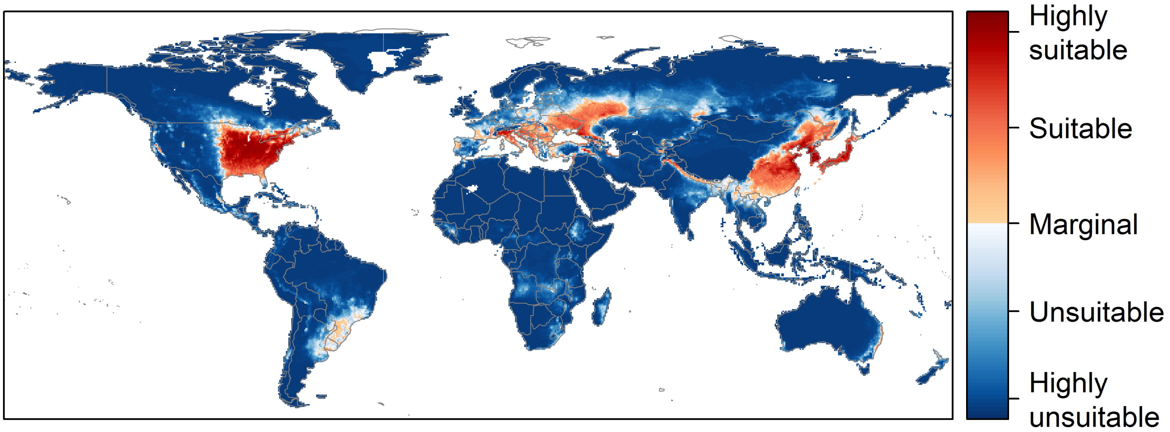


Figure 5. Projected global suitability for *Humulus scandens* establishment in the current climate. For visualisation, the projection has been aggregated to a 0.5 x 0.5 degree resolution, by taking the maximum suitability of constituent higher resolution grid cells. The threshold for marginal suitability was determined by the 'minimum ROC distance' method. Any white areas on land have climatic conditions outside the range of the training data so were excluded from the projection.

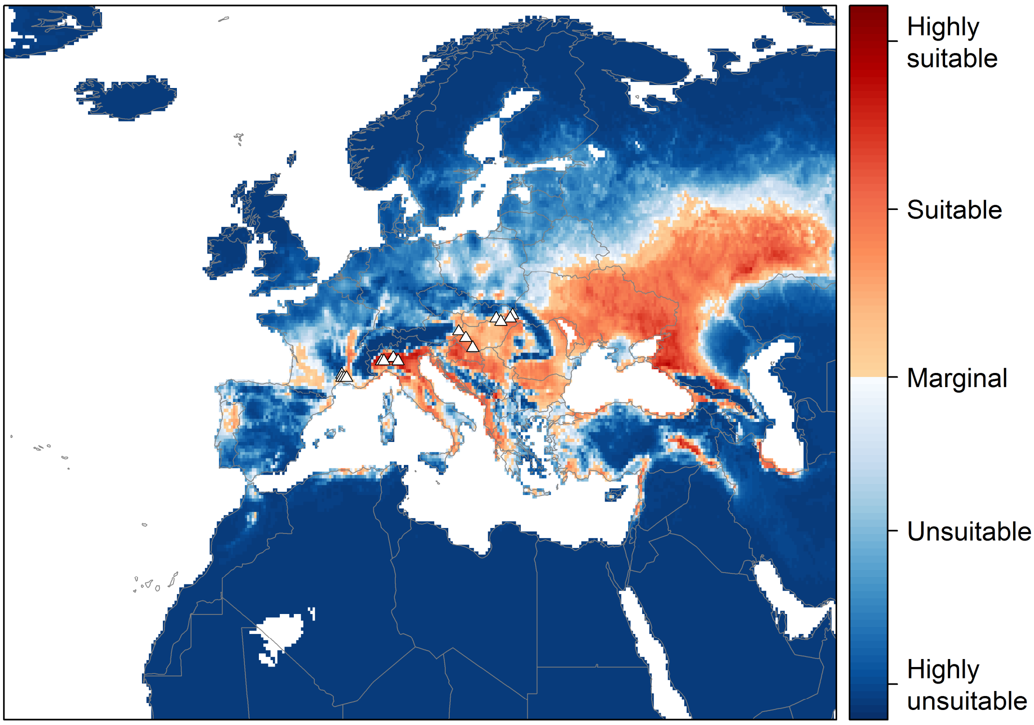


Figure 6. Projected current suitability for *Humulus scandens* establishment in Europe and the Mediterranean region. Any white areas on land have climatic conditions outside the range of the training data so were excluded from the projection. Points show European occurrences used in the modelling.

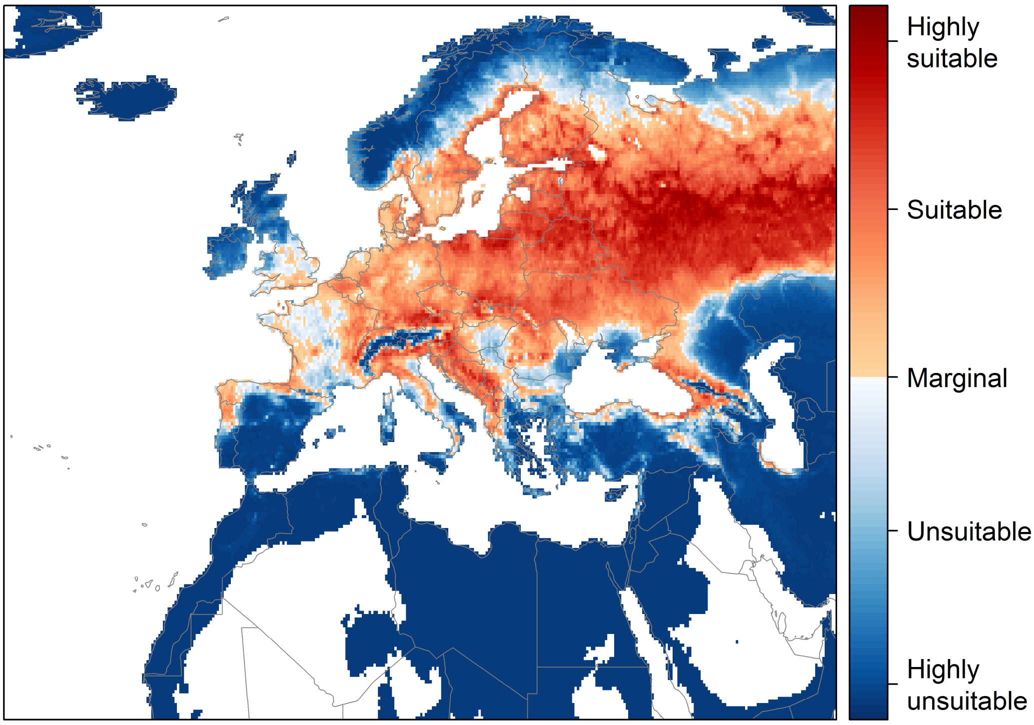


Figure 7. Projected suitability for *Humulus scandens* establishment in Europe and the Mediterranean region in the 2070s under climate change scenario RCP8.5, equivalent to Fig. 6.

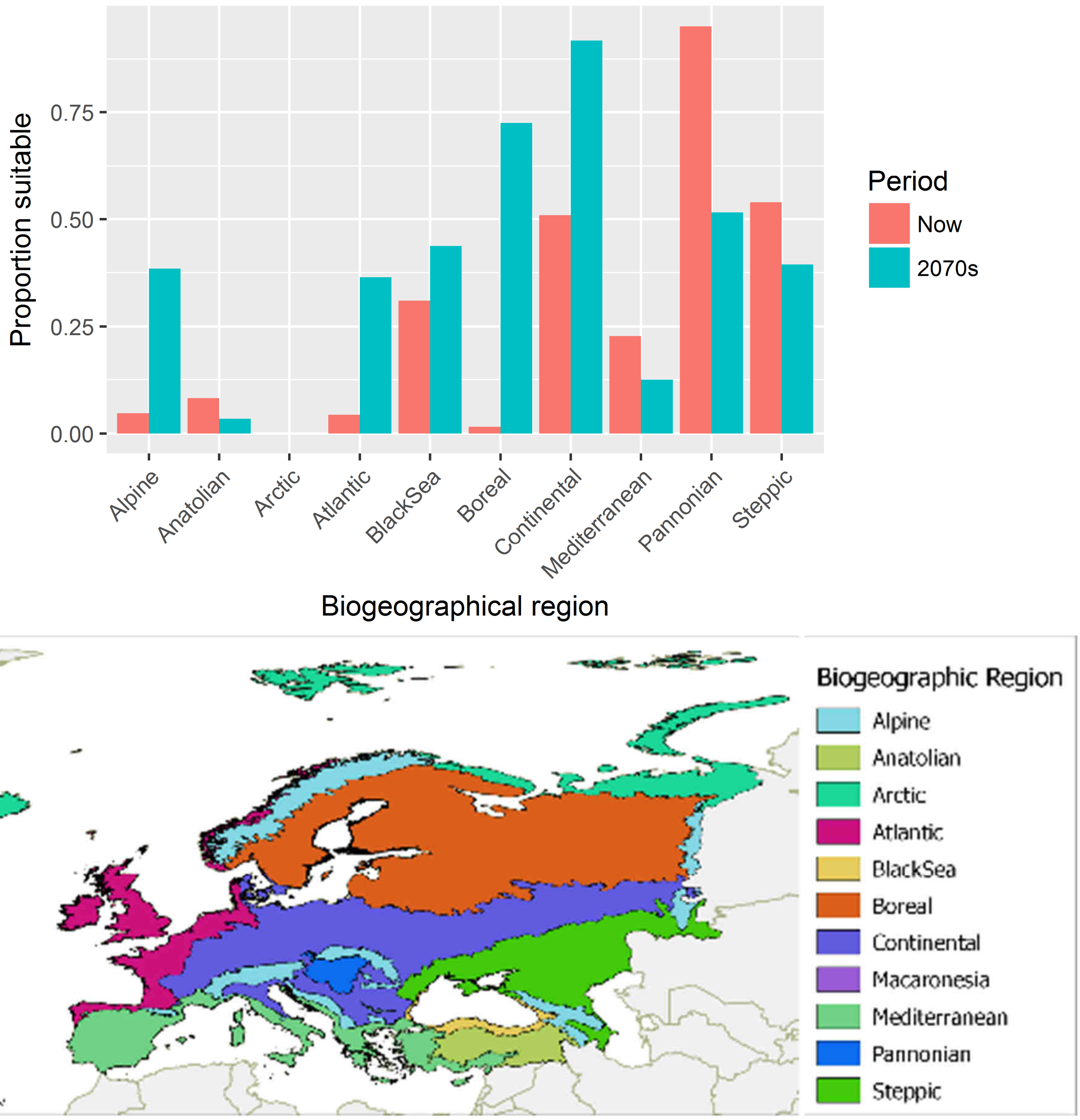


Figure 8. Variation in projected suitability among Biogeographical regions of Europe (Bundesamt fur Naturschutz (BfN), 2003). The bar plots show the proportion of grid cells in each region classified as suitable for the *Humulus scandens* in the current climate and projected climate for the 2070s under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

Caveats to the modelling

To remove spatial recording biases, the selection of the background sample was weighted by the density of Tracheophyte records on the Global Biodiversity Information Facility (GBIF) (Figure 3). While this is preferable to not accounting for recording bias at all, a number of factors mean this may not be the perfect null model for species occurrence:

- The GBIF API query used to did not appear to give completely accurate results. For example, in a small number of cases, GBIF indicated no Tracheophyte records in grid cells in which it also yielded records of the focal species.
- We used additional data sources to GBIF, which may have different biases to the GBIF records.

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

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

References

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

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

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

L. Balogh & I. Dancza (2008) Humulus japonicus, an emerging invader in Hungary. *Plant Invasions: Human Perception, Ecological Impacts and Management (Ed. Tokarska-Guzi B, Brock JH, Brundu G, Child CC, Daehler C & Pyšek P)*, 73-91.

M. Feng, J. O. Sexton, S. Channan & J. R. Townshend (2016) A global, high-resolution (30-m) inland water body dataset for 2000: First results of a topographic–spectral classification algorithm. *International Journal of Digital Earth* **9**, 113-133.

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.

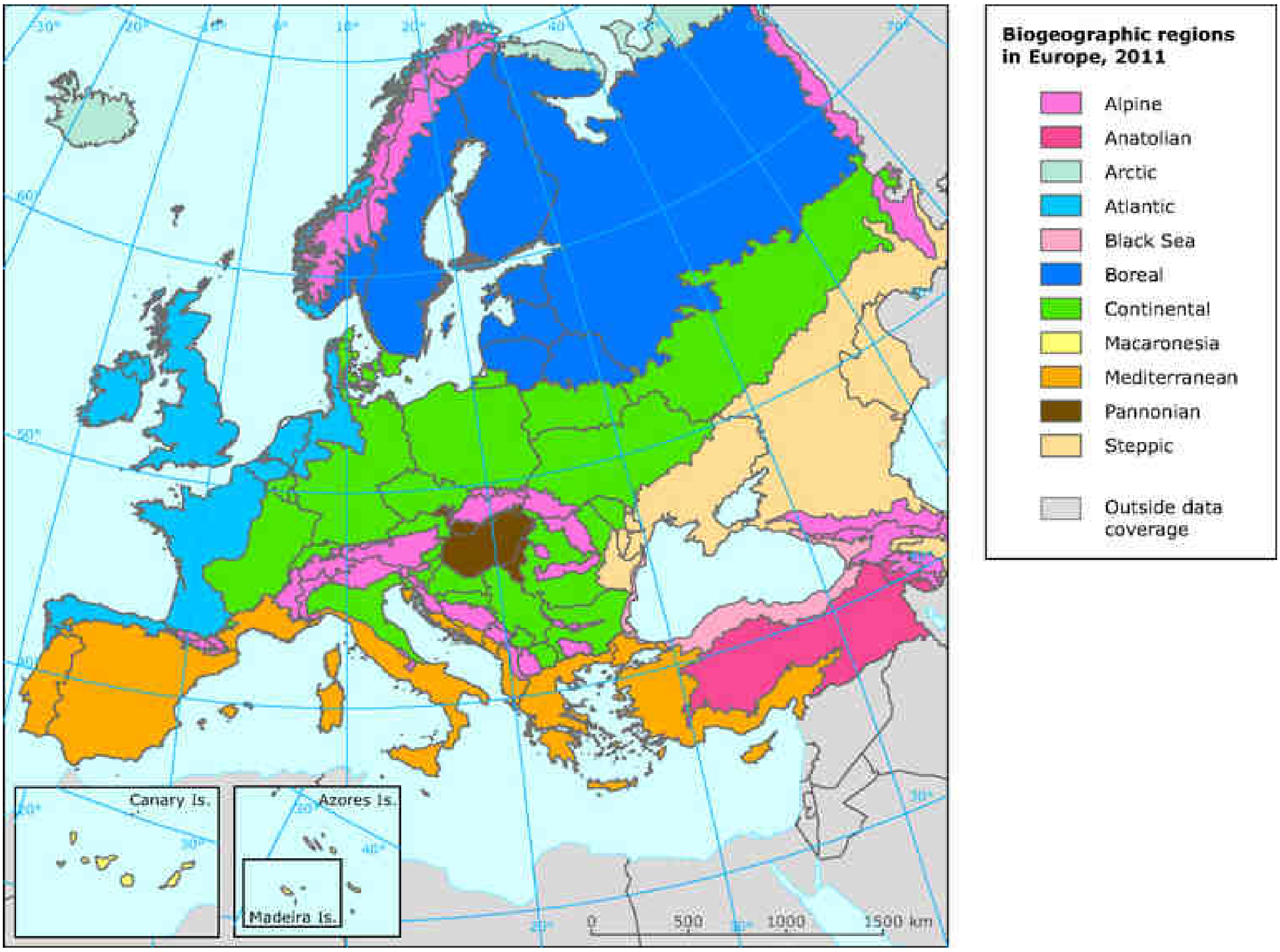
W. Thuiller, D. Georges & R. Engler (2014) biomod2: Ensemble platform for species distribution modeling. R package version 3.3-7 *Available at: https://cran.r-project.org/web/packages/biomod2/index.html*.

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

M. Hassler (2017) World Plants: Synonymic Checklists of the Vascular Plants of the World (version Jan 2017). In *Species 2000 & ITIS Catalogue of Life, 27th February 2017. Digital resource at www.catalogueoflife.org/col*. Species 2000: Naturalis Leiden, the Netherlands.

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

Appendix 2 Biogeographical regions of Europe



Appendix 3. Relevant illustrative pictures (for information)

Photo 1 Three 7-lobed leaves of *H. scandens* (below) compared to 1-4 lobed leaves of *H. lupulus* (above). See the petiole longer than the leaf for *H. scandens* and the lighter green colour of the leaves. © *Guillaume FRIED (Anses)*

Photo 2 Male inflorescence of *H. scandens*
© Guillaume FRIED (Anses)

Photo 3 Female inflorescence of *H. scandens*
© Guillaume FRIED (Anses)

Photo 4 Seeds of *H. scandens*
(c) Carole Ritchie, hosted by the USDA-NRCS PLANTS Database *Source/ copyright owner*

Photo 5 Massive seedling emergence of *H. scandens in early March*
© Guillaume FRIED (Anses)

Photo 6 Oxyloma elegans (Riso, 1826) feeding on *H. scandens* seedlings, 16/IV/2013 © Guillaume Fried (Anses)

Photo 7 *Cuscuta campestris* parasiting *H. scandens*
© Guillaume FRIED (Anses)

Photo 8 *Oidium* on leaves of *H. scandens in*
© Guillaume FRIED (Anses)

Photo 9 Dense stands of *H. scandens in one of the study site on the Gardon River © Guillaume FRIED (Anses)*

Photo 10 Part of 600 m² covered by an almost monospecific stands of *H. scandens on the Gardon River*
© Guillaume FRIED (Anses)

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	YES	YES	–
Croatia	–	–	YES	
Cyprus	–	–	–	–
Czech Republic	YES	–	YES	–
Denmark	–	–	YES	–
Estonia	–	–	YES	–
Finland	–	–	YES	–
France	YES	YES	YES	YES
Germany	YES	–	YES	–
Greece	–	–	YES	–
Hungary	YES	YES	YES	YES
Ireland	–	–	–	–
Italy	YES	YES	YES	YES
Latvia	–	–	YES	–
Lithuania	–	–	YES	–
Luxembourg	–	–	YES	–
Malta	–	–	–	–
Netherlands	–	–	YES	–
Poland	YES	–	YES	–
Portugal	–	–	YES	
Romania	YES	–	YES	–
Slovakia	YES	–	YES	–
Slovenia	YES	–	YES	–
Spain	–	–	YES	–
Sweden	–	–	YES	–
United Kingdom	–	–	YES	–

Biogeographical regions

	Recorded	Established (currently)	Established (future)	Invasive (currently)
Alpine	–	–	YES	–
Atlantic	–	YES	YES	–
Black Sea	–	–	YES	–
Boreal	–	–	YES	–
Continental	–	–	YES	–
Mediterranean	YES	YES	YES	YES
Pannonian	YES	YES	YES	YES
Steppic	YES	–	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. Distribution maps for Humulus scandens [3]

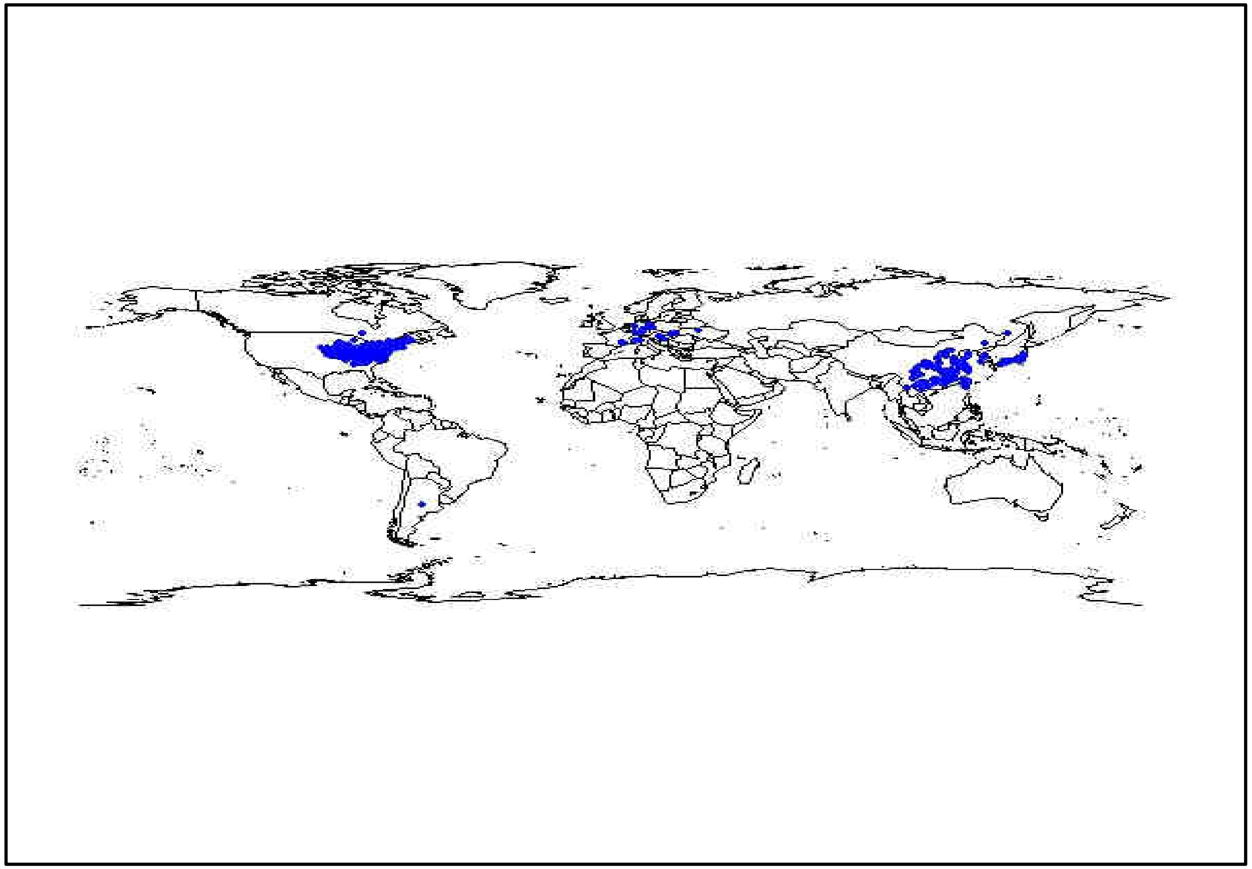


Figure 1: World distribution of *H. scandens*

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

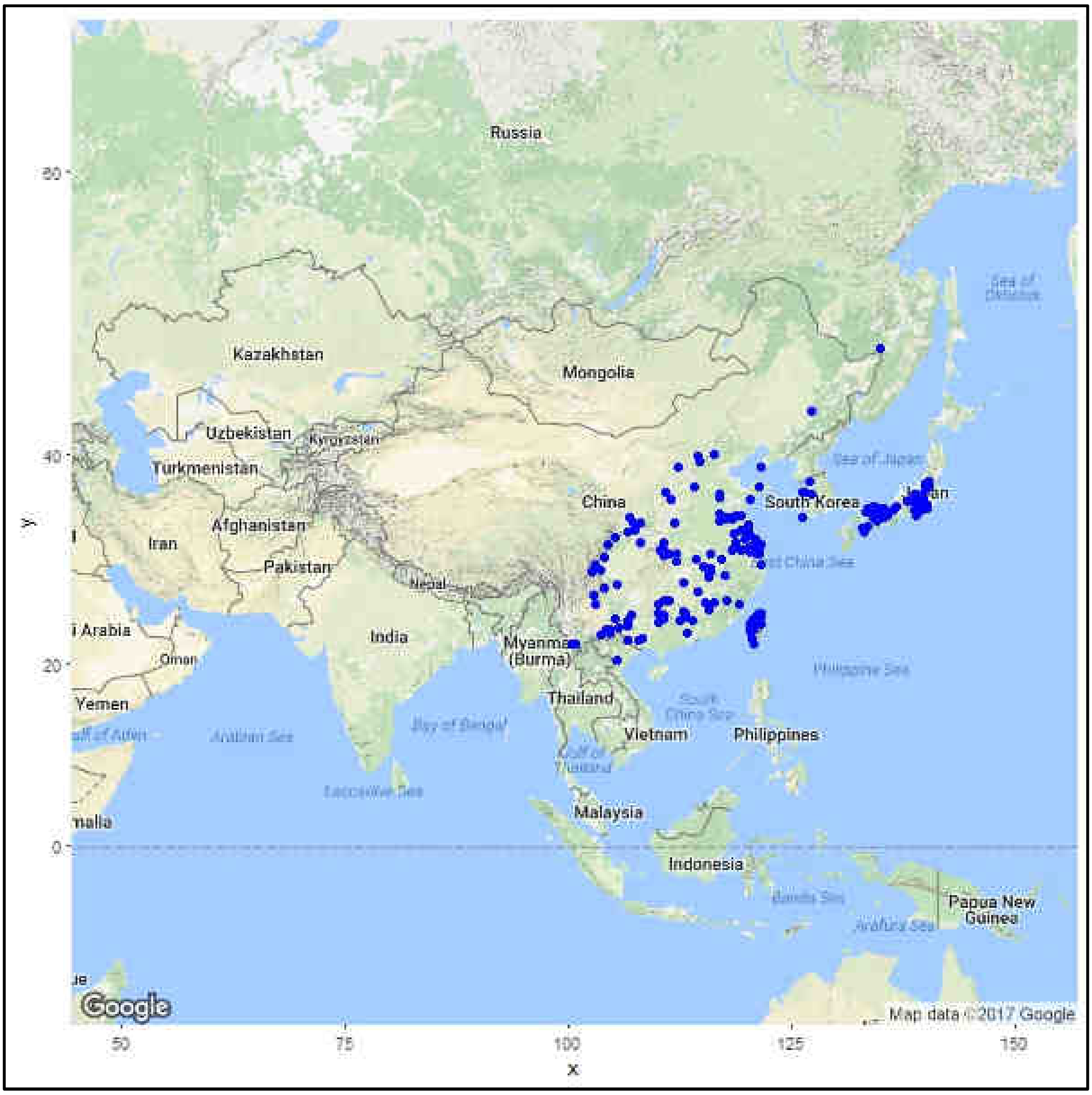


Figure 2: Distribution of *H. scandens* in Asia

Figure 3: Distribution of *H. scandens* in Europe

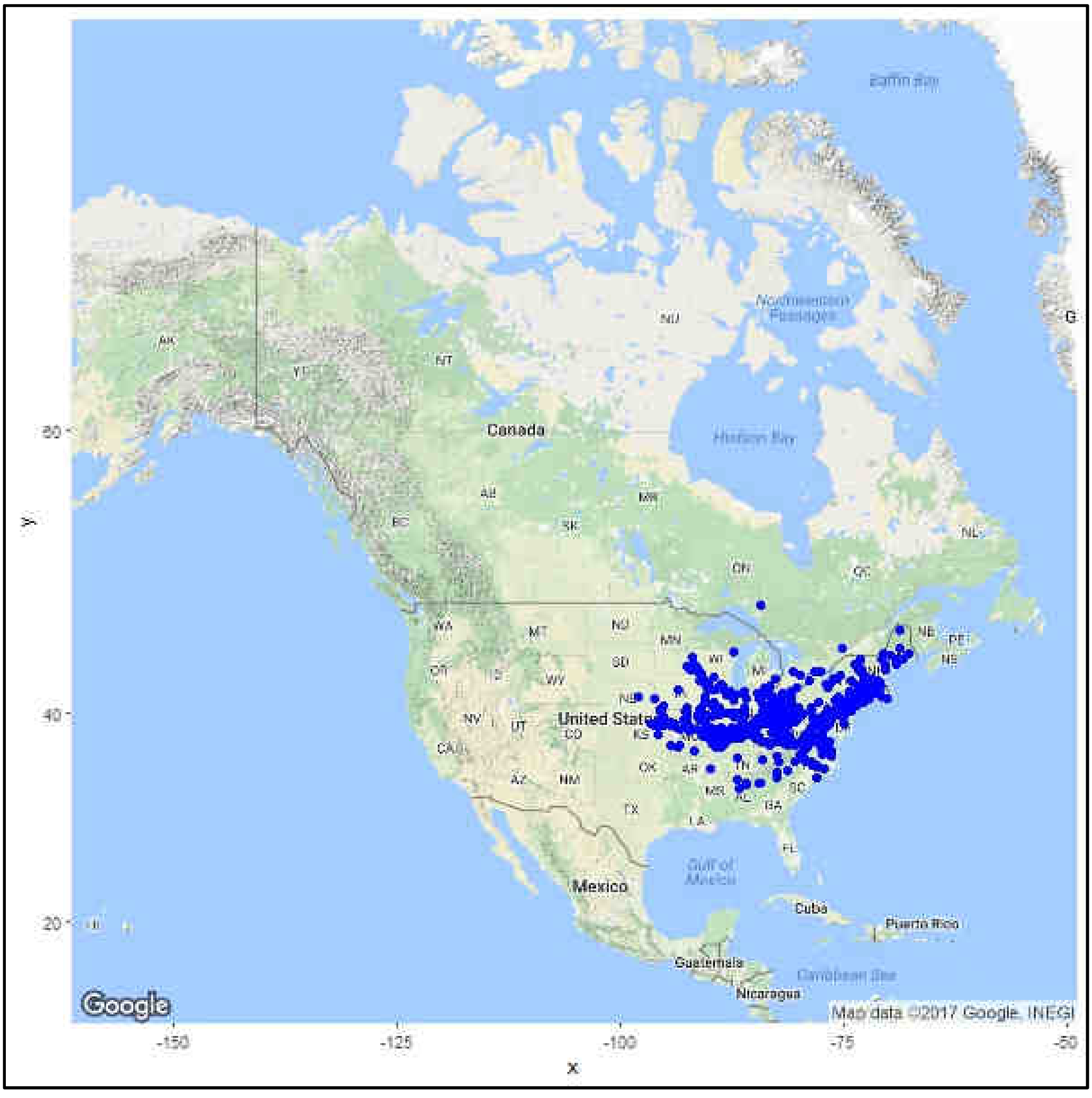


Figure 4: Distribution of *H. scandens* in North America