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

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Pest Risk assessment for *Triadica sebifera*

2018

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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: *Triadica sebifera* infestation in North America (Image courtsey of Nancy Loewenstein, Auburn University, Bugwood.org)

EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION

Pest risk assessment for *Triadica sebifera*

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

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The pest risk assessment for *Triadica sebifera* has been performed under the LIFE funded project:

LIFE15 PRE FR 001

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

In partnership with

EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION

And

NERC CENTRE FOR ECOLOGY AND HYDROLOGY

Review Process

- This PRA on **Triadica sebifera** was first drafted by S. Luke Flory and Austin Young, University of Florida.
- The PRA was further evaluated by international experts which made up an Expert Working group that physically met in Paris in 2017.
- The PRA has been reviewed by the EPPO Panel on Invasive Alien Plants in 2017.
- The PRA was reviewed by the EPPO Core Members for PRA (2017/18)
- The PRA was reviewed by the EU Scientific Forum (2018)

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

Contents

Summary[1] of the Express Pest Risk assessment for *Triadica sebifera*

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

Describe the endangered area:

The Expert Working Group (EWG) considers that the endangered area is primarily coastal habitats, woodland and forests, grassland, land sparsely wooded and heathland within the Mediterranean and Black Sea biogeographic regions, including the following EU countries: Portugal, Spain, southern coast of France, Italy, Croatia, Greece. Turkey and Israel are also within the endangered area. The species distribution model (current climatic projection) predicts a region of potential suitability for *Triadica sebifera* in southern Europe (Appendix 1. Figure 5). Countries in which *T. sebifera* may be capable of establishing widely include all those bordering the northern Mediterranean Sea, from Portugal to Turkey, as well as the Black Sea coasts of Turkey, Georgia and Russia. The model predicts that establishment in the rest of Europe will largely be prevented because of low summer temperature, with moisture limitation in central Spain and frost limitation in far eastern central Europe (Appendix 1, Figure 6).

Within the EPPO region the species is currently absent from the natural environment. However, the EWG consider that the species will be able to establish within the EPPO region in similar habitats to that of its invasive range in the USA.

Main conclusions

The results of this PRA show that *Triadica sebifera* poses a high risk for biodiversity to the endangered area (Mediterranean and Black Sea biogeographical region) with a high uncertainty. *Triadica sebifera* is an aggressive invader in the southern United States and Australia. The most serious impacts of invasion appear to have occurred following widespread commercial and ornamental planting of the species (USDA 2008; Scheld and Cowles 1981; Bruce *et al.* 1997). While it displays broad habitat suitability, *T. sebifera* appears limited by cold winter temperatures and steep land gradients in the USA (Gan *et al.* 2009; USDA 2008). Warmer regions in the PRA area, specifically the Mediterranean, face the highest risk of *T. sebifera* establishment.

Entry

Plants for planting is the main pathway for entry into the EPPO region. The likelihood of entry is high with a moderate rating of uncertainty.

Establishment

The likelihood of establishment in the natural and managed environment is moderate with a high uncertainty for the former and moderate uncertainty for the latter. Temperature and precipitation are the most straightforward climatic factors to determine likelihood of establishment of the species in the non-native north American range. This is likely to be similar in the EPPO region. Areas that experience winters with temperatures regularly dipping below -12°C are most likely to constitute the northern limits of *T. sebifera* establishment in the EPPO region (Gan *et al*. 2009; Grace 2001). *Triadica sebifera* is not adapted to dry conditions and this can restrict the species establishment in dry habitats not close to waterbodies in the Mediterranean region.

Spread

Triadica sebifera has a high capacity of spread with low uncertainty. A variety of bird species (for example the European Starling) have been recorded consuming and spreading the seeds of *T. sebifera*, contributing to new establishments and the invasion success of *T. sebifera* in the Southern USA (Renne *et al*.1999; 2001; 2002; Jubinksy and Anderson 1996). *Triadica sebifera* can also spread

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

along waterways, after heavy rains, flooding, or proximity to rivers and streams as seeds can float (Jubinksy and Anderson 1996; Bruce *et al*. 1997; NSW Factsheet 2017). Deliberate planting of *T. sebifera* seeds or young plants remains the most likely form of human-assisted spread. *Triadica sebifera* has the potential to be spread through the horticultural trade where there are a number of suppliers selling the species within the EPPO region (for example http://www.panglobalplants.com/). The species is present in a limited number of botanical gardens within the EPPO region.

Potential impacts in the EPPO region

As *T. sebifera* is absent from the natural environment in the EPPO region, all data on impacts comes from the species' invasive range elsewhere. Thus, all information on impacts can only be used as a proxy to the EPPO region. The EWG consider impacts in the EPPO region will be similar to that seen in other invasive regions (USA and Australia). Impacts on biodiversity and ecosystem services will be high with a high level of uncertainty. Socio-economic impacts will be low with a moderate uncertainty. The habitats where the species has biodiversity and ecosystem service impacts in the USA are present in the EPPO region, including coastal habitats, woodland and forests (including riparian forests), grassland, land sparsely wooded and heathland. In similar climatic conditions to the EPPO region, such as California, the species has been recorded as naturalised with the potential to spread along low lying riparian habitats (Bower *et al*. 2009). On the basis of climatic and habitat similarity, similar impacts may be expected for the EPPO region.

In the most severely affected region, the Southern USA, it is possible that a high propagule pressure exacerbated the invasion. The USDA began promoting the large-scale planting of *T. sebifera* in the Gulf Coast states in the early 1900s. *Triadica sebifera* has been widely grown and planted for ornamental trade in Houston, Texas (USDA 2000; Carmarillo *et al*. 2015). Therefore, without this propagule pressure occurring in the EPPO region (the species is not considered a popular ornamental species), such impacts may not be realised.

In addition, warm, moist low-lying forest and coastal grasslands feature more prominently in the USA Gulf coast states than across the PRA region. The most severe impact of *T. sebifera* is the conversion of grassland to woody thickets.

Habitats where the species is most likely to establish within the EPPO region include: coastal habitats, woodland and forests, wet grassland, land sparsely wooded and heathland. *Triadica sebifera* will establish in a wide range of soil types: clays, loams, and sands.

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

Climate change

The climate change projections for the 2070s suggest that under the less extreme RCP4.5 scenario the suitable region in Europe will have extended northwards, especially in western Europe where warmer summers may mean that the southern United Kingdom and the southern Baltic coast become more suitable (Appendix 1, Figure 7). Under the more extreme RCP8.5 scenario, the northwards expansion is even greater, especially in eastern Europe (Appendix 1, Figure 8). This is likely driven by a relaxation of frost constraints.

In the evaluated climate change scenarios, predicted suitability was stable in the Mediterranean but increased in the Black Sea. Other biogeographic regions predicted to strongly increase in suitability are Atlantic, Continental, Pannonian and Steppic (Figure 9). The countries within the endangered area under climate change include: Portugal, Spain, France, Germany, Ukraine, Georgia, Turkey, Russia, Greece, Albania, Bosnia and Herzegovina, Croatia, Slovenia, Austria, Hungary, Italy, Israel and the north coastline of Algeria. The influence of projected climate change scenarios has not been

considered in the overall scoring of the risk assessment based on the high levels of uncertainty with future projections. **The results of this PRA show that *Triadica sebifera* poses a high risk to the endangered area (Mediterranean and Black Sea biogeographical region) with a high uncertainty.**			
Phytosanitary risk (including impacts on biodiversity and ecosystem services) for the *endangered area* (current/future climate) **Pathway for entry** Plants for planting: High/Moderate Likelihood of establishment in natural areas: Moderate/High Likelihood of establishment in managed areas: Moderate/High Spread: High/High **Impacts (EPPO region)** Biodiversity: High/High Ecosystem services: High/High Socio-economic: Low/Moderate	High X	Moderate	Low
Level of uncertainty of assessment (current/future climate) **Pathway for entry** Plants for planting: Moderate/Moderate Likelihood of establishment in natural areas: High/High Likelihood of establishment in managed areas: Moderate/High Spread: Low/High **Impacts (EPPO region)** Biodiversity: High/High Ecosystem services: High/High Socio-economic: Moderate/High	High X	Moderate	Low

Express Pest Risk assessment:

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(*Triadica sebifera)*

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Date: October 2017

Stage 1. Initiation

Reason for performing the PRA:

Triadica sebifera is currently absent from the natural environment in the European Union and the non-EU countries of the EPPO region. *Triadica sebifera* was included in a list of 95 invasive alien species that are likely to "arrive, establish, spread and have an impact on biodiversity or related ecosystem services in the EU over the next decade" (Roy *et al*. 2015). In 2016, the species was prioritized (along with 36 additional species from the EPPO List of Invasive Alien Plants and a recent horizon scanning study[2]) for PRA within the LIFE funded project "Mitigating the threat of invasive alien plants to the EU through pest risk analysis to support the Regulation 1143/2014' (see www.iap-risk.eu). *Triadica sebifera* was one of 16 species identified as having a high priority for PRA. In North America, *T. sebifera* readily invades a variety of natural habitats and disturbed sites, especially grasslands and areas adjacent to water (Gan *et al*. 2009, Pile *et al*. 2017). In these habitats, *T. sebifera* can dramatically alter community species composition, reduce diversity, and affect nutrient cycling (Pile *et al*. 2017). Species distribution modelling predicts that *T. sebifera* can establish in the EPPO region including EU Member States in northern Mediterranean biogeographical region, from Portugal to Turkey.

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

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

All information relating to EU Member States is included in the Pest risk assessment and information from the wider EPPO region only acts to strengthen the information in the PRA document. The PRA defines the endangered area where it lists all relevant countries within the 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'.

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

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:

Kingdom: Plantae, Tracheophyta, Spermatophytina, Magnoliopsida Rosanae, Malpighiales, Euphorbiaceae, Triadica Lour. Species: *Triadica sebifera* (L.) Small (ITIS Standard Report 2017).

Synonyms: *Croton sebiferum* L., *Sapium sebiferum* (L.) Roxb., *Stillingia sebifera* (L.) Michx., *Carumbium sebiferum* (L.) Kurz, *Excoecaria sebifera* (L.) Müll. Arg., *Seborium chinense* Raf.

This genus was for many years united with *Sapium* as sect. *Triadica*. Recently it has been considered to constitute a separate genus characterized by peculiar fruits, seeds, and leaf glands (Esser *et al.* 1997).

Common name:

English: Chinese tallow tree, Small – tallowtree, chicken tree; Florida aspen; popcorn tree; vegetable tallow; white wax berry

Spanish: arbol del sebo

French: arbre à suif; arbre savon; glutier

Chinese: wujiu

German: Chinesischer Talgbaum

Plant type: Deciduous medium sized tree species

Related species in the EPPO region: None

2. Pest overview

Introduction

Triadica sebifera is a deciduous tree up to 20 – 30 meters in height. It is native to China and Japan, but due to its commercial applications and popularity as an ornamental plant, *T. sebifera* has been introduced to Europe, North America, South America, Africa, Asia and the Australian continents (GBIF, EDDMAPS, CABI). After escape and spread, it is now recorded widely in the southern United States and Australia (NSW Department of Primary Industries, 2017; USDA 2008). Often, more than 95% of seeds are viable, but viability drops to between 10 and 50 % after one year in natural settings (Renne *et al*. 2002). A mature tree can produce an average of 100,000 seeds annually, depending on environmental conditions (USDA 2000; Jubinksy and Anderson 1996; Bruce *et al*. 1997). According to Scheld and Cowles (1981), *T. sebifera* can grow up to 2.8 m tall within two years after germination. In addition to intentional plantings by humans, birds and waterways disperse *T. sebifera* seeds (Bruce *et al*. 1997; Jubinksy and Anderson 1996; Renne *et al*. 1999). *Triadica sebifera* readily invades a variety of natural habitats and disturbed sites, especially grasslands and areas adjacent to water (Gan *et al*. 2009, Pile *et al*. 2017). In these habitats, *T. sebifera* can dramatically alter community species composition, reduce diversity, and affect nutrient cycling (Pile *et al*. 2017).

Environmental Requirements

Altitude

- In the southern forests of the United States approximately 80 % of tallow invasions occur at elevations lower than 50 m or slopes of < 2°. At higher elevations and with steeper slopes, the likelihood of invasion drops dramatically and “no invasion was reported in the FIA [Forest Inventory Analysis] data for sites where elevation was greater than 165 m or slopes were steeper than 18°” (Gan *et al*. 2009).
- In Taiwan, *T. sebifera* plantations occur at elevations of 400-700 m (Lin *et al*. 1958).
- Surveys of *T. sebifera* in the Indian Himalayas recorded trees at an altitude limit of 1,600 m (Jaryan *et al*. 2013).
- Pattison and Mack (2007) cites a record in the Himalayas of *T. sebifera* at 1,800 m, but the EWG was unable to retrieve the cited material.

Temperature

- In the southern forests of the United States *T. sebifera* does not occur at survey sites where the mean minimum temperature in January was below –12 °C (10°F) (Gan *et al*. 2009).
- Grace (1998) suggested that the likeliest northern boundary of *T. sebifera* to be where average minimum winter temperatures dip to -12 to -15 °C, or USDA zone 7b.
- In a climate modelling study, temperatures of 12 °C and 24 °C were determined as the lower temperature threshold for growth and lower limit of optimal temperature growth, respectively. The upper temperature limit for optimal growth and the upper temperature threshold for growth were determined to be 35 °C and 40 °C, respectively. They reached these values after consultation with average annual temperature data from the native range of *T. sebifera* (Pattison and Mack, 2008).

Precipitation

- In Taiwan, *T. sebifera* has been reported on sites with average annual precipitation ranging from 1,070 mm – 3,733 mm (Lin *et al*. 1958; Kirmse 1989; Meyer 2011).
- In the US and mainland China, 1,000 - 2,000 mm average annual precipitation (pers comm. E Siemann, 2017).
- Kirmse and Fisher (1989) described a New Mexico plantation (US) where *T. sebifera* grew well with average annual precipitation of 243 mm, although trees were irrigated for the first 2 months after transplanting (90.6% survival).

Soil

- Evidence from plantations and the native and naturalized range of *T. sebifera* indicates it is compatible with a wide range of soil types: clays, loams, and sands (Scheld and Cowles 1981; Bruce *et al*. 1995; Radford *et al*. 1968).
- *Triadica sebifera* is tolerant of saline soils (Scheld and Cowles 1981; Lin *et al*. 1958).
- In Taiwan, Lin *et al*. 1958 determined the chemical properties of soils on the "18 main habitats of *T. sebifera* tree." Total nitrogen was 0-0.20% and pH was 2.9-8.5.
- *Triadica sebifera* growth, including height, diameter, aboveground biomass, shoot mass, and root mass was correlated with higher soil nutrition such as greater amounts of nitrogen, potassium, and phosphorus (Siemann and Rogers 2003; Rogers and Siemann 2002).
- Meyer (2011) summarized the findings of research on greater nitrogen content and the growth/establishment success of *T. sebifera.* The addition of nitrogen in soils enhances survival and growth but sometimes has no effect. It never has a negative effect.
- Gan *et al*. (2009) found that in sites throughout the Southeast USA, the probability of invasion was greater closer to water bodies, likely due in part to soil moisture levels that were favourable for establishment.
- *Triadica sebifera* exhibits significantly lower seedling survival in treatments with 23% soil moisture compared to treatments with ≥ 31% soil moisture (Meyer 2011; Bruce *et al*. 1995).
- Pattison and Mack (2008) analysed moisture conditions in the native and naturalized ranges to determine optimum soil moisture conditions. They described these as 0.225 for the lower soil moisture survival threshold and 0.35 as the low soil moisture threshold for optimal growth (these values relate to the index of soil moisture used in CLIMEX when the soil moisture is to 0.2, this commonly results in grass wilting, whilst the value of 1 indicates the soil is saturated (Suthrest *et al*. 2004).

Light

- Jones and McLeod 1990 found a positive relationship between light availability and biomass production where the greatest production was achieved under 100 % light. In greenhouse experiments, seedling shoot and total biomass were significantly lower in ambient light than under an 87 % shade cloth. In the field, seedlings perform much better in open than shaded habitats.

Habitats

In North America, *T. sebifera* has a wide environmental tolerance and can thrive in many different habitats including forests (can invade closed and open forests), wetlands, grasslands, coastal prairie, mesic sites, disturbed sites, low-lying fields, swamp, and scrubby flatlands (Bruce *et al*. 1997; Carmarillo *et al*. 2015; Langeland 2015). In the native range, in China, *T. sebifera* is found in disturbed habitats at low densities. In Australia, the species is reported from wet areas, along river, lakes, streams and swamps. However, it also grows in drier conditions including roadsides and disturbed areas (NWS Department of Primary Industries, 2017).

Symptoms (Impacts)

Where it invades, *T. sebifera* can disrupt ecosystem processes, decrease biodiversity, and alter community structure (Bruce *et al*. 1997; Jubinksy and Anderson 1996; Cameron and Spencer 1989). Due to its rapid leaf decomposition, *T. sebifera* can alter soil chemistry (Cameron and Spencer 1989), which may allow it to better compete with native plants (Camarillo *et al*. 2015). *Triadica sebifera* readily replaces native vegetation and can establish dominant stands (Bruce *et al*. 1997; Camarillo *et al*. 2015; Neyland and Meyer 1997). In Texas, invasions of *T. sebifera* have converted coastal grasslands into forests (Bruce *et al*. 1997; Camarillo *et al*. 2015). Harcombe *et al*. (1993) showed that 15-year-old *T. sebifera* stands had significantly higher net productivity than the ecosystem it replaced. Established stands of *T. sebifera* are very difficult to eradicate (USDA 2000; Camarillo *et al*. 2015; Bruce *et al*. 1997).

Identification

There are no congeneric species within the EPPO region including the EU Member States. A deciduous tree 20 to 30 meters tall (Appendix 3, Figure, 1). Low-spreading and multi-forked to tall and columnar. Stem often crooked and gnarled (Appendix 3, Figure, 2). Bark is grey, brown, and rough. Exudes a milky sap. Twigs slender. Petioles 2-6 cm long, with 2 sessile disc-shaped glands at the apex. Leaf-blades broadly rhombic-ovate, 2-7.5 x 1.5-7 cm, abruptly acutely acuminate, broadly cuneate to rounded, subtruncate at the base, entire, lateral nerves 7-12 pairs, glaucous beneath. Stipules 1-2 mm long, obtuse. *T. sebifera* flowers from April to June, producing both male and female flowers. Fruits are 1 cm three-lobed capsules expected to mature in the autumn. Seeds are 8 mm long and chalky white (covered by a white wax) (Flora of China 1972; Bruce *et al*. 1997; Scheld and Cowles 1981) (Appendix 3, Figure, 3). For additional information on identification including variations in morphology see Flora of China (1972).

Existing PRAs

Hawaii: Australia/New Zealand Weed Risk Assessment adapted for the Pacific. Pacific Island Ecosystems at Risk (PIER). This risk assessment predicts the likelihood of invasions of species in Australia, Hawaii, and the high islands of the Pacific. Results are also sometimes modified for the State of Florida. The risk assessment for Hawaii scored *T. sebifera* 14, indicating that the species poses a significant risk of becoming a problematic invader (PIER 2005). Accessed at: http://www.hear.org/pier/wra/pacific/triadica_sebifera_htmlwra.htm

Florida: Australia/New Zealand Weed Risk Assessment adapted for Florida. Data used for analysis published in: Gordon, D.R., D.A. Onderdonk, A.M. Fox, R.K. Stocker, and C. Gantz. 2008. Predicting Invasive Plants in Florida using the Australian Weed Risk Assessment. Invasive Plant Science and Management 1: 178-195. Score: 18 Accessed at: http://www.hear.org/wra/tncflwra/pdfs/tncflwra_sapium_sebiferum_ispm.pdf

California: Bower M. J., Aslan C. E., Rejmánek M. 2009. Invasion potential of *T. sebifera* tree (*Triadica sebifera*) in California's Central Valley. *Invasive Plant Science and Management* 2: 386–395. This study determined California's Central valley to be highly susceptible to invasion by *T. sebifera*.

Georgia: The species was rejected with a high risk of invasiveness (score 19) and with a confidence of 75.8 out of 100.
(https://pre.ice.ucdavis.edu/sites/default/files/pdf/farm_bill/PRE-5690.pdf)

Texas: The species was rejected with a high risk of invasiveness (score 20) and with a confidence of 81 out of 100.
Texas: https://pre.ice.ucdavis.edu/sites/default/files/pdf/farm_bill/PRE-5238.pdf

Spain: Andreu & Vilà (2009) performed two different types of Weed Risk Assessments (WRAs) for 80 species for Spain, including *T. sebifera*. For both the "Australian" WRA and "Weber-Gut" WRA methodologies *T. sebifera* earned an "intermediate" level of risk of invasion (Andreu & Vilà, 2009).

Socio-Economic Benefits

Triadica sebifera is a highly valued species for both its ornamental qualities and productive capability in agricultural and industrial sectors. Tallow wood is white and close-grained, suitable for carvings, furniture, carts, and match making as well as incense (Lin *et al*. 1958; USDA 2000). The leaves are used to make a black dye and manure (Lin *et al*. 1958; USDA 2000).

Triadica sebifera seeds are a source of vegetable tallow, a drying oil, and protein food. The outer covering of the seeds contains solid fat known as Chinese vegetable tallow and the kernels produce a drying oil called Stillingia oil. Candles, soap, cloth dressing, and fuel are made from the tallow. The oil is used in machine oils, as a crude lamp oil, and in making varnishes and paints, because of its quick-drying properties. The presscake remaining after tallow and oil extraction can be processed to make a valuable animal feed and human food, rich in protein. Different parts of the plants are used in traditional Chinese medicine (USDA 2000, PROSEA 2001, Gao *et al*.2016).

In the early 20th century, the Foreign Plant Introduction Division of the U.S. Department of Agriculture promoted tallow tree planting in the Gulf Coast and Southern US states to establish a local soap industry (Dewalt *et al*. 2011; USDA 2000). When cultivated under conventional agriculture methods, *T. sebifera* can be grown over extensive areas of land and can provide woody biomass for direct burning or conversion to charcoal, ethanol, and methanol (USDA 2000; Scheld and Cowles 1981). Wen *et al*. (2010) demonstrated *T. sebifera* seed oil can be converted to biodiesel. Due to its ability to re-sprout, its rapid growth rate, and its tolerance to flooding, drought and salt, *T. sebifera* has been considered as biomass crop for the Gulf coast region of the US (Scheld and Cowles 1981; USDA 2000).

Birds, wild and domestic, will feed on the seeds and it is sometime recommended as a bird food (USDA 2000, Renne *et al*. 1999). The flowers of *T. sebifera* are visited by honeybees, contributing to a commercially desirable, light-colored honey (Renne *et al*. 1999; USDA 2000). *Triadica sebifera* is recognized as an important species for commercial honey production in Louisiana (Lieux 1975).

Repeated introductions: *T. sebifera* has an extensive history of cultivation and sale and as an ornamental, especially in the in United States (Bruce *et al*. 1997, Camarillo *et al*. 2015, Siemann and Rogers 2003). By 1983, 200,000-300,000 trees were being grown for ornamental trade in Houston, Texas alone (USDA 2000).

Within the EPPO region, apart from the species in ornamental plant trade, there are no current socio-economic benefits for the species. Currently, there is little information available on the value of the species in horticulture. The species is listed as available from two suppliers in the UK (https://www.rhs.org.uk/Plants/Nurseries-Search-Result?query=239677). The EWG did not find any additional information for suppliers within the EPPO region including EU Member States except for the information below.

Seeds of the species are available via a number of online supplier:

http://b-and-t-world-seeds.com/cartall.asp?species=Triadica%20sebifera&sref=545154

https://www.amazon.com/Chinese-Tallow-Triadica-sebifera-Ornamental/dp/B01L3A1DR4

http://www.panglobalplants.com/

Historically at the beginning of the 19th century in Europe, many countries (for example Italy and France) have explored the economic benefits of the species for oil production (Antonelli, 1820; Société nationale d'horticulture de France., 1832; Loiseleur-Deslongchamps, 1832).

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

In North America, *T. sebifera* is repeatedly described as relatively free of serious pests and even pest resistant (Rogers and Siemann 2002; Scheld and Cowles 1981; Jubinsky and Anderson 1996). No descriptions of negative ecological effects resulting from the transmission of a pest or pathogen into a novel environment by *T. sebifera* were found in the literature we reviewed.

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

No vector is necessary for *T. sebifera* to enter into or spread within the PRA area. Ornamental plantings, bird dispersal, and waterways, are primary mechanisms of seed dispersal (Bruce *et al*. 1997; Jubinksy and Anderson 1996).

5. Regulatory status of the pest

In the USA, *T. sebifera* is listed as a noxious weed in the following States: Florida, Mississippi, Texas, and Louisiana (https://plants.usda.gov/core/profile?symbol=TRSE6)

In Australia, *T. sebifera* is regarded as an environmental weed in New South Wales and a potential environmental weed in south-eastern Queensland (Brisbane City Council, 2018).

In the EPPO region there are no regulations specific to *T. sebifera*.

6. Distribution[3]

Continent	***Distribution*** *(list countries, or provide a general indication , e.g. present in West Africa)*	***Provide comments on the pest status in the different countries where it occurs*** *(e.g. widespread, native, introduced….)*	***Reference***
Africa	South Africa, Sudan, Uganda, Zambia	Non-native. Limited distribution. At this time, the EWG consider the species shows no signs of invasiveness in Africa.	CABI (2017), GBIF (2017, EDDMAPPS, USDA (2008);
Americas	USA (Mississippi, Texas, Florida, Georgia, South Carolina, North Carolina, California, Louisiana, Arkansas, Alabama, Hawaii, Louisiana, Oklahoma, Virginia) Mexico Caribbean (Martinique, Cuba) Brazil Peru	Non-native and invasive. Non-native and planted without showing signs of invasiveness	CABI (2017), GBIF (2017, EDDMAPPS, USDA (2008); Bruce (1997); Carmarillo *et al*. (2015), Siemann and Rogers (2003); Chapman *et al*. (2008); DeWalt *et al*. (2011)
Asia	China, Japan, South Korea India, Pakistan, Taiwan	Native Non-native and mostly planted. Taiwan (uncertain status)	CABI (2017), GBIF (2017), EDDMAPPS, USDA (2008), Bruce *et al*. (1997); Siemann and Rogers 2003;); DeWalt *et al*. (2011)
Europe		Long history of planting within the region for ornamental purposes and other uses. Present in botanical gardens. Not present in the natural environment.	Antonelli, (1830), Banfi and Visconti (2013); Batchelor (2017); Dillwyn and Collinson (1843); Hortus Collinsonianus (1843); Hortus Paddingtonensis (1797); Hortus Kewensis (1814).
Oceania	Australia, New Zealand	Introduced and invasive in Australia New Zealand – planted individuals,	CABI (2017), GBIF (2017), EDDMAPPS, NSW Primary Industries (2017); Wang and Ecroyd (2009).

[3] 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, introduced….)	Reference
		not showing signs of invasiveness	

Introduction

Triadica sebifera is native to China and Japan with a non-native distribution showing invasive behaviour in the USA and Australia.

North America

In the Southern USA, *T. sebifera* is a major invasive species. Although it was first introduced in the late 18th century, it did not become invasive until the 20th century, especially the latter half. This invasion pattern may be due to greater propagule pressure brought about by large-scale commercial plantings and hurricanes. Invasions convert grasslands to woody thickets, displaces native species, and disrupts ecological processes. According to DeWalt *et al*. (2011): "Present populations near the sites of the earliest introductions of Chinese tallow tree to the southeastern USA (Charleston, South Carolina and Savannah, Georgia) appear to differ in genetic composition as well as genetic diversity from populations resulting from introductions made approximately 120 years later to the rest of the southeastern USA."

Central and South America

In Central and South America, there is no evidence of widespread establishment or invasion by *T. sebifera.*

Australia

According to the NSW Government in Australia: "It is fast becoming an invasive environmental weed of water courses and native vegetation areas… Originally introduced to Australia as an ornamental tree with beautiful coloured foliage. It has been planted in streets and garden in southeast Queensland and northern New South Wales (NSW). Naturalised populations have now been identified in various locations throughout southeast Queensland. The largest infestation of *T. sebifera* tree exists near Casino, NSW. Smaller infestations are evident throughout the North Coast, Central Coast and New England regions of NSW. Localized plants also exist in Victoria." (NSW Factsheet 2017). According to DeWalt *et al*. (2011): "We are unaware of when Chinese tallow was introduced to Australia; however, its genetic similarity to the rest of the southeastern USA indicates that it may have been introduced in the early 1900s to Australia at the same time it was being extensively planted in areas along the USA coast of the Gulf of Mexico or that it represents a secondary invasion from the southeastern USA."

Europe

Triadica sebifera was introduced and planted in the south of France since the 19th century (Société nationale d'horticulture de France, 1832). The "Colonial Garden" of Paris tested the species for oil production during the beginning of 20th century. In the UK, it was introduced in the 18th century, probably as early as 1703 (Batchelor, 2017; Dillwyn and Collinson, 1843). In Italy, it was introduced and planted in Botanic Gardens and Agricultural experimental fields at least since the 19th century (Banfi and Visconti, 2013). In the Netherlands, it was introduced and planted in the

Botanic Garden of Amsterdam (pers. comm. G. Brundu, 2017). In Germany, Portugal and Spain, it was introduced and planted in Botanic Gardens (pers. comm. G. Brundu, 2017).

7. Habitats and their distribution in the PRA area

Habitats	**EUNIS habitat types**	**Status of habitat (eg 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***
Coastal habitats	For example, B1.8 Moist and wet dune slacks	Partially threatened	No	Major	Pile *et al*. 2017
Mires, bogs, fens	For example, D5 Sedge and reed beds normally without free-standing water	Partially threatened	No	Medium	Pile *et al*. 2017
Woodland, forest and other wooded land	For example: G1, 1.1, 2, 3, 4 and 5	Partially threatened	No	Major	Pile *et al*. 2017
Grasslands	For example: E2, E3, E5 and E7	Partially threatened	No	Major	Pile *et al*. 2017
Habitat complexes	For example, X13 – 16, 24, 25	NA	No	Major	Pile *et al*. 2017
Heathland, scrub and tundra	For example: F9, FA & B	Partially threatened	No	Major	Pile *et al*. 2017

In North America, *T. sebifera* has a wide environmental tolerance and can thrive in many different habitats including forests (capable of invading closed and open forest systems), wetlands, grasslands, coastal prairie, mesic sites, disturbed sites, low-lying fields, swamp, and scrubby flatlands (Bruce *et al*. 1997; Camarillo *et al*. 2015; Langeland 2009). In the native range, in China, *T. sebifera* is found in disturbed habitats at low densities.

Within the EPPO region and Europe in particular, the species is currently absent from the natural environment. However, the EWG consider that the species will be able to establish within the EPPO region in similar habitats to that of its invasive range in the USA. These include coastal habitats, woodland and forests, grassland, land sparsely wooded and heathland. Other habitats detailed above can be at risk (see above).

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

Possible pathways	**Pathway: Plants and seeds for planting** **(CBD terminology: Escape from confinement)**
Short description explaining why it is considered as a pathway	*T. sebifera* has a long history of deliberate planting within the EPPO region (see for example Kew, 1814; Antonelli, 1830). Seeds can be bought on the internet and shipped nearly anywhere in the EPPO zone (see below). *T. sebifera* is available via nurseries within the EPPO region. The species can also be purchased via online suppliers outside of the EPPO region. Examples of online suppliers include: http://b-and-t-world-seeds.com/cartall.asp?species=Triadica%20sebifera&sref=545154 https://www.amazon.com/Chinese-Tallow-Triadica-sebifera-Ornamental/dp/B01L3A1DR4 http://www.panglobalplants.com/
Is the pathway prohibited in the PRA area?	No, the pathway is not prohibited within the EPPO region.
Has the pest already intercepted on the pathway?	Yes, the species is actively sold via a number of internet suppliers within the region and outside of the EPPO region (see above).
What is the most likely stage associated with the pathway?	All growth forms except for large trees are associated with this pathway, including trade of seeds.
What are the important factors for association with the pathway?	Nurseries and seed suppliers will ship stock throughout the world. The seed will survive storage.
Is the pest likely to survival transport and storage in this pathway?	Yes, seeds will survive storage and live plants will be shipped to ensure plant survival.
Can the pest transfer from this pathway to a suitable habitat?	Yes. Likely through intentional introductions by humans. However, given the seeds can be dispersed by birds and waterways, any tree producing berries within the EPPO region could be the origin of a new establishment, especially trees that are planted near moving bodies of water. *T. sebifera* can survive in urban, rural, natural, and disturbed habitat.
Will the volume of movement along the pathway support entry?	It is likely that all seed stock is obtained from outside of the EPPO region. However, the EWG does not have any figures on the volume of movement along this pathway.
Will the frequency of movement along the pathway support entry?	Yes, as it is likely that all seed stock is obtained from outside of the EPPO region. However, the EWG does not have any figures on the frequency of movement along this pathway.
Likelihood of entry	*Low* ☐ *Moderate* *High* X
Likelihood of uncertainty	*Low* ☐ *Moderate* **X** *High* ☐

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

Do other pathways need to be considered? NO

9. Likelihood of establishment in the natural environment PRA area

Temperature and precipitation are the most straightforward climatic factors to determine likelihood of establishment of the species in the non-native north American range. This is likely to be similar in the EPPO region including the EU territory. Areas that experience winters with temperatures regularly dipping below -12°C are most likely to constitute the northern limits of *T. sebifera* establishment in the EPPO region (Gan *et al*. 2009; Grace 1998). *Triadica sebifera* is not adapted to dry conditions and this can restrict the species establishment in habitats not close to waterbodies in the Mediterranean region.

Habitats where the species is most likely to establish within the EPPO region include: coastal habitats, woodland and forests, grassland, land sparsely wooded and heathland. *T. sebifera* will establish in a wide range of soil types: clays, loams, and sands.

The model predicts a region of potential suitability for *T. sebifera* in southern Europe (Appendix 1, Figure 5). Countries in which *T. sebifera* may be capable of establishing widely include all those bordering the northern Mediterranean Sea, from Portugal to Turkey. The model predicts that establishment in the rest of Europe will largely be prevented because of low summer temperature, with moisture limitation in central Spain and frost limitation in far eastern central Europe (Appendix 1, Figure 6).

In terms of Biogeographical Regions, those predicted to be most suitable for *T. sebifera* establishment in the current climate are the Mediterranean and Black Sea assuming the species is present close to waterbodies in micro-habitats with high soil moisture (Appendix 1, Figure 9).

Potential reasons why the species has not established within the EPPO region to-date, despite being planted historically may include, a lack of propagule pressure, lack of suitable genotypes, the species being contained when historically planted, and low precipitation or low temperatures specifically affecting seedling establishment.

There are no known natural enemies for this species in the EPPO region.

A moderate rating of likelihood of establishment has been given for the natural environment based on the lack of propagule pressure. A high rating of uncertainty has been given as the species is currently not present in the natural environment within the PRA area.

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

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

Although *T. sebifera* is a popular ornamental species, there is no evidence that professional landscapers in Europe and the wider EPPO region plant this tree. The species has been grown within greenhouses in botanical gardens. *T. sebifera* is known to establish in disturbed environments in its invasive range (Renne *et al*. 1999; Jubinksy and Anderson 1996), so it is expected to be the same in the PRA area.

A moderate rating of likelihood of establishment in the PRA area in the manged environment has been given as the species has been shown to establish in these situations in similar climatic conditions to the EPPO region (EWG opinion). However, as this has yet to be realised in the EPPO region including the EU, a moderate rating of uncertainty is given.

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

11. Spread in the PRA area

Natural Spread

A variety of bird species (for example the European Starling outside of the EPPO region) have been recorded consuming and spreading the seeds of *T. sebifera*, contributing to new establishments and invasion success of *T. sebifera* in the Southern US (Renne *et al*. 1999; 2001; 2002; Jubinksy and Anderson 1996). *Triadica sebifera* can also spread along waterways, after heavy rains, flooding, or proximity to rivers and streams because seeds can float (Jubinksy and Anderson 1996; Bruce *et al*. 1997; NSW Factsheet 2017). In the US, under natural means, *T. sebifera* has been shown to spread up to 350 km over a 20-year period (pers. comm. Siemann, 2017). Therefore, natural spread is likely to facilitate transfer to suitable habitats in the EPPO region including EU Member States. At present however, the volume of movement will not support spread within the PRA area as the species is not present in the natural environment.

Human assisted spread

Deliberate planting of *T. sebifera* seeds or young plants remains the most likely form of human assisted spread. *Triadica sebifera* has the potential to be spread through the horticultural trade as numerous suppliers selling the species within the EPPO region (for example http://www.panglobalplants.com/). The species is currently present in a limited number of botanical gardens within the EPPO region including EU Member States. Human assisted spread and the likelihood of transfer to a suitable habitat is high within the PRA area.

A high rating of spread has been given as the species has the potential to be spread by birds over long distances and via waterbodies, coupled with the movement of the species by humans, with moderate uncertainty, as natural spread has not yet occurred in the PRA area

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

12. Impact in the current area of distribution

12.01 Impacts on biodiversity

In the USA, *T. sebifera* displaces native plant species and establishes dominant stands, and can transform areas of prairie and grassland to woody thickets within ten years (Bruce *et al*. 1995, Bruce *et al*. 1997, Siemann and Rogers 2003, Cameron and Spencer 1989). *Triadica sebifera* has been shown to invade south east coastal prairie that is the sole habitat of the federally endangered Attwater's prairie chicken (*Tympanuchus cupido attwateri*), the exclusive wintering ground of the federally endangered whooping crane (*Grus americana*), and important habitat for several other critically imperilled grassland birds. In addition, one federally endangered and 12 critically imperilled (category 11) plant species occur in the remaining fragments of this once vast system.

When leaf material becomes incorporated into the water body, this has shown to be toxic to amphibians (Cotton *et al*. 2012). Leonard (2008) showed that the leaf litter can impact the native habitat by: (1) Leaf litter has a direct effect on water quality (2) *T. sebifera* can cause differential survival and performance of tadpoles (3) Differences in water quality due to leaf litter can cause changes in tadpole behavior (4) *T. sebifera* leaf litter breaks down much faster than litter from native trees and this influences aquatic community composition.

Triadica sebifera exhibits rapid leaf decay, which may alter soil nutrients (primarily higher levels of nitrogen) in ecosystems with fewer deciduous trees. *Triadica sebifera* can alter nutrient cycling and the species composition of decomposers.

Triadica sebifera supports a lower diversity of arthropods than co-occurring native trees in Texas (Hartley *et al*. 2010) and native prairies it displaces (Hartley *et al*. 2004, Cameron and Spencer 2010).

The NSW Department of Primary Industries (2017) highlights that impacts seen in the US are similar to that seen in Australia.

At 15 years old, *T. sebifera* stands in Texas demonstrated significantly higher net primary productivity than adjacent native prairie (Harcombe *et al*. 1993). Cameron and Spencer (1989) found that in *T. sebifera* woodland the concentration of nutrients P, K, NO_3, N, Zn, Mn, and Fe were significantly higher than native prairie, while Mg and Na were significantly lower. *T. sebifera* exhibits rapid leaf decay, which may increase nutrient alteration in ecosystems with fewer deciduous trees (Cameron and Spencer 1989).

In invasive contexts, *T. sebifera* can alter nutrient cycling and species composition among decomposers (Weber 2003; Zou *et al* 2006; Cameron and Spencer 1989). Siemann and Rogers (2003) demonstrated that the competitive advantage displayed by *T. sebifera* in the Southern US may be due to escape from specialist herbivores. After comparing populations from the invasive range in Texas to populations from the native range in China, Siemann and Rogers (2005) concluded that "invasive *Sapium* ecotypes have a greater capacity to compensate for herbivory damage than native *Sapium* ecotypes."

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

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

12.01. Impacts on ecosystem services

Ecosystem service	**Does the IAS impact on this Ecosystem service?** Yes/No	**Short description of impact**	**Reference**
Provisioning	Yes	*T. sebifera* can decrease water quality. The species can also displace native species reducing genetic resources.	Leonard 2008
Regulating	Yes	*T. sebifera* seedlings can establish at such high densities that fine fuels are lacking even in a stand of smaller trees. These changes in fuel characteristics result in patchier and/or less severe fires, negatively impacting native species (Meyer 2011). *T. sebifera* may render some areas inflammable. *T. sebifera* stands in Texas demonstrated higher net productivity than the original grassland ecosystem.	Meyer 2011; Grace 1998, Weber 2003; Zou *et al* 2006; Cameron and Spencer 1989; Harcombe *et al*. 1993
Cultural	Yes	Transforms grassland into woody thickets which can reduce human access to areas for recreational purposes and possibly adjacent waterways.	Bruce *et al*. 1997; Jubinksy and Anderson 1996

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

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

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

Removal of large trees is expensive (mulching can cost up to $1 000 per acre) and *T. sebifera* will regenerate if not fully excavated (Jubinksy and Anderson, 1996, USDA, 2000, Meyer, 2011). However, current management practices are to apply herbicide to cut stumps. In addition, following up monitoring will be needed to exhaust the seed bank in areas under control. This will incur additional costs. In the USA, the species has been shown to degrade pasture land (Pile *et al*. 2017).

Human contact with the sap can causes irritation and ingesting any part of this plant can cause gastrointestinal upset, nausea, and vomiting (USDA, 2000). The species is also toxic to livestock (Russell *et al*. 1969).

Based on the cost of removal and the fact that the species has been shown to cause impacts to human and livestock a moderate rating of socio-economic impact has been given, with low uncertainty.

Rating of the magnitude of 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

As *T. sebifera* is absent from the natural environment in the EPPO region, all data on impacts comes from other regions of the invaded range. Thus, all information on impacts can only be used as a proxy to the EPPO region including the EU territory.

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

The habitats where the species has biodiversity and ecosystem service impacts in the US are present in the EPPO region, and EU territory in particular, including coastal habitats, woodland and forests (including riparian forests), grassland, land sparsely wooded and heathland. In similar climatic conditions to the PRA area, such as California, the species has been recorded as naturalised with the potential to spread along low lying riparian habitats (Bower *et al*. 2009). On the basis of climatic and habitat similarity, similar impacts may be expected for the EPPO region and the and EU territory.

However, in the most severely affected region, the Southern USA, it is possible that a high propagule pressure exacerbated the impact. The USDA began promoting the large-scale planting of *T. sebifera* in the Gulf Coast states in the early 1900s (though potentially as early as the 1700s (Pile *et al*. 2017). *T Triadica sebifera* has been widely grown and planted for ornamental trade in Houston, Texas alone (USDA 2000; Carmarillo *et al*. 2015). Therefore, without this propagule pressure occurring in the EPPO region, such impacts may not be realised.

In addition, warm, moist low-lying forest and coastal grasslands feature more prominently in the USA Gulf States than across the PRA region. The most severe impact of *T. sebifera* is the conversion of grassland to woody thickets.

Based on climate modelling (see appendix 1), the areas that would face the greatest risk of severe impact are wet grasslands and riparian woodlands in the Mediterranean and Black Sea.

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

13.01. Negative impacts on biodiversity

A higher rating for uncertainty (compared to the current area of distribution) reflects the fact that the species is not currently present in the natural environment within the EPPO region and EU Member States.

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

13.02. Negative impact the pest may have on categories of ecosystem services

A higher rating for uncertainty (compared to the current area of distribution) reflects the fact that the species is not currently present in the natural environment within the EPPO region and EU Member States.

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

13.03 Socio-economic impact of the species

A lower rating of socio-economic impact and a higher rating of uncertainty (compared to the current area of distribution) reflects the fact that the species is not present in the EPPO region and EU Member States and thus management costs and other associated costs would not be as significant as in the invaded range.

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

14. Identification of the endangered area

The EWG considers that the endangered area is primarily woodland and forests, grassland, land sparsely wooded, heathland and dune slacks within the Mediterranean and Black Sea biogeographic regions. Within this area, habitats most susceptible are those with sufficient soil moisture such as margins of small waterbodies (e.g. rivers, ponds or lakes). Although there is limited suitability in other regions, e.g. the Atlantic areas, the EWG considers that these areas are less likely to be at risk from invasion.

The model predicts a region of potential suitability for *T. sebifera* in southern Europe (Figure 5). Countries in which *T. sebifera* may be capable of establishing widely include all those bordering the northern Mediterranean Sea, from Portugal to Turkey. The model predicts that establishment in most of the rest of Europe (see Figure 6) is less likely because of low summer temperature. In addition, moisture is expected to be limiting in central Spain and frost may reduce suitability in far eastern central Europe (Figure 6).

In terms of Biogeographical Regions those predicted to be most suitable for *T. sebifera* establishment in the current climate are the Mediterranean and Black Sea biogeographical regions, including the following countries EU: Portugal, Spain, southern coast of France, Italy, Croatia, and Greece.

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.

The climate change projections for the 2070s suggest that under the less extreme RCP4.5 scenario the suitable region in Europe will have extended northwards, especially in western Europe where warmer summers may mean that the southern United Kingdom and the southern Baltic coast become more suitable (Figure 7). Under the more extreme RCP8.5 scenario, the northwards expansion is even greater, especially in eastern Europe (Figure 8). This is likely driven by a relaxation of frost constraints.

In the evaluated climate change scenarios, predicted suitability was stable in the Mediterranean but increased in the Black Sea. Other biogeographic regions predicted to strongly increase in suitability are Atlantic, Continental, Pannonian and Steppic (Figure 9). The climate change projections for the 2070s suggest that under the less extreme RCP4.5 scenario the suitable region in Europe will have extended northwards, especially in western Europe where warmer summers mean the species may be capable of establishing in southern United Kingdom and the southern Baltic coast (Figure 7). Under the more extreme RCP8.5 scenario, the northwards expansion is even greater, especially in eastern Europe (Figure 8). This is likely driven by a relaxation of frost constraints. The countries within the endangered area under climate change include: Portugal, France, Germany, Ukraine, Georgia, Turkey, Russia, Greece, Albania, Bosnia and Herzegovina, Croatia, Slovenia, Austria, Hungary, Italy, and the north coastline of Algeria.

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

Climate projection: 2070

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

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

Are the **introduction pathways** likely to change due to climate change? **(If yes, provide a new risk and uncertainty score)**	**Reference**
No. The introduction pathways are unlikely to change (moderate with moderate uncertainty) as a result of climatic change because the primary pathway for entry into the EPPO region is intentional landscape plantings.	EWG opinion
Is the **risk of establishment** likely to change due to climate change? **(If yes, provide a new risk and uncertainty score)**	**Reference**
Yes. The area climatically suitable for *T. sebifera* will increase, therefore the risk of establishment in the overall EPPO region will increase as well. If precipitation increases due to climate change *T. sebifera* could increase the possibility of establishment. The rating for establishment is increased from moderate to high with high uncertainty for the natural environment and from moderate to high with a high uncertainty for the managed environment.	Wang *et al*. 2011; Gan *et al*. 2009
Is the **risk of spread** likely to change due to climate change? **(If yes, provide a new risk and uncertainty score)**	**Reference**
In the PRA region, winter temperature is a major limiting factor for the establishment and spread of *T. sebifera*. If average winter temperatures increase due to climate change, potential range of *T. sebifera* could increase as well. The rating of spread will remain high and the uncertainty will raise from low to high	(See climate modelling appendix)
Will **impacts** change due to climate change? **(If yes, provide a new risk and uncertainty score)**	**Reference**
With increasing temperature it is possible *T. sebifera* may impact the EPPO region as the area of suitability increases. Given the majority of suitable land in the EPPO region is at the northern limits of *T. sebifera* establishment, higher temperatures could cause more	EWG opinion

rapid growth and biomass accumulation, resulting in greater impacts to native species. However, the rating for impact on biodiversity and ecosystem services will remain high with high uncertainty and socio-economic impacts will increase from low to moderate with a high uncertainty.	

16. Overall assessment of risk

The results of this PRA show that *Triadica sebifera* poses a high risk to biodiversity in the endangered area (Mediterranean and Black Sea biogeographical region) with a high uncertainty. *Triadica sebifera* is an aggressive invader in the southern United States. The most serious effects of invasion appear to have occurred following widespread commercial and ornamental planting of the species (USDA 2008; Scheld and Cowles 1981; Bruce *et al*. 1997). While it displays broad habitat suitability, *T. sebifera* appears limited by cold winter temperatures and steep gradients (Gan *et al*. 2009; USDA 2008). Warmer regions in the PRA area, specifically the Mediterranean, face the highest risk of *T. sebifera* establishment. However, there is currently no evidence of *T. sebifera* establishment in the PRA region.

Pathways for entry:

Plants for planting

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

Likelihood of establishment in the natural environment in the PRA area

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

Likelihood of establishment in managed environment in the PRA area

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

Spread in the PRA area

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

Impacts
Impacts on biodiversity and the environment

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

Impacts on ecosystem services

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

Socio-economic impacts

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

Impacts in the PRA area

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

Impacts on biodiversity in the PRA area

Rating of magnitude of impact on biodiversity in the area of potential establishment	*Low* □	*Moderate* □	*High* X
Rating of uncertainty	*Low*	*Moderate* □	*High* X

Impact on ecosystem services in the PRA area

Rating of magnitude of impact on ecosystem services in the area of potential establishment	*Low* □	*Moderate* □	*High* X
Rating of uncertainty	*Low*	*Moderate* □	*High* X

Socio-economic impact in the PRA area

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

17. Uncertainty

There is a high uncertainty for establishment in the natural environment within the EPPO region. The species has historically been planted within the EPPO region but it has not shown any signs of invasiveness. In the US, establishment has been aided by high propagule pressure where the USDA began promoting the large-scale planting of *T. sebifera* in the Gulf Coast states in the early 1900s. *T. sebifera* was widely planted as an ornamental in Houston during the 1950 -1980s (USDA 2000; Carmarillo *et al*. 2015). Therefore, without this propagule pressure occurring in the EPPO region, such impacts may not be realised. Finally, a high level of uncertainty has been highlighted for impacts on biodiversity and ecosystem services. This uncertainty is linked to the uncertainty in establishment and the low propagule pressure in the absence of widespread planting. The high uncertainty of invasion risk within the PRA area is further supported by a lack of information concerning the source and amount of plant material introduced from outside of the EPPO region.

Uncertainty relating to the modelling includes:

Modelling the potential distributions of range-expanding species is always difficult and uncertain. We did not have sufficient information to determine whether all records used in the modelling were from established populations rather than plantations. If the latter were included, management to alleviate climatic stresses (such as irrigation) may have caused the model to over-estimate the niche breadth and potential establishment distribution of *T. sebifera*.
Triadica sebifera is largely restricted to wet micro-habitats such as river banks in the more arid parts of its global distribution (e.g. California and Mexico), so it is likely that establishment in the more arid parts of the suitable region in Europe would also be restricted to such habitats. Although we attempted to model this interaction by including river density in the model, local habitat factors are unlikely to be well represented at the scale of the model.
The limiting factors map may have under-estimated the limiting influence of winter temperatures in Europe, since two of the algorithms in the ensemble did not model a strong limitation of suitability at very cold temperatures. This will have raising the ensemble model suitability response to very cold winter temperatures.
Other variables potentially affecting the distribution of the species, such as edaphic variables, were not included in the model.
To remove spatial recording biases, the selection of the background sample was weighted by the density of Tracheophyte records on the Global Biodiversity Information Facility (GBIF). While this is preferable to not accounting for recording bias at all, a number of factors mean this may not be the perfect null model for species occurrence:

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

18. Remarks

The EWG recommend that *Triadica sebifera* is not utilised as a bioenergy crop within the EPPO region. At the present time this has not be realised in the EPPO region. Low and Booth (2007) state: US Biofuel company AgriBioFuels claims that Chinese tallow can produce 500 gallons of oil per acre, compared to 48 gallons for soybeans. They are working with Texas A&M Research Centre to develop the plant as a crop. Oil company Chevron has built a biodiesel plant in Texas, and Chinese tallow is considered a major potential feedstock. There has also been interest in Australia. A 2001 report on biofuels by the Western Australian Department of Agriculture recommended Chinese tallow as one of several oil-bearing plants “that should undergo some preliminary studies in Western Australia”. Its potential has been discussed on the Biofuels Forum, the forum of the Australian Biofuel Users group.

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Appendix 1: Projection of climatic suitability for *Triadica sebifera* establishment

Aim

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

Data for modelling

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

- Mean minimum temperature of the coldest month (Bio6 °C) reflecting exposure to frost. *Triadica sebifera* suffers substantial damage after exposure to freezing temperatures for 36 hours or more (Grace *et al.* 2000). In its invaded range in North America, *T. sebifera* did not occur at survey sites where the mean minimum temperature in January was below –12 °C (Gan *et al.* 2009).
- Mean temperature of the warmest quarter (Bio10 °C) reflecting the growing season thermal regime. Previous CLIMEX modelling inferred a lower temperature threshold for growth of 12 °C, optimal growing conditions between 24 and 35 °C and an upper temperature threshold of 40 °C (Pattison & Mack, 2008).
- Climatic moisture index (CMI, ratio of mean annual precipitation, Bio12, to PET) reflecting plant moisture regimes. *Triadica sebifera* occurrence may be restricted by drought since plantations in arid regions are irrigated (Kirmse & Fisher, 1989).
- Temperature seasonality (Bio15, coefficient of variation for monthly precipitations) as another measure of the moisture regime. *Triadica sebifera* is likely to favour even precipitation regimes where periods of drought stress are minimal.
- Precipitation of the coldest quarter (Bio19, mm) as winter recharge of soil moisture is likely to minimise drought stress of germinating seedlings in spring.

To estimate the effect of climate change on the potential distribution, equivalent modelled future climate conditions for the 2070s under the Representative Concentration Pathway (RCP) 4.5 and 8.5 were also obtained. For both scenarios, the above variables were obtained as averages of outputs of eight Global Climate Models (BCC-CSM1-1, CCSM4, GISS-E2-R, HadGEM2-AO, IPSL-CM5A-LR, MIROC-ESM, MRI-CGCM3, NorESM1-M), downscaled and calibrated against the WorldClim baseline (see http://www.worldclim.org/cmip5_5m).
RCP 4.5 is a moderate climate change scenario in which CO_2 concentrations increase to approximately 575 ppm by the 2070s and then stabilise, resulting in a modelled global temperature rise of 1.8 C by 2100. RCP8.5 is the most extreme of the RCP scenarios, and may therefore represent the worst case scenario for reasonably anticipated climate change. In RCP8.5 atmospheric CO_2 concentrations increase to approximately 850 ppm by the 2070s, resulting in a modelled global mean temperature rise of 3.7 °C by 2100.
In the models the following habitat variables were also included:

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

- Tree cover as *T. sebifera* may be restricted from closed canopy forest (Bruce, 1993, Jones & McLeod, 1989). 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, from which mean cover was aggregated to the 0.25 x 0.25 degree grid.
- Density of permanent rivers was estimated from the Vector Map (VMAP0; http://gis-lab.info/qa/vmap0-eng.html). River vectors were rasterised at 0.02 x 0.02 degree resolution. Then, the percentage of these grid cells containing rivers within each of the 0.25 x 0.25 degree cells used in the model was calculated.

Species occurrence data were obtained from the Global Biodiversity Information Facility (GBIF), USDA Biodiversity Information Serving Our Nation (BISON), Berkeley Ecoinformatics Engine and Eddmaps. Occurrence records were scrutinised to remove those from regions where the species is not known to be well established, those that appeared to be dubious or planted specimens (e.g. plantations, botanic gardens) and those where the georeferencing was too imprecise (e.g. records referenced to a country or island centroid) or outside of the coverage of the predictor layers (e.g. small island or coastal occurrences). The remaining records were gridded at a 0.25 x 0.25 degree resolution for modelling (Figure 1a). In total 858 grid cells contained records of *T. sebifera*.
Additionally, the recording density of vascular plants (phylum Tracheopthyta) on GBIF was obtained as a proxy for spatial recording effort bias (Figure 1b).

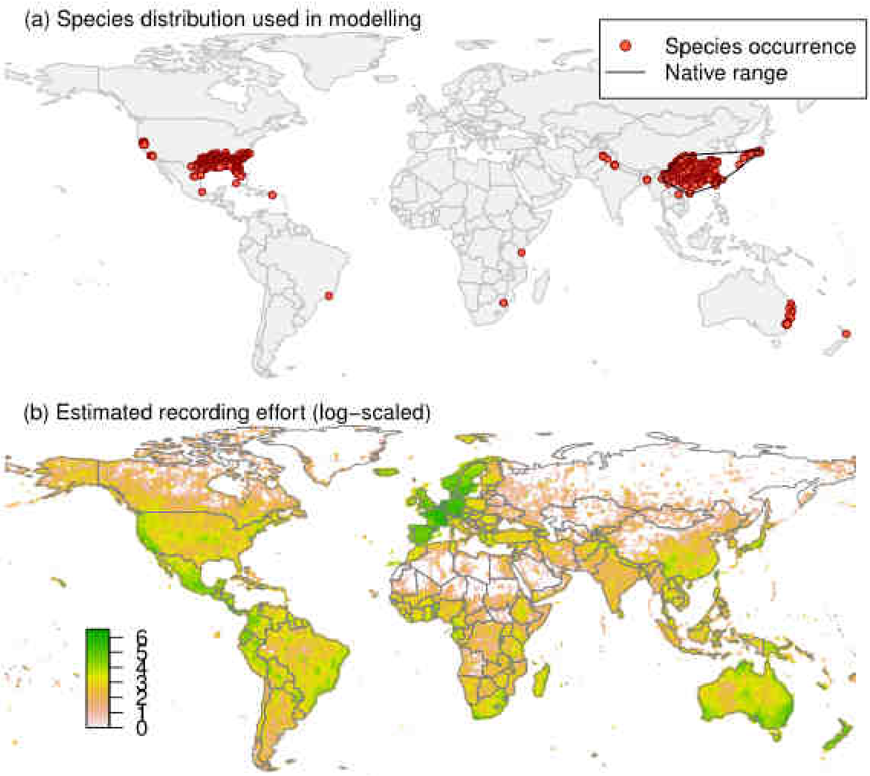


Figure 1. (a) Occurrence records obtained for *Triadica sebifera* and used in the modelling, showing the native range and (b) a proxy for recording effort – the number of Tracheophyta records held by the Global Biodiversity Information Facility, displayed on a $\log_{10}$ scale.

Species distribution model

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

- The area accessible by native *T. sebifera* populations (see Fig. 1a), in which the species is likely to have had sufficient time to disperse to all locations. The accessible native region was defined as a 300 km buffer around the minimum convex polygon bounding all native occurrences in East Asia; AND
- A relatively small 30 km buffer around all non-native occurrences, encompassing regions likely to have had high propagule pressure for introduction by humans and/or dispersal of the species; AND
- Regions where we have an *a priori* expectation of high unsuitability for the species (see Figure 2). Absence from these regions is considered to be irrespective of dispersal constraints. Based on published ecophysiological information described above and the extremes of the climatic predictors at the species occurrences the following rules for unsuitability were applied:
    - Mean minimum temperature of the coldest month (Bio6) < -5 °C.
    - Mean temperature of the warmest quarter (Bio10) < 16 °C.
    - Mean temperature of the warmest quarter (Bio10) > 29 °C.
    - Climatic moisture index (CMI) < 0.45.
    - Precipitation of coldest quarter (Bio19) < 20 mm.

In all, 3.7 % of occurrence grid cells exceeded any one of these thresholds. From this background region, ten samples of 10,000 randomly chosen grid cells were obtained (Figure 2). To account for recording effort bias, sampling of background grid cells was weighted in proportion to the Tracheophyte recording density (Figure 1b).

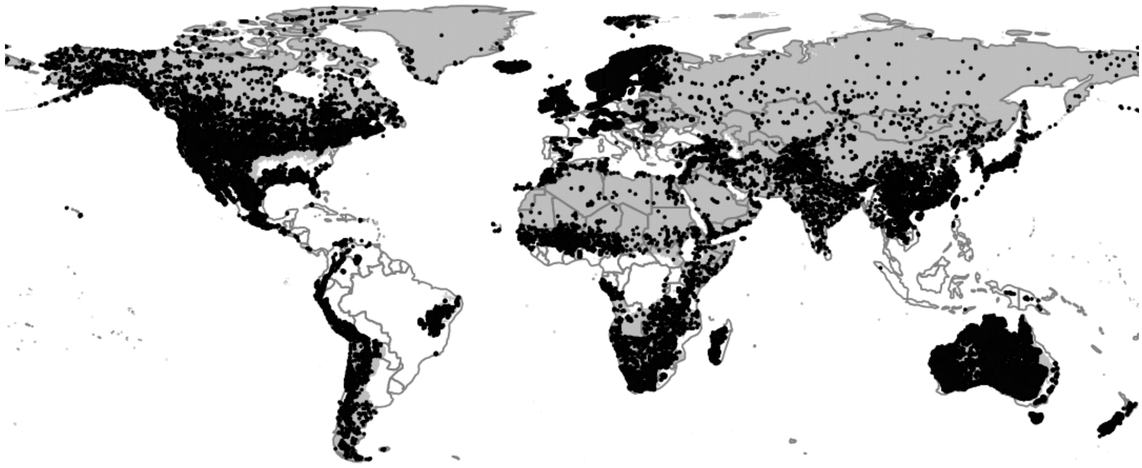


Figure 2. Randomly selected background grid cells used in the modelling of *Triadica sebifera*, mapped as black points. Points are sampled from the native range, a small buffer around non-native occurrences and from areas expected to be highly unsuitable for the species (grey background region), and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

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

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

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

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

rejected. In this way, ensemble projections were made for each dataset and then averaged to give an overall suitability.
Global model projections were made for the current climate and for the two climate change scenarios, avoiding model extrapolation beyond the ranges of the input varaibles. The optimal threshold for partitioning the ensemble predictions into suitable and unsuitable regions was determined using the 'minimum ROC distance' method. This finds the threshold where the Receiver-Operator Curve (ROC) is closest to its top left corner, i.e. the point where the false positive rate (one minus specificity) is zero and true positive rate (sensitivity) is one.
Limiting factor maps were produced following Elith *et al*. (2010). For this, projections were made separately with each individual variable fixed at a near-optimal value. These were chosen as the median values at the occurrence grid cells. Then, the most strongly limiting factors were identified as the one resulting in the highest increase in suitability in each grid cell. Partial response plots were also produced by predicting suitability across the range of each predictor, with other variables held at near-optimal values.

Results
The ensemble model suggested that suitability for *T. sebifera* was most strongly determined by summer temperature, moisture availability and winter temperature (Table 1). From Figure 3, suitability was restricted by low summer temperature, drought and low winter temperatures. A weaker preference for human-influenced regions, wet winters, and even precipitation regimes was also modelled, but tree cover and river density had very little effect at the scale of the model. For all predictors, there was substantial variation in the partial response plots between algorithms (Figure 3).
Global projection of the model in current climatic conditions indicates that the main clusters of native and known invaded records fell within regions predicted to have high suitability (Figure 4). The model predicts potential for further northwards expansion of the non-native range in North America, as well as in South America and southern Africa, where there are currently very few records of invasive populations (Figure 4).

The model predicts a region of potential suitability for *T. sebifera* in southern Europe (Figure 5). Countries in which *T. sebifera* may be capable of establishing widely include all those bordering the northern Mediterranean Sea, from Portugal to Turkey, as well as the Black Sea coasts of Turkey, Georgia and Russia. The model predicts that establishment in the rest of Europe will largely be prevented because of low summer temperature, with moisture limitation in central Spain and frost limitation in far eastern central Europe (Figure 6).

The climate change projections for the 2070s suggest that under the less extreme RCP4.5 scenario the suitable region in Europe will have extended northwards, especially in western Europe where warmer summers mean the species may be capable of establishing in southern United Kingdom and the southern Baltic coast (Figure 7). Under the more extreme RCP8.5 scenario, the northwards expansion is even greater, especially in eastern Europe (Figure 8). This is likely driven by a relaxation of frost constraints.

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

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

Algorithm	**Predictive AUC**	**In the ensemble**	**Variable importance**						
			Minimum temperature of coldest month	**Mean temperature of warmest quarter**	**Climatic moisture index**	**Precipitation seasonality**	**Precipitation of coldest quarter**	**Human influence index**	**Tree cover**
GBM	0.9797	yes	13%	47%	32%	0%	6%	1%	0%
GAM	0.9773	yes	18%	42%	24%	1%	3%	11%	1%
ANN	0.9765	yes	21%	38%	26%	2%	4%	6%	4%
MARS	0.9752	yes	17%	44%	29%	1%	3%	5%	0%
Maxent	0.9713	yes	17%	45%	17%	7%	8%	5%	1%
RF	0.9707	yes	6%	67%	10%	5%	4%	5%	2%
GLM	0.9706	yes	20%	47%	22%	0%	1%	7%	2%
FDA	0.9649	yes	9%	67%	17%	0%	6%	0%	0%
CTA	0.9435	no	19%	38%	30%	4%	7%	2%	1%
MEMLR	0.8507	no	15%	21%	7%	31%	16%	1%	9%
Ensemble	0.9788		15%	50%	22%	2%	5%	5%	1%

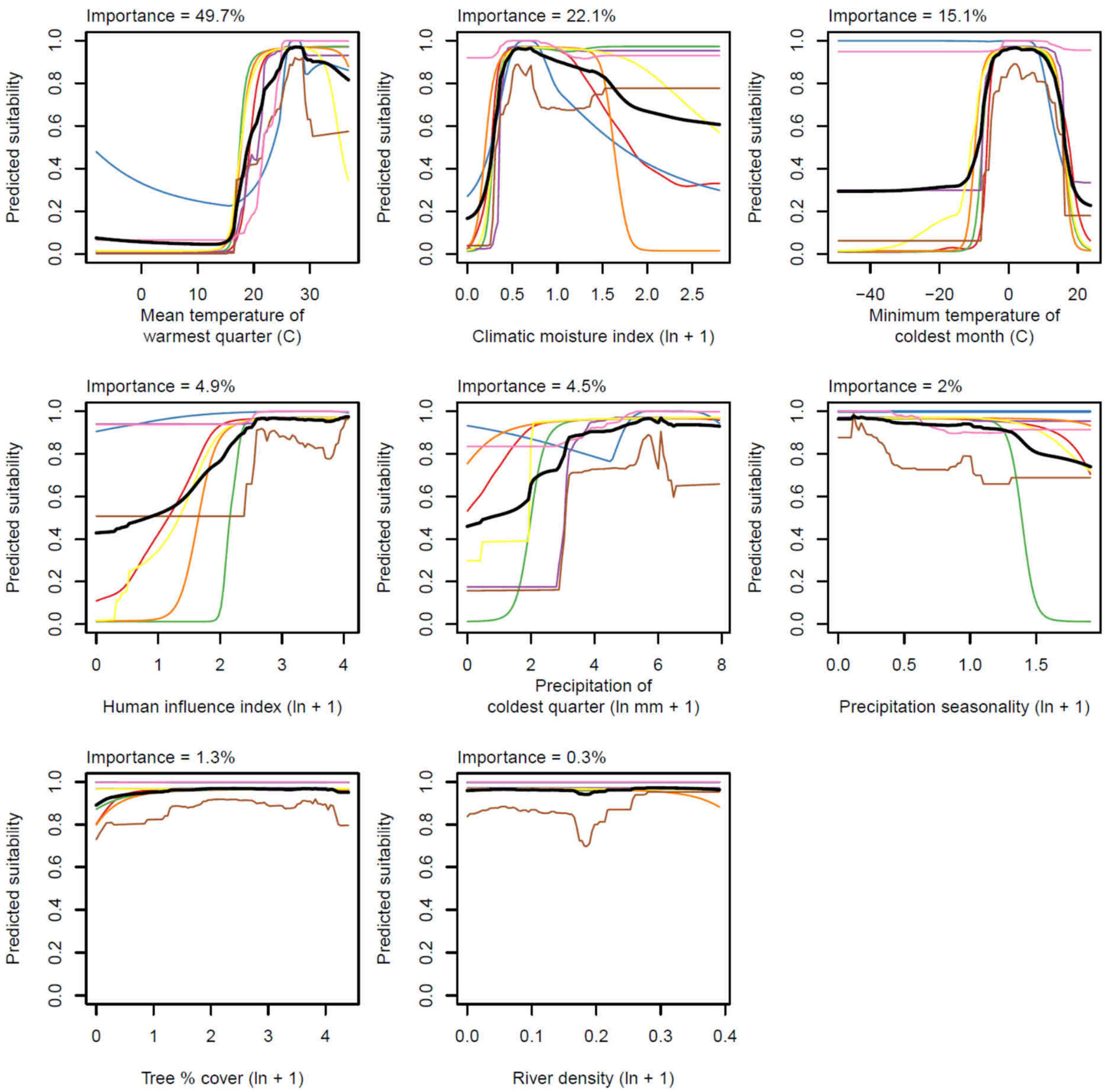


Figure 3. Partial response plots from the fitted models, ordered from most to least important. Thin coloured lines show responses from the algorithms in the ensemble, while the thick black line is their ensemble. In each plot, other model variables are held at their median value in the training data.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

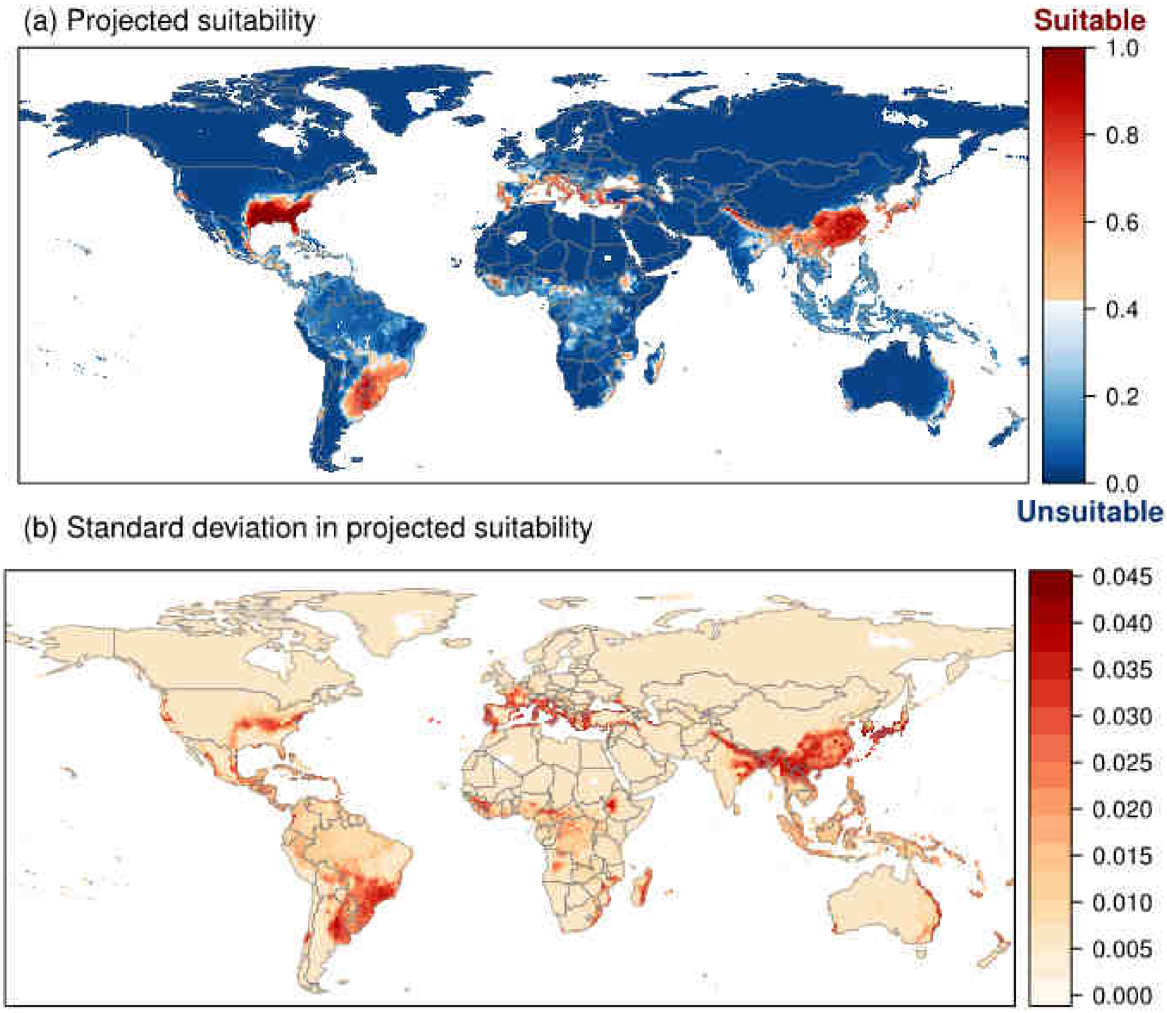


Figure 4. (a) Projected global suitability for *Triadica sebifera* establishment in the current climate. For visualisation, the projection has been aggregated to a 0.5 x 0.5 degree resolution, by taking the maximum suitability of constituent higher resolution grid cells. Red shading indicates suitability.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

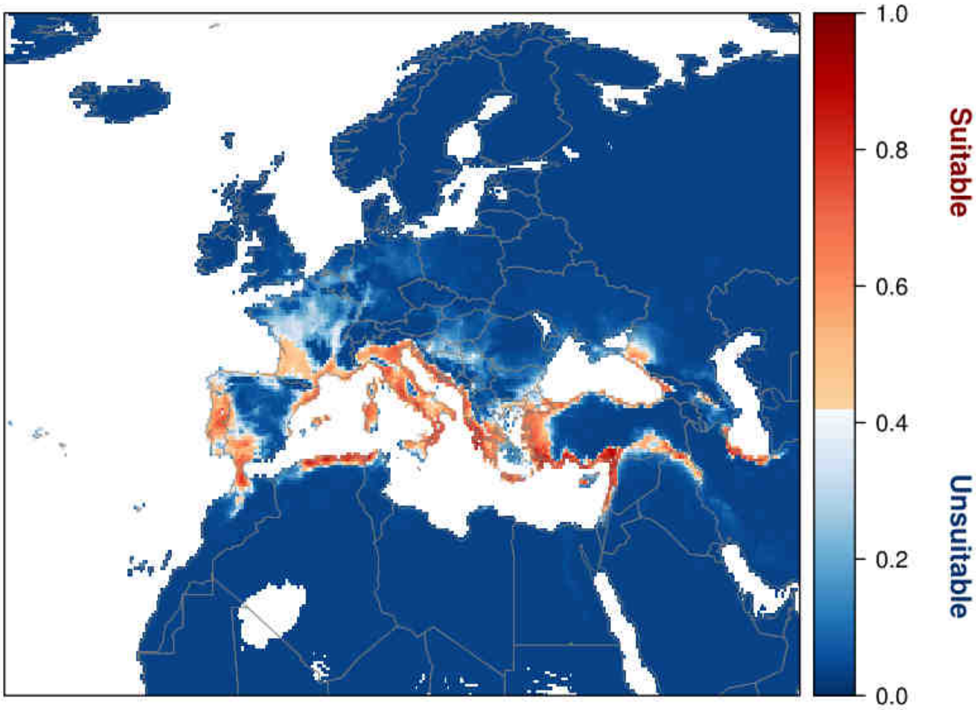


Figure 5. Projected current suitability for *Triadica sebifera* establishment in Europe and the Mediterranean region. The white areas have climatic conditions outside the range of the training data so were excluded from the projection.

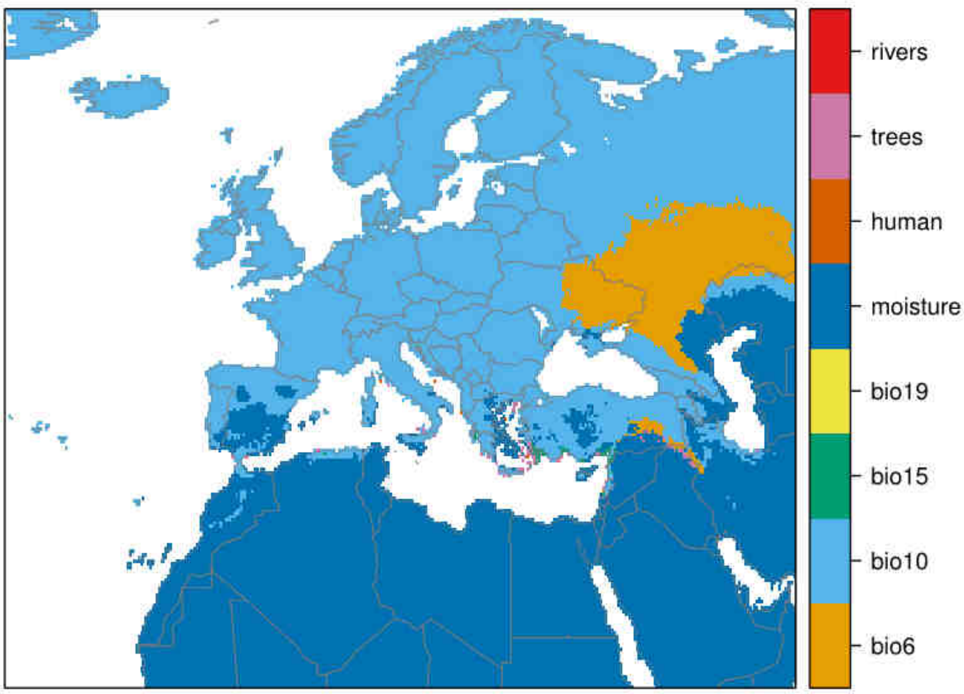


Figure 6. Limiting factor map for *Triadica sebifera* establishment in Europe and the Mediterranean region in the current climate. Shading shows the predictor variable most strongly limiting projected suitability, which is most informative for places predicted unsuitable for the species. See section 'data for modelling' for information relating to Bio6-19.

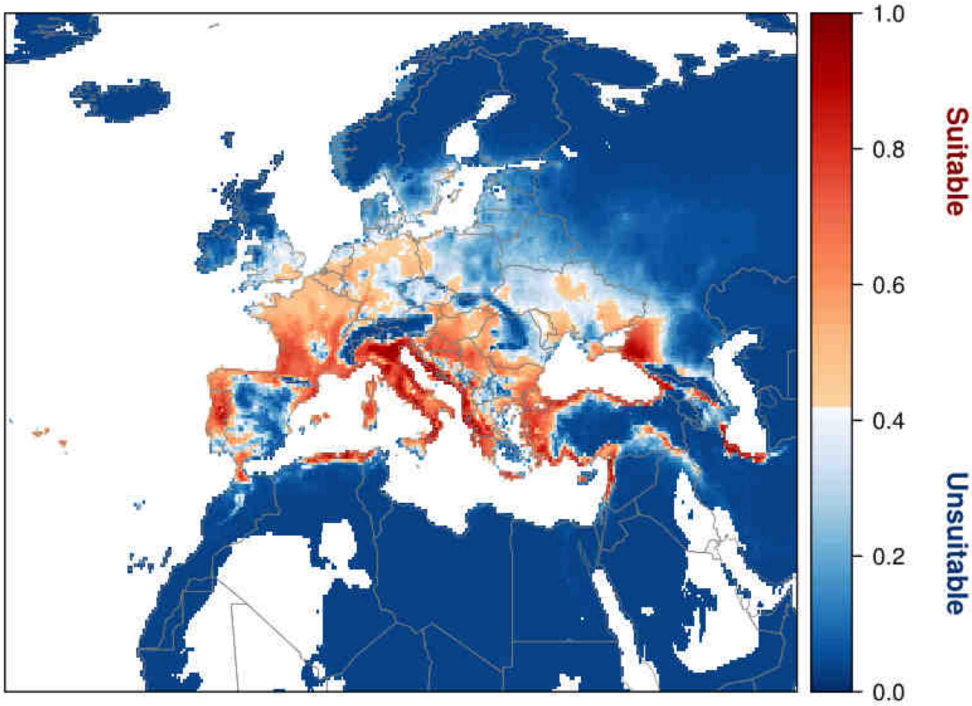


Figure 7. Projected suitability for *Triadica sebifera* establishment in Europe and the Mediterranean region in the 2070s under climate change scenario RCP4.5, equivalent to Figure 5.

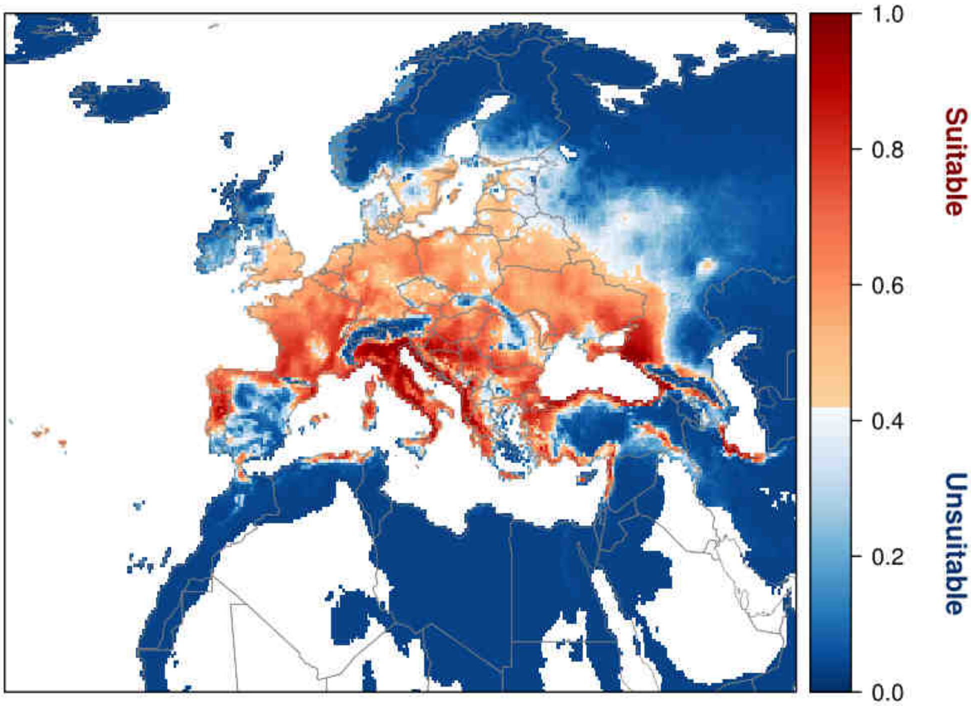
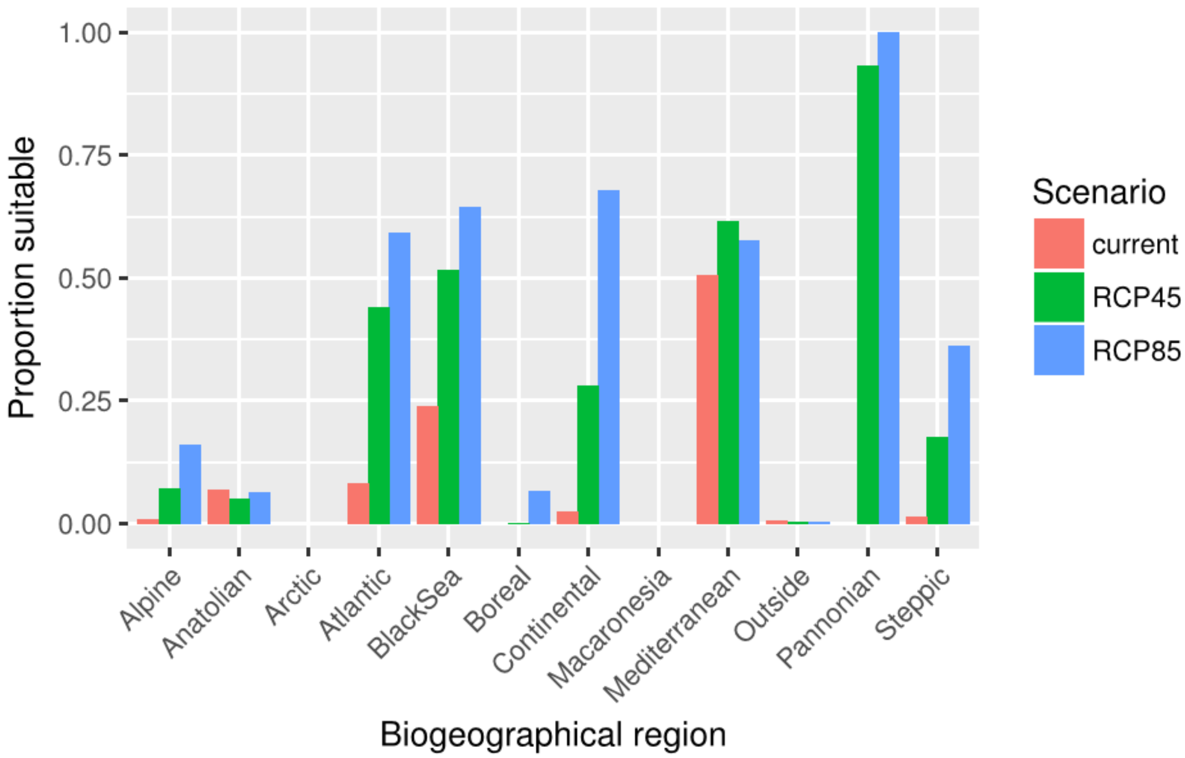


Figure 8. Projected suitability for *Triadica sebifera* establishment in Europe and the Mediterranean region in the 2070s under climate change scenario RCP8.5, equivalent to Figure 5.



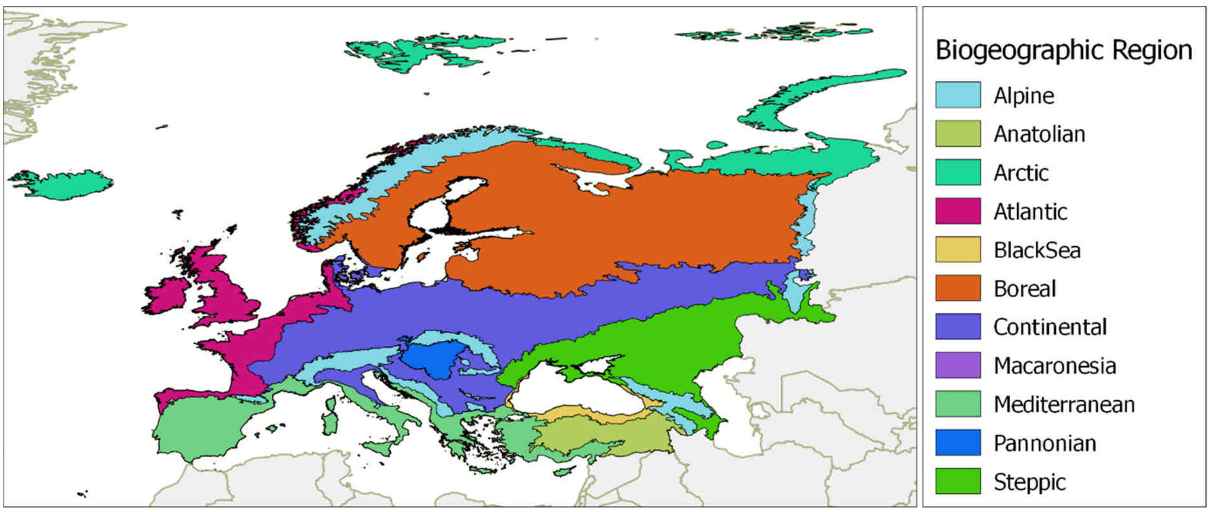


Figure 9. Variation in projected suitability among Biogeographical regions of Europe. The bar plots show the proportion of grid cells in each region classified as suitable in the current climate and projected climate for the 2070s under emissions scenarios RCP4.5 and RCP8.5. The coverage of each region is shown in the map below.

Caveats to the modelling

Modelling the potential distributions of range-expanding species is always difficult and uncertain. We did not have sufficient information to determine whether all records used in the modelling were from established populations rather than plantations. If the latter were included, management to alleviate climatic stresses (such as irrigation) may have caused the model to over-estimate the niche breadth and potential establishment distribution of *T. sebifera*.

Triadica sebifera is largely restricted to wet micro-habitats such as river banks in the more arid parts of its global distribution (e.g. California and Mexico), so it is likely that establishment in the more arid parts of the suitable region in Europe would also be restricted to such habitats. Although we attempted to model this interaction by including river density in the model, local habitat factors are unlikely to be well represented at the scale of the model.

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

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

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

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

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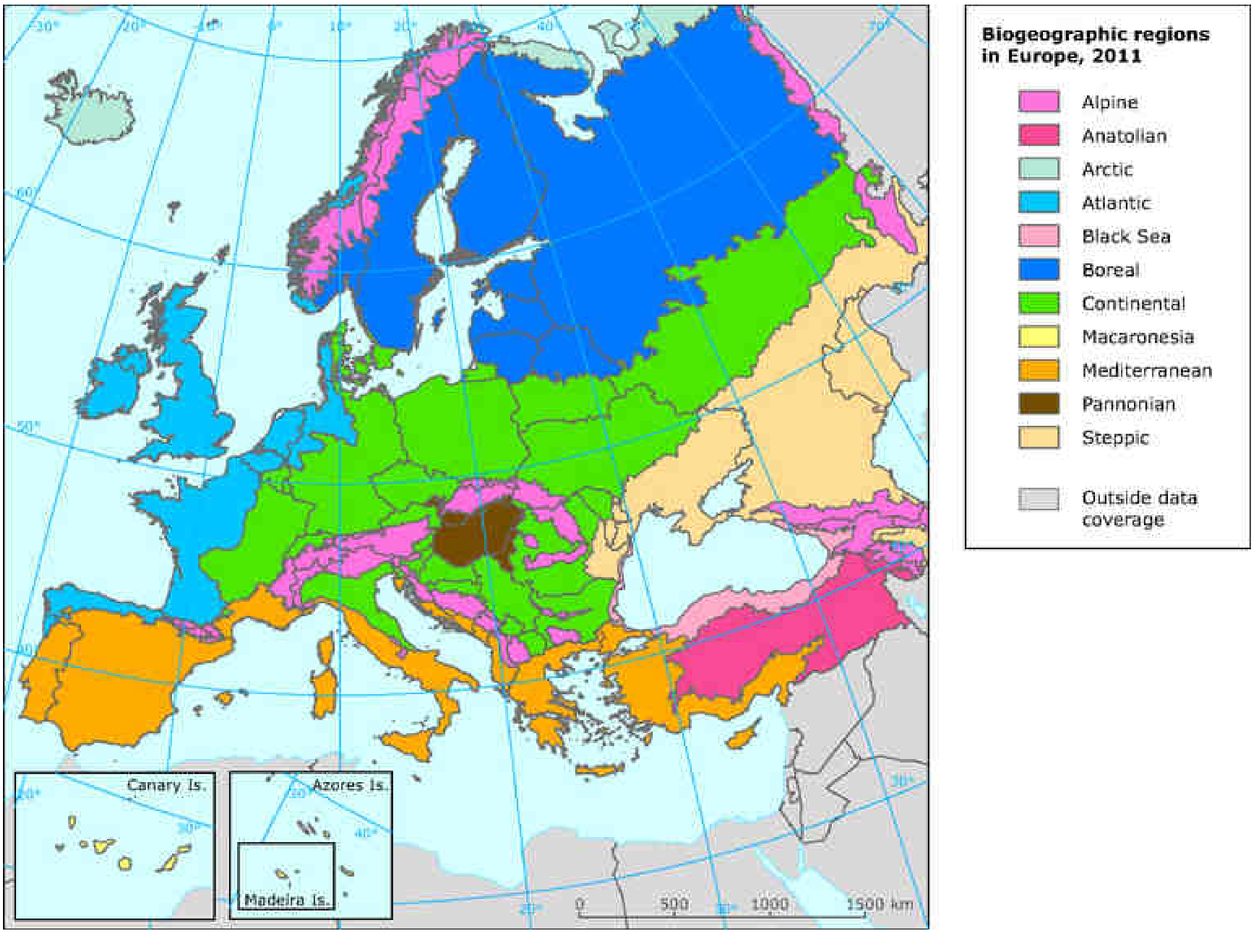
Appendix 2. Biogeographical regions



Appendix 3: Images

Figure 1. *Triadica sebifera* invasion in North America

Figure 2. *Triadica sebifera* trunk

Figure 3. *Triadica sebifera* fruits

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

Member States:

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

Biogeographical regions

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

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

Appendix 5: Distribution maps[4]

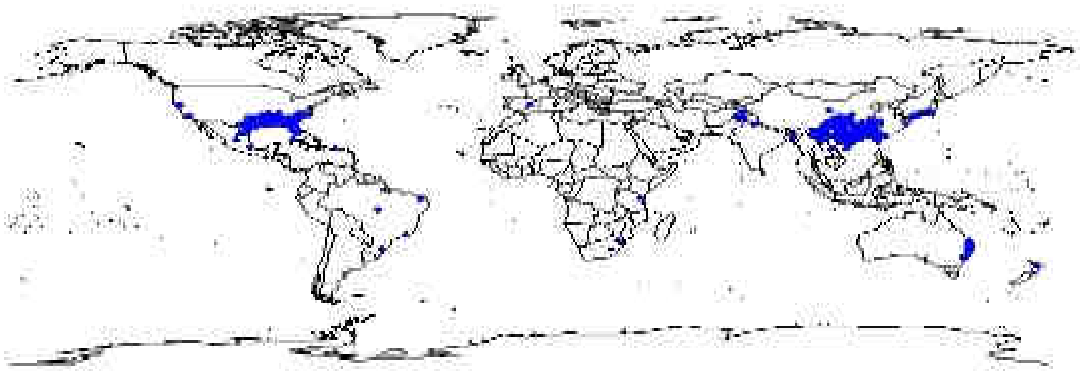


Figure 1. Global distribution of *Triadica sebifera*

[4] 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.

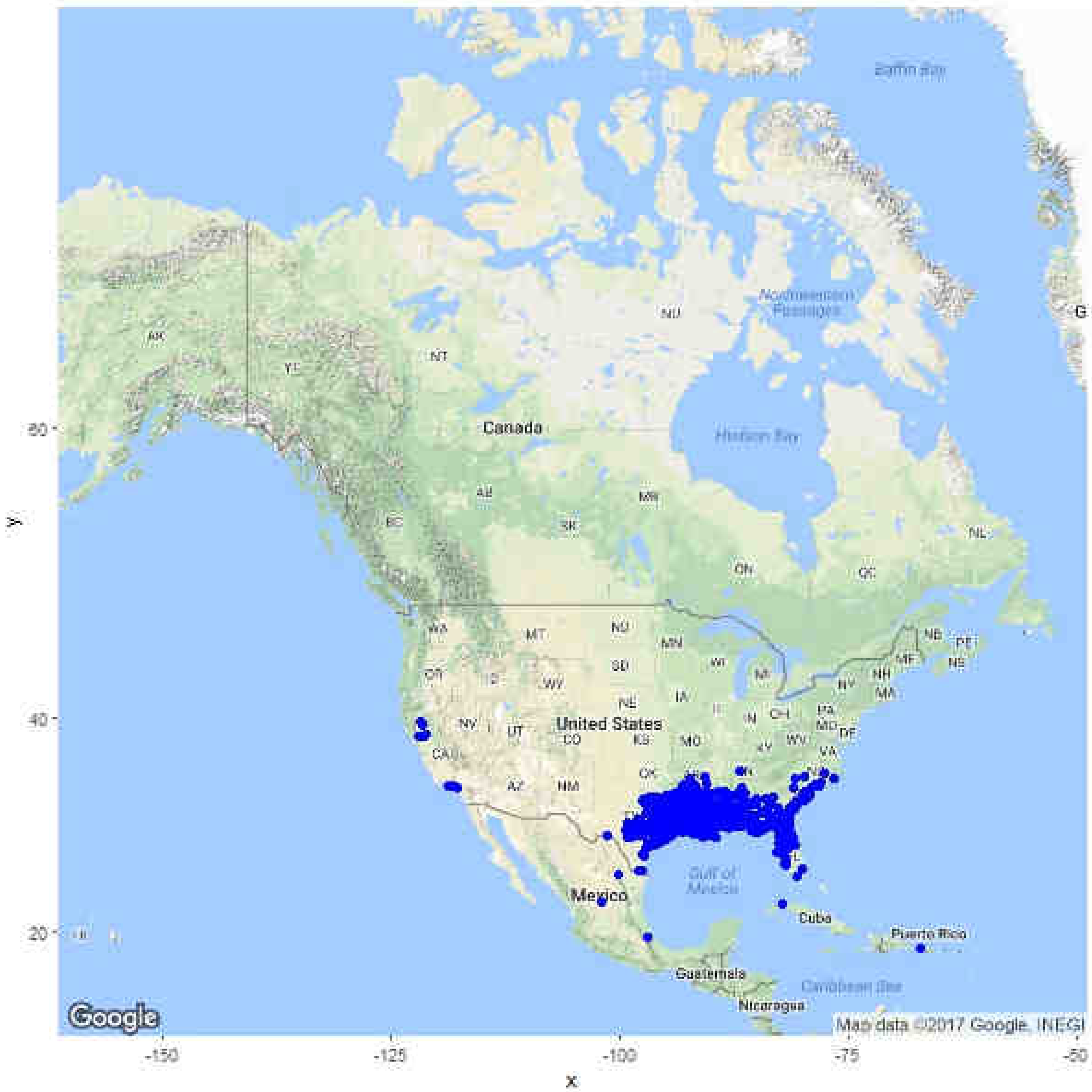


Figure 2. North American distribution for *Triadica sebifera*

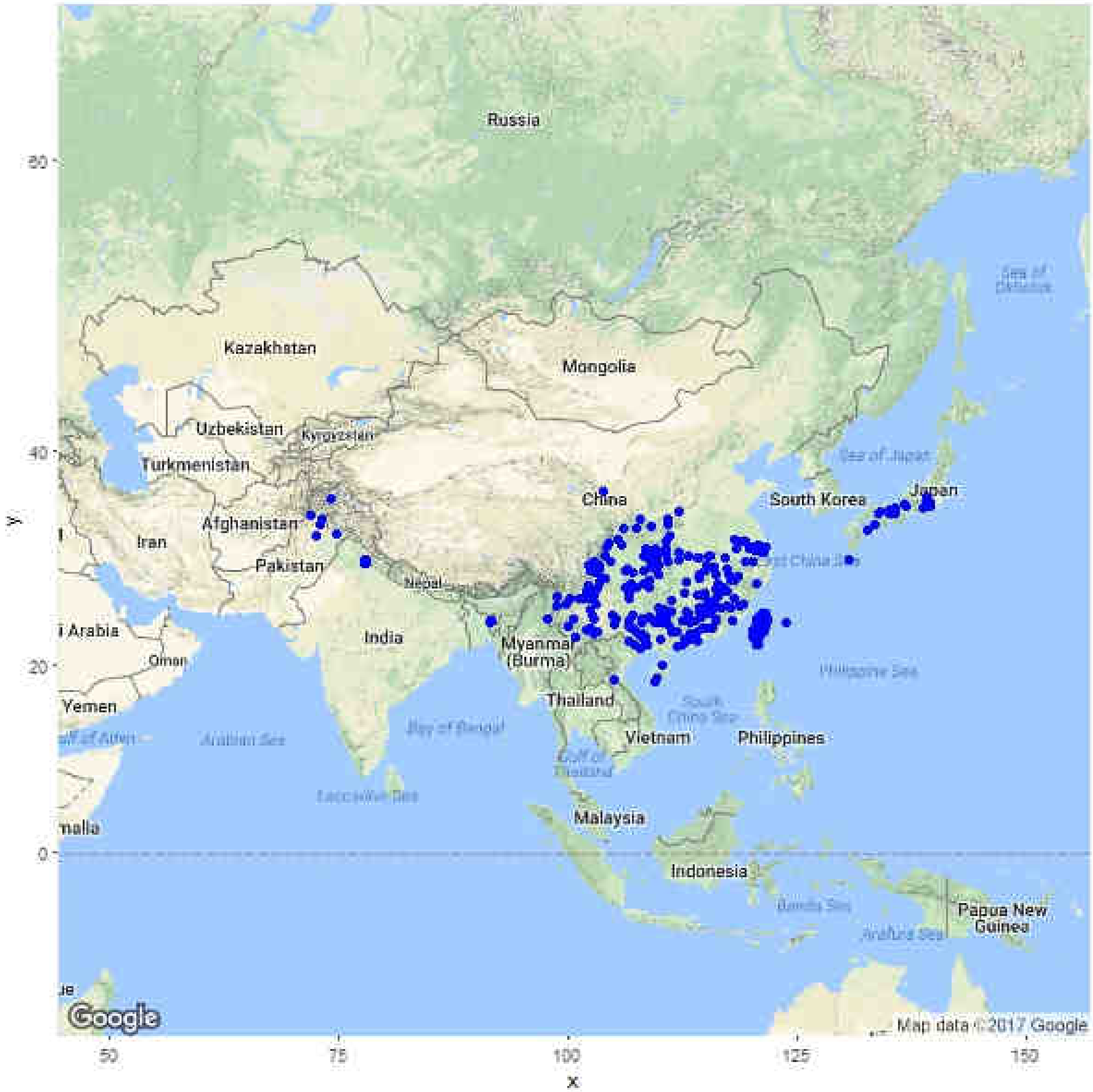


Figure 3. Asia distribution for *Triadica sebifera*

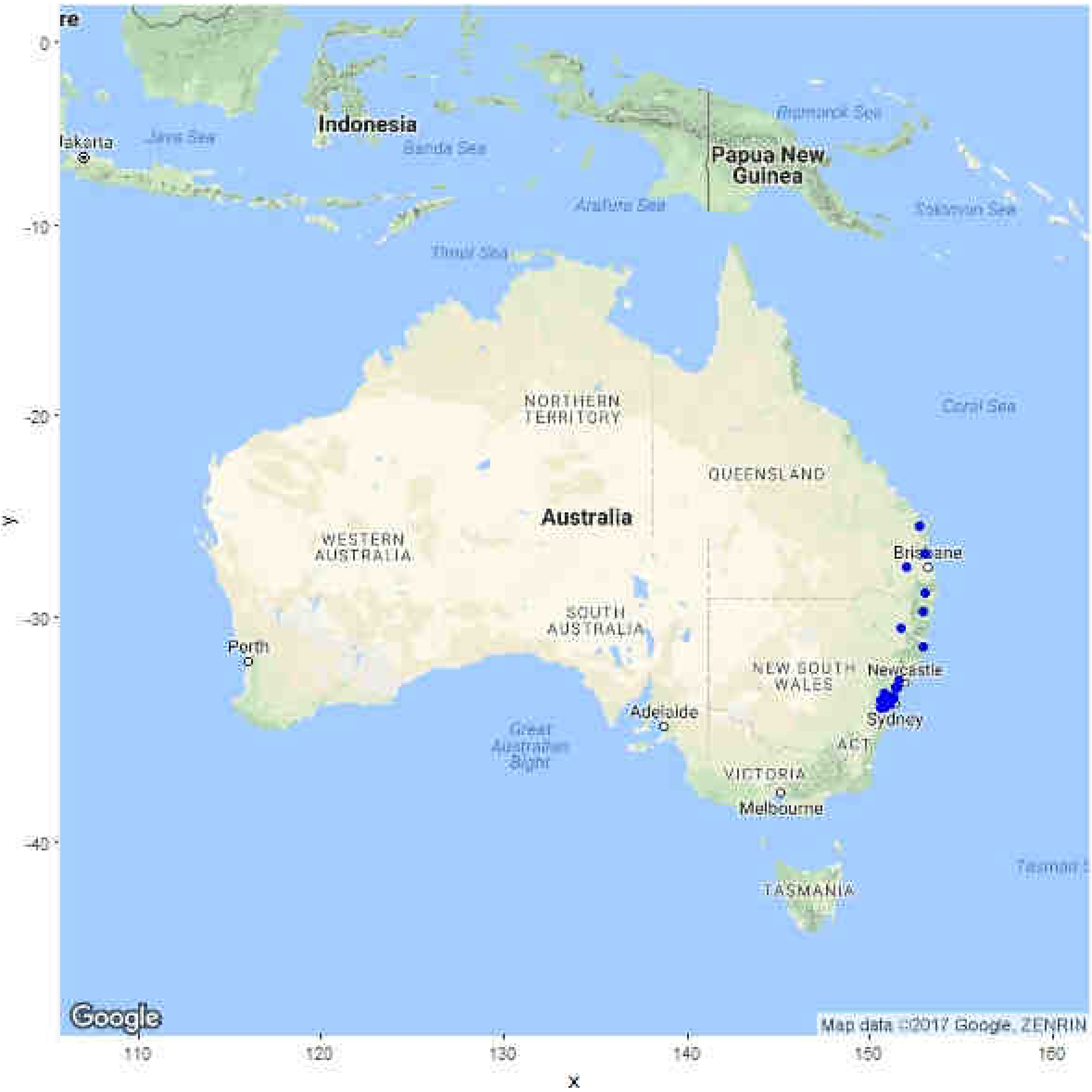


Figure 4. Australia distribution for *Triadica sebifera*