Study on Invasive Alien Species – Development of risk assessments to tackle priority species and enhance prevention

Contract No 07.0202/2016/740982/ETU/ENV.D2

Final Report

Annex 7: Risk Assessment for *Solenopsis invicta* Buren, 1972

Risk assessment template developed under the "Study on Invasive Alien Species – Development of risk assessments to tackle priority species and enhance prevention" Contract No 07.0202/2016/740982/ETU/ENV.D2

Based on the Risk Assessment Scheme developed by the GB Non-Native Species Secretariat (GB Non-Native Risk Assessment - GBNNRA)

Name of organism: *Solenopsis invicta* Buren, 1972

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Risk Assessment Area: The geographical coverage of the risk assessment is the territory of the European Union (excluding the outermost regions)

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This risk assessment has been peer-reviewed by three independent experts and discussed during a joint expert workshop. Details on the review and how comments were addressed are available in the final report of the study.

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RISK SUMMARIES

	RESPONSE	CONFIDENCE	COMMENT
Summarise Entry	**likely**	**medium**	The most important pathway of introduction for *S. invicta* in Europe is the entry of nests as contaminant of nursery material (including soil) and as stowaway/hitchhiker in container/bulk or other commodities (e.g. vehicles, machinery, packaging material). However, the propagule pressure of nests is largely unknown. Queen ants are also likely to arrive as hitchhikers, but only aircrafts will allow a fast transfer that will allow a successful establishment.
Summarise Establishment	**likely**	**high**	According to different models, *S. invicta* could become established in all countries around the Mediterranean Sea, on the Southern Atlantic Coast from Southern France to Portugal. Beyond that, establishment in the Macaronesian region is also very likely. Predictions on the geographic extent of potential establishment vary with the models. It is likely that if established, the ant will have a patchy distribution in Southern Europe, with high densities and extent in suitable habitats in direct contact with permanent water bodies and in irrigated areas.
Summarise Spread	**moderately**	**medium**	In all potentially infested biogeographical regions, *S. invicta* will probably spread moderately rapidly compared to other insects. Although *S. invicta* can spread by natural means over several kilometres per year, its spread will occur mainly through human-assisted transport, in particular with soil and infested items, but its distribution will be constrained by climate and habitat suitability.
Summarise Impact	**major**	**medium**	The species has a major to massive environmental, economic and social impacts elsewhere in the world.

			Similar impacts may occur in Southern Europe. However, the transferability to Europe is hindered by uncertain data on habitat/climatic suitability that may limit the geographic area that is most favourable to the insect. In other words, if only limited zones in the Mediterranean region will be favourable for the ant, impacts will be largely restricted to these zones.
Conclusion of the risk assessment	**high**	**medium**	*Solenopsis invicta* is among the most damaging invasive insects on earth. There is little doubt that it can enter Europe through a variety of pathways, but its establishment and impact will be constrained by climatic and habitat suitability. It is likely that it may become a serious environmental, economic and social pest in some areas of southern Europe, but the extent of its potential distribution remains unclear.

Distribution Summary (for explanations see EU chapeau and Annex IV):

Member States

	Recorded	Established (currently)	Established (future)	Invasive (currently)
Austria	–	–	-	–
Belgium	–	–	-	–
Bulgaria	–	–	-	–
Croatia	–	–	yes	–
Cyprus	–	–	yes	–
Czech Republic	–	–	-	–
Denmark	–	–	-	–
Estonia	–	–	-	–
Finland	–	–	-	–
France	–	–	yes	–
Germany	–	–	-	–

Greece	–	–	yes	–
Hungary	–	–	-	–
Ireland	–	–	-	–
Italy	–	–	yes	–
Latvia	–	–	-	–
Lithuania	–	–	-	–
Luxembourg	–	–	-	–
Malta	–	–	yes	–
Netherlands	–	–	-	–
Poland	–	–	-	–
Portugal	–	–	Yes	–
Romania	–	–	-	–
Slovakia	–	–	-	–
Slovenia	–	–	yes	–
Spain	–	–	Yes	–
Sweden	–	–	-	–
United Kingdom	–	–	-	–

EU biogeographical regions

	Recorded	Established (currently)	Established (future)
Alpine	-	-	-
Atlantic	yes	-	?
Black Sea	-	-	-
Boreal	-	-	-
Continental	-	-	-
Mediterranean	-	-	yes
Pannonian	-	-	-
Steppic	-	-	-

EU CHAPEAU		
QUESTION	**RESPONSE**	**COMMENT**
Ch1. In which EU biogeographical region(s) or marine subregion(s) has the species been recorded and where is it established?	Workers of *S. invicta* have been intercepted occasionally during import inspections and, in at least one occasion in the Netherlands (Atlantic Region) in 2002, a nest was found in soil of imported ficus plants from the USA (Boer and Vierbergen 2008; Noordijk 2010). No established populations are recorded in the EU, nor in Western Palaearctic in general.	In the Netherlands, the first interception record of workers was in 1958 and 2 to 5 interceptions were made until 2008 (Boer and Vierbergen 2008; Noordijk 2010). Data from other countries were not found.
Ch2. In which EU biogeographical region(s) or marine subregion(s) could the species establish in the future under current climate and under foreseeable climate change?	According to various climate and ecophysiological models, *S. invicta* could become established in the Mediterranean Biogeographical region under current climate, although the geographic extent of current or future establishment varies with the models and there is no clear consensus. For more details see Qu. 1.13. Beyond that, establishment on the Southern Atlantic biogeographical region, in particular the coast from Southern France to Portugal is considered possible (e.g. Morrison et al. 2004). However, according to Bertelsmeier et al. (2015), *S. invicta* will not establish widely in Europe under current climate, but may have the capacity to do so under future climatic conditions until 2080 in Ireland, Spain, Italy, Germany, Slovenia, and Hungary. Beyond that, the model indicated Switzerland, Norway and Iceland as suitable for *S. invicta* at that date.	One reason for the different predictions of these models is that they use different methodological approaches (ecophysiological vs climatic data) in modelling the potential distribution of the species.
Ch3. In which EU member states has the species been recorded? List them with an indication of the timeline of observations.	Workers have been found occasionally during import inspections and, in at least one occasion in the Netherlands in 2002, a nest has been found in	Ants are not listed as quarantine pests in the EU and, therefore, records rarely appear in the national and international lists of intercepted

	the soil of imported ficus plants from the USA (Noordijk 2010).	pests.
Ch4. In which EU member states has this species established populations? List them with an indication of the timeline of establishment and spread.	No established populations recorded in the EU, nor in Western Palaearctic in general.	
Ch5. In which EU member states could the species establish in the future under current climate and under foreseeable climate change?	According to various climate and ecophysiological models, *S. invicta* could become established in all EU member states around the Mediterranean biogeographical region under current climate, including the following countries: Portugal, Spain, France, Italy, Slovenia, Croatia, Greece and Cyprus (e.g. Morrison et al. 2004). Beyond that, establishment on the Southern Atlantic Coast from Southern France to Portugal is considered possible. However, according to Bertelsmeier et al. (2015) *S. invicta* will not establish in Europe outside some areas in the Mediterranean biogeographical region, but under current climate, but may have the capacity to do so under future climatic conditions until 2080 in Ireland, Spain, Italy, Germany, Slovenia, and Hungary. Beyond that, the model indicated Switzerland, Norway and Iceland as suitable for *S. invicta*. The geographic extent of current or future establishment varies with the models and there is no clear consensus. For more details see Qu. 1.13.	
6. In which EU member states has this species shown signs of invasiveness?	None. There are no established populations recorded in the EU, nor in Western Palaearctic in general.	
7. In which EU member states could this species become invasive in the future under current climate and under foreseeable climate change?	Based on the information available, the species may become invasive in any country, where it is able to establish, e.g. in the Mediterranean biogeographical	

	region (Portugal, Spain, France, Italy, Slovenia, Croatia, Greece and Cyprus) under current climate, and the Mediterranean, Atlantic (Ireland), Continental (Germany) and Pannonian (Hungary) biogeographical regions under foreseeable climate change.	

SECTION A – Organism Information and Screening		
Organism Information	**RESPONSE**	**COMMENT**
A1. Identify the organism. Is it clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?	Scientific name: *Solenopsis invicta* Buren 1972 Class: Insecta Order: Hymenoptera Family: Formicidae Genus: *Solenopsis* Westwood, 1840 Synonyms: *Solenopsis wagneri* (Santschi), *Solenopsis saevissima* var. *wagneri* Taber (2000) provided a history of the taxonomic status of *S. invicta*. A comprehensive and regularly updated list can be found at www.antweb.org. Common names: Red imported fire ant, Rote importierte Feuerameise, Hormiga roja de fuego, Fourmi de feu. No varieties or breeds are known, but hybridization between *Solenopsis* species is regularly observed. While *S. invicta* and *S. richteri* are reproductively isolated in the native range (Ross & Shoemaker 2005), extensive hybridization between *S. invicta* x *S. richteri* is documented in the southern U.S.A. (e.g. Ross et al. 1987). The hybrid taxon is excluded from this assessment.	Genetic data indicate that *S. invicta* is a polyphyletic, cryptic species group composed of several species that cannot be distinguished morphologically (Martins et al. 2014).
A2. Provide information on the existence of other	The genus *Solenopsis* contains about 200 species,	There are over 20 native *Solenopsis* species

species that look very similar	among which 18 to 20 are "true fire ants", which all look very similar and have the potential of becoming invasive. In particular, *S. richteri* is very similar to *S. invicta* and, in North America, where both species are invasive, hybrids are observed. There is considerable uncertainty about species delimitation in the native range and morphological separation is notably difficult and sometimes considered impossible, certainly in the field. A key for separation of the taxa in the *S. geminata* species-group was provided by Trager (1991).	occurring in Europe and in the risk assessment area, most of which live an elusive subterranean life with small populations. Therefore, confusion with native species cannot be completely ruled out, and specific taxonomic expertise is needed to confirm ant species identity, but life-history and colony structure might be helpful indicators with regard to invasive non-native *Solenopsis* species.
A3. Does a relevant earlier risk assessment exist? (give details of any previous risk assessment and its validity in relation to the EU)	A risk assessment has been made for fire ants (*Solenopsis* spp.) in the Netherlands, which concludes that, although they are regularly found during import inspections in the Netherlands, it is unlikely that they can establish outdoors in the country. However, establishment in permanently heated buildings is possible, and can cause nuisance to humans through their sting and the destruction of equipment such as electrical equipment (including air conditioner units, computers, etc.) (Noordijk 2010). Another RA has been carried out for New Zealand, which classified *S. invicta* as having the highest risk of the 75 non-native ant species assessed (MAF Biosecurity 2002; Harris, undated).	
A4. Where is the organism native?	*Solenopsis invicta* is native to (sub-) tropical South America, including parts of Argentina and Brazil, Bolivia, Paraguay, Peru and Uruguay (CABI 2017). It prefers tropical and subtropical climates with warm temperatures and high annual precipitation,	

	but tolerates savanna climates with dry summers, temperate climates without extended winter frost periods, and arid to semi-arid climates (Tschinkel 2006). It occurs in a wide range of, mostly, disturbed/developed habitats, including roadsides, in the vicinity and inside of buildings, grasslands, crop fields, pastures, lawns, gardens, and parks, where colonies are established in the soil or other suitable media. In its native range it also occurs in rainforests, secondary forests and plantation but, in the non-native range, it demonstrates a strong preference for urban and agricultural environments (Tschinkel 2006).	
A5. What is the global non-native distribution of the organism (excluding the Union, but including neighbouring European (non-Union) countries)?	It was unintentionally introduced (and subsequently spread) in southern US States (from California to Florida), Mexico, Panama and many Caribbean islands (e.g. Virgin Islands, Bahamas, etc.), Australia (Queensland) and New Zealand (eradicated), China (South East), Malaysia, Singapore and Taiwan (CABI 2017).	The first confirmed records of *S. invicta* outside its native range are documented from 1942, when it was collected by E.O. Wilson in the area of Mobile, Alabama (USA); already abundant at that time, the time of arrival was estimated to be within 1933 and 1942 (Tschinkel 2006). In Australia it was first discovered in Brisbane in 2001 (Nattrass and Vanderwoude 2001). It was introduced but did not establish in New Zealand (Ward 2009). Introduced in Taiwan and mainland China in the early 2000s (Chen et al. 2006, Zhang et al. 2007).
A6. Is the organism known to be invasive (i.e. to threaten organisms, habitats or ecosystems) anywhere in the world?	Yes. It is considered to be amongst the 100 most invasive species on earth and it is the invasive insect that has been most studied for its ecological impact worldwide (Kenis et al. 2009).	Negative impacts have been studied mainly in Southern USA and include competition with and displacement of native ants, predation on hatchlings of birds and reptiles (see Qu. 2.18). In addition, fire ants can have negative effects on

		agriculture, as well as animal and human health, ranging from minor allergic reactions to lethal allergic reactions (see Qu. 2.26 – 2.32). Data derived from the IUCN Red List and the IUCN Global Invasive Species Database show that globally *S. invicta* has a known or suspected negative impacts on 3 endangered species, more specifically: *Cyclura lewisi*, Grand Cayman Blue Iguana (IUCN: EN). *Holbrookia lacerata*, Spot-tailed Earless Lizard (IUCN: NT) ("*S. invicta* likely to constitute a threat to this species"). *Podomys floridanus*, Florida Deermouse (IUCN: VU) ("Red imported fire ants (Solenopsis invicta) are a potential predatory threat to gopher tortoises and might be a direct threat to Podomys as well (Wetterer and Moore 2005)").
A7. Describe any known socio-economic benefits of the organism in the risk assessment area.	At present there are no socio-economic benefits in the RA area as the species is not present in the RA area.	In invaded areas, *S. invicta* is a predator of some pest arthropods such as ticks and caterpillars. It can feed on crop pests and in sugarcane production and it is occasionally preserved to reduce sugarcane borer population levels (e.g. Charpentier et al. 1967, Rossi and Fowler 2002). Its mound-building activities are sometimes considered to improve soil quality, e.g. by reducing soil compaction or increasing NH4+ levels (e.g. Lafleur et al. 2005).

SECTION B – Detailed assessment

Important instructions:

- In the case of lack of information the assessors are requested to use a standardized answer: "No information has been found."
- For detailed explanations of the CBD pathway classification scheme consult the IUCN/CEH guidance document.
- With regard to the scoring of the likelihood of events or the magnitude of impacts see Annex.
- With regard to the confidence levels, see Annex.

PROBABILITY OF INTRODUCTION and ENTRY

Important instructions:

- Introduction is the movement of the species into the EU.
- Entry is the release/escape/arrival in the environment, i.e. occurrence in the wild. Not to be confused with spread, the movement of an organism within Europe.
- For organisms which are already present in Europe, only complete this section for current active or if relevant potential future pathways. This section need not be completed for organisms which have entered in the past and have no current pathway of introduction and entry.

QUESTION	RESPONSE [chose one entry, delete all others]	CONFIDENCE [chose one entry, delete all others]	COMMENT
1.1. How many active pathways are relevant to the potential entry of this organism? (If there are no active pathways or potential future pathways respond N/A and move to the Establishment section)	**many**	**high**	*Solenopsis invicta* is suspected of having arrived in the USA in the 1930s in the ballast of cargo ships from Paraguay (Vinson 1997). However, soil ballast is not used anymore for intercontinental shipping and this pathway is here considered not active.
1.2. List relevant pathways through which the organism could enter. Where possible give detail about the specific origins and end points of the pathways as well as a description of the associated commodities.	a) Transport-Stowaway (Hitchhikers in or on airplane)		*Solenopsis invicta* is termed a "tramp" ant, it can hitchhike with many commodities through many pathways. However, only the entry of queen ants and nests present a risk of establishment. Furthermore,

For each pathway answer questions 1.3 to 1.10 (copy and paste additional rows at the end of this section as necessary). Please attribute unique identifiers to each question if you consider more than one pathway, e.g. 1.3a, 1.4a, etc. and then 1.3b, 1.4b etc. for the next pathway.	b) Transport-Contaminant (nursery material and other matters from the horticultural trade) c) Transport-Stowaway (nests transported in container/bulk, including sea freight, airfreight, train, etc.)		queens must find a nest quickly after mating. These restrictions limit the number of active pathways. MAF Biosecurity (2002) provides a very detailed analysis of potential pathways of introduction of *S. invicta* in New Zealand, which is also highly relevant for Europe. Noordijk (2010) provides a brief assessment of pathways for the Netherlands as well as interception data.
Pathway name:	a) Transport-Stowaway (Hitchhikers in or on airplane)		
1.3a. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)?	**unintentional**	**very high**	
1.4a. How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year? Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place. Subnote: In your comment discuss the volume of movement along this pathway.	**moderately likely**	**low**	Newly-mated queens start forming a nest within 6-7 hours. After that time, their chance of survival and of establishing a nest decreases. Considering that ships from the nearest infested areas take more than a week to reach the EU, newly-mated queens can only arrive successfully in airplanes. However, it cannot be ruled out that newly mated queen ants establish a nest on a ship (see Qu. 1.5).
1.5a. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.	**moderately likely**	**medium**	Considering the fact that a flight from infested areas (e.g. Southern US or China) takes at least 10 hours, not considering embarking and disembarking of containers, commodities, etc., a queen may not arrive in its best condition for establishing nests. Likelihood of survival will decrease with increasing travel duration, but is

			possible. However, multiplication and the establishment of a small nest during such an intercontinental flight is highly unlikely.
1.6a. How likely is the organism to survive existing management practices during passage along the pathway?	N/A		There are no management practices against hitchhiking ants or ant queens in or on airplanes in place.
1.7a. How likely is the organism to enter Europe undetected?	**likely**	**high**	A single queen ant or even several queens or small nests are not easy to detect in cargo airplanes.
1.8a. How likely is the organism to arrive during the months of the year most appropriate for establishment?	**likely**	**high**	Nuptial flights of ant queens have been recorded throughout the year and commodities with which ants can enter Europe occur throughout the year.
1.9a. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	**likely**	**high**	Many airports in the Mediterranean region are surrounded by suitable habitats including irrigated/watered gardens and parks. Indeed this species simply requires soil as a substrate in which to establish a nest and has been found to occur in diverse habitats from roadside verges to forests.
1.10a. Estimate the overall likelihood of entry into Europe based on this pathway?	**moderately likely**	**medium**	The likelihood is scored moderately likely because the number of queen ants travelling through this pathway is probably relatively low and the duration of the transportation would be unlikely to favour survival of the queen. MAF Biosecurity (2002) scored the likelihood of introduction of a queen ant by aircraft as "low".
Pathway name:	b) Transport-Contaminant (nursery material and other matters from the horticultural trade)		
1.3b. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)?	**unintentional**	**very high**	This concerns both fully developed nests (with active workers) and newly-founded nests (before workers are developed and start foraging) transported in nursery material by the horticultural trade. Newly-founded nests

			can also be formed by queens transported in ships before the nursery material arrives at destination.
1.4b. How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year? Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place. Subnote: In your comment discuss the volume of movement along this pathway.	**likely**	**low**	There are very limited data on ant nests arriving through the horticultural trade in Europe. At least some nests have reached Europe (the Netherlands) and New Zealand. Ants are not listed as quarantine pests in the EU and, therefore, records rarely appear in the national and international lists of intercepted pests. However, millions of plants arrive with soil or in pots (with substrates) from infested areas (Southern US, Mexico, Caribbean islands and China) every year in Europe and, although the soil/substrate is supposed to be sterile, infestation by ants can occur just before or during transport. Flower pots are one of the preferred habitats for *S. invicta* in invaded regions, in particular because of their humidity and because they are usually in contact with the ground. Other horticultural material such as mulch, hay and other plant material can harbour ant nests. Both polygynous and monogynous nests occur in *S. invicta*. Polygynous colonies are particularly large since they include many queens and may contain thousands of workers. The maximum size of a fully developed colony may reach more than 200,000 workers (Tschinkel 2006). Ant nests might get onto the pathway in large numbers as contaminant of horticultural materials including soil. The likelihood of reinvasion after eradication is identical to the likelihood of introduction in the first place.

1.5b. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.	**very likely**	**high**	Once sealed in a newly-founded nest, a queen is able to survive 13 to 95 days on her own reserves, i.e. much longer than before nest establishment (Markin et al. 1972; Porter 1988). Likelihood of survival nevertheless will decrease with increasing travel duration. However, multiplication of a small nest during intercontinental translocation is highly unlikely.
1.6b. How likely is the organism to survive existing management practices during passage along the pathway?	**likely**	**medium**	Horticulture plants and soils/substrates are usually chemically treated before shipment but can be easily infested after treatment either before departure or during transport.
1.7b. How likely is the organism to enter Europe undetected?	**likely**	**high**	Fully developed nests are quite visible. In contrast, newly-founded nests with few queen(s) and workers in the soil/substrate can easily arrive undetected.
1.8b. How likely is the organism to arrive during the months of the year most appropriate for establishment?	**likely**	**high**	The horticultural trade is active throughout the year.
1.9b. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	**likely**	**high**	Potted plants and plant materials are likely to be transported outdoors in gardens, which may adjoin to a suitable habitat. It is expected that suburban and urban habitats are most at risk at the beginning of an invasion.
1.10b. Estimate the overall likelihood of entry into Europe based on this pathway?	**likely**	**medium**	We consider this pathway as the most likely pathway of introduction of *S. invicta* into Europe. Similarly, Noordijk (2010) and MAF Biosecurity (2002) also consider the horticultural trade as the most likely pathway for introduction in the Netherlands and New Zealand. MAF Biosecurity (2002) classifies "commercial importation of untreated soil that undergoes no inspection or post-arrival quarantine" as the single pathway presenting a very high likelihood.
Pathway name:	c) Transport-Stowaway (nests transported in container/bulk, including sea freight, airfreight, train, etc.)		
1.3c. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the	**unintentional**	**very high**	This section includes travelling nests that are not directly associated with the horticultural trade. Virtually

organism is a contaminant of imported goods)?			any article of commerce can host hitchhiking nests of all sizes and ages, including newly-founded and fully developed nests. There are very many articles of commerce and container types that are grouped here together. This includes, e.g. sea containers but also vehicles (incl. used car parts), machinery, building material, packaging materials, bark, aquaculture material, used electric equipment.
1.4c. How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year? Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place. Subnote: In your comment discuss the volume of movement along this pathway.	**likely**	**low**	There are very limited data on ant nests arriving in Europe. See containers and all articles of commerce cited above were scored by MAF Biosecurity (2002) as presenting a high likelihood of introduction for nests of *S. invicta*. Ants are not listed as quarantine pests in the EU and, therefore, records rarely appear in the national and international lists of intercepted pests. Polygynous nests include many queens and may contain thousands of workers. The maximum size of a fully developed colony may reach more than 200,000 workers (Tschinkel 2006). Ant nests might get onto the pathway in large numbers as stowaway in containers or other bulk freight, including soil. The likelihood of reinvasion after eradication is identical to the likelihood of introduction in the first place.
1.5c. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.	**very likely**	**high**	Once sealed in a newly-founded nest, a queen is able to survive 13 to 95 days on her own reserves, i.e. much longer than before nest establishment (Markin et al. 1972; Porter 1988). This is sufficient to survive longer trips to Europe from any origin. Likelihood of survival nevertheless will decrease with increasing travel duration.

1.6c. How likely is the organism to survive existing management practices during passage along the pathway?	**very likely**	**high**	In most of the commodities in this pathway, there are no management practices in place.
1.7c. How likely is the organism to enter Europe undetected?	**likely**	**high**	Many of these commodities are not carefully inspected. While established nests are usually obvious, newly-founded nests are often inconspicuous. In contrast, newly-founded nests with few queen(s) and workers can easily arrive undetected.
1.8c. How likely is the organism to arrive during the months of the year most appropriate for establishment?	**likely**	**high**	Commodities that can carry *S. invicta* are active throughout the year.
1.9c. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	**likely**	**high**	Several of the potential commodities and items in which nests can hide can be transported to suitable habitats since the ant particularly likes disturbed soils, which are found everywhere, specifically in urban and semi-urban habitats.
1.10c. Estimate the overall likelihood of entry into Europe based on this pathway?	**likely**	**high**	Given the high numbers and types of containers, commodities and items that can be associated with *S. invicta*, this pathway can be considered as having a high likelihood of introduction, as determined by MAF Biosecurity (2002) and Noordijk (2010).
End of pathway assessment, repeat as necessary.			
1.11. Estimate the overall likelihood of entry into Europe based on all pathways in relevant biogeographical regions in current conditions (comment on the key issues that lead to this conclusion).	**likely**	**medium**	The species has been recorded/intercepted already in Europe and it is likely that this will happen again, specifically with contaminated soil in the horticultural trade and/or as stowaway with container/bulk imports in sea or air freights.
1.12. Estimate the overall likelihood of entry into Europe based on all pathways in relevant biogeographical regions in foreseeable climate change conditions?	**likely**	**medium**	Climate change is not changing the risk of introduction or likelihood of entry based on the mentioned active pathways.

PROBABILITY OF ESTABLISHMENT

Important instructions:

- For organisms which are already established in parts of the Union, answer the questions with regard to those areas, where the species is not yet established. If the species is established in all Member States, continue with Question 1.16.

QUESTION	RESPONSE	CONFIDENCE	COMMENT
1.13. How likely is it that the organism will be able to establish in the EU based on the similarity between climatic conditions in Europe and the organism's current distribution?	**likely**	**medium**	Various climatic models have been developed to assess climatic preferences for *S. invicta*, which can be used to assess the likelihood of establishment of the ant related to climate preferences. However, they do not all agree in their conclusions. Morrison et al. (2004) used the model of Korzukhin et al. (2001) to map suitable areas for the reproduction of *S. invicta* worldwide. The model used a dynamic, ecophysiological model of colony growth, superposing temperature and precipitation requirements to predict the potential global range distribution of the ant. The model showed that large parts of the Mediterranean region fall in the area suitable for *S. invicta* establishment (Fig. A1 in Annex 4) Sutherst and Maywald (2005) used the CLIMEX climate modeling software to assess the potential geographic range of *S. invicta* based on an ecoclimatic index (EI). For Europe, the analysis showed that climate per se will not constrain the ant from colonizing countries bordering the Mediterranean and western France. Two versions of the model are available that show some differences in the distribution range, i.e. the original from Sutherst and Maywald (2005) and an

			improved but unpublished version included as template in the CLIMEX software V4. (Fig. A2 and A3 in Annex 4). In both cases, EI for Europe was significantly lower than for the regions where the ant is highly invasive (e.g. in North America and East Asia), suggesting that, in Europe, establishment and population growth may be less straightforward, except in irrigated lands and in habitats in direct contact with permanent water bodies. Indeed, the model shows much higher EIs when irrigation is added (Fig. A4, as compared to Fig. A2, in Annex 4). Bertelsemeier et al (2014), using a climate matching model (Maxent) based on present distributions, mapped suitable areas globally for 15 of the worst invasive ant species (incl. *S. invicta*), both currently and with predicted climate change (in 2080). They showed that less than 2% of the European continent is presently suitable for *S. invicta*, but predicted that the potential distribution of *S. invicta* will until 2080 in Ireland, Spain, Italy, Germany, Slovenia, and Hungary. Beyond that, the model indicated Switzerland, Norway and Iceland as suitable *for S. invicta* (Fig. A5 in Annex 4).
1.14. How likely is it that the organism will be able to establish in the EU based on the similarity between other abiotic conditions in Europe and the organism's current distribution?	**likely**	**high**	Other abiotic conditions should not be a constraint for the establishment of *S. invicta* in Europe, maybe except for high-altitude environments. The ant particularly likes disturbed soils, which are found everywhere, specifically in urban and semi-urban habitats.
1.15. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, terraria,	**moderately likely**	**high**	*Solenopsis invicta* frequently invades buildings in its invaded range. In regions with unsuitable climates, it may survive under warm conditions in buildings or greenhouses as well as in gardens and

zoological gardens) in Europe? Subnote: gardens are not considered protected conditions			parks in cities. The ant has shown temporary indoor colony establishments including at least once in the Netherlands (Noordijk 2010, see also Morril 1977, Tschinkel 2006). However, indoor colonies often can be eradicated easily.
1.16. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Europe?	**widespread**	**medium**	*Solenopsis invicta* prefers disturbed habitats, which are found everywhere in Europe. However, in dry areas, it reproduces preferably in habitats associated with waters, including irrigated areas, which may limit its distribution in the Mediterranean region, at least in natural areas.
1.17. If the organism requires another species for critical stages in its life cycle then how likely is the organism to become associated with such species in Europe?	**N/A**	**very high**	*Solenopsis invicta* does not require another species for establishment.
1.18. How likely is it that establishment will occur despite competition from existing species in Europe?	**moderately likely**	**medium**	*Solenopsis invicta* is a highly competitive species. In its invaded range, it has locally displaced native ants but also highly invasive ants such as the Argentine ant (Holway et al. 2002). However, Tschinkel (2006) suggests that, at range margins, the competition with local ant species that are better adapted to the climate might impede *S. invicta* establishment and/or reproduction. In several suitable areas it will have to face the competition with the Argentine ant. This species is able to limit *S. invicta* establishment and confrontations will be asymmetric as the Argentine ant already forms colonies of many hundred thousands of individuals.
1.19. How likely is it that establishment will occur despite predators, parasites or pathogens already present in Europe?	**likely**	**medium**	Only few *Solenopsis* spp. are native to Europe, and no specific natural enemy of *Solenopsis* spp. occurs in Europe. Thus, only generalist natural enemies of ants may affect the establishment of the ant.
1.20. How likely is the organism to establish despite	**likely**	**medium**	No specific management practices are in place

existing management practices in Europe?			against invasive ants in the wild in Europe. Eradication of single nests is straightforward in buildings but much less so outdoors. However, some eradication programmes have succeeded, such as in New Zealand (Christian 2009).
1.21. How likely are existing management practices in Europe to facilitate establishment?	**likely**	**medium**	Disturbed habitats, in particular irrigated areas, are favourable for *S. invicta* and so increases in urbanization will be beneficial for this species.
1.22. How likely is it that biological properties of the organism would allow it to survive eradication campaigns in Europe?	**likely**	**medium**	The eradication of *S. invicta* outdoors is difficult, especially when polygynous *S. invicta* colonies are present with many nests and many queens per nest (Noordijk 2010).
1.23. How likely are the biological characteristics of the organism to facilitate its establishment?	**likely**	**high**	*Solenopsis invicta* has monogynous and polygynous populations. The polygynous form can more easily establish because the higher number of queens increases reproduction potential, especially in the critical early stages of establishment. For other characteristics, see also Q1.25. Inseminated females (queens) lay up to 200 eggs per hour (Tschinkel 1988). Within one year, the colony can grow to several thousands of workers, within three years it can reach 50,000 (Markin et al. 1973) or even up to 230,000 workers (Tschinkel 1988). The peculiar, almost unique, reproductive caste system of eusocial ants can facilitate establishment. For the Argentine ant, it was shown that as few as 10 workers are sufficient for a colony to grow quickly (Hee et al. 2000).
1.24. How likely is the capacity to spread of the organism to facilitate its establishment?	**moderately likely**	**medium**	At introduction, *Solenopsis invicta* will not spread far by itself. However, if arriving in soil or other substrates (e.g. potted plants), then spread may be facilitated by the movement of soil and plants to

			suitable places.
1.25. How likely is the adaptability of the organism to facilitate its establishment?	**likely**	**high**	*Solenopsis invicta* is highly adaptable. It can live in a variety of habitats, especially those that are related to humans, and it is also considered an opportunistic omnivore. Also, in contrast to many ants, it does not have a restricted flight period. Nuptial flights have been recorded throughout the year and foraging can occur over a wide soil surface temperature range (12-51 °C) while maximum worker ants foraging occurs between 22-36 °C (Porter and Tschinkel 1987). This indicates that *S. invicta* has a high adaptability to new circumstances.
1.26. How likely is it that the organism could establish despite low genetic diversity in the founder population?	**likely**	**high**	Most invasive ants, which are among the most invasive insects worldwide, establish following the entry of single nests or queens (Holway 2002). Therefore, low genetic diversity does not seem a barrier to establishment.
1.27. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Europe? (If possible, specify the instances in the comments box.)	**likely**	**high**	*Solenopsis invicta* has been introduced and become established in Southern US and various Caribbean Islands (Tschinkel 2006), and more recently Australia (Nattrass and Vanderwoude 2001) and China and Taiwan (Chen et al. 2006, Zhang et al. 2007). It was also introduced and eradicated in New Zealand (Ward 2009), the Netherlands (Noordijk 2010) and probably other parts of the world. Furthermore, *Solenopsis geminata*, a closely-related species has been even more successful in invading several continents (albeit they may have slightly different biotic and abiotic requirements). Thus, should the climate of Southern Europe be suitable and habitats available for the species, the history of invasion elsewhere clearly shows that it is likely to be introduced and establish in Europe.

1.28. If the organism does not establish, then how likely is it that casual populations will continue to occur? Subnote: Red-eared Terrapin, a species which cannot re-produce in GB but is present because of continual release, is an example of a transient species.	**moderately likely**	**high**	As shown with interception data from countries such as the Netherlands and New Zealand, *S. invicta* and related *Solenopsis* spp. are regularly intercepted at ports of entry. However, in most cases, these are sterile workers that cannot establish in the wild. Ants are not listed as quarantine pests in the EU and, therefore, interception data are not good indicators of their frequency of entry because they do not have to be mentioned in the national and international lists of intercepted pests. It has to be assumed that there are a considerable number of unreported cases.
1.29. Estimate the overall likelihood of establishment in relevant biogeographical regions in current conditions (mention any key issues in the comment box).	**likely**	**medium**	In the Mediterranean and Macaronesian biogeographical regions, establishment under current conditions is likely, at least in the most humid or irrigated habitats. Also, the southern Atlantic region from Southern France to Portugal is considered to be potentially susceptible, but there is no agreement across climate models (see e.g. Bertelsmeier et al. 2015).
1.30. Estimate the overall likelihood of establishment in relevant biogeographical regions in foreseeable climate change conditions	**likely**	**high**	Under foreseeable climate change, *S. invicta* may establish in the Atlantic, Mediterranean, Continental and Pannonian biogeographic region (according to Bertelsmeier et al. 2015). Bertelsmeier et al. (2015), who are the least positive about a wide establishment in the Mediterranean region, predict an increase of the potential range for *S. invicta* in Europe in the future.

PROBABILITY OF SPREAD

Important notes:

- Spread is defined as the expansion of the geographical distribution of an alien species within the assessment area.
- Repeated releases at separate locations do not represent spread and should be considered in the probability of introduction and entry section.

QUESTION	RESPONSE	CONFIDENCE	COMMENT
2.1. How important is the expected spread of this organism in Europe by natural means? (Please list and comment on each of the mechanisms for natural spread.)	**moderate**	**high**	Queen ants disperse during nuptial flights and for nesting. Most queens do not fly far from the colony of origin but some may fly up to 12 kilometres (Tschinkel 2006, Dhami & Booth 2008). Nuptial flights occur throughout the year. Polygynous colonies can also spread by "budding", i.e. alates mate in the nest and queens disperse only short distances and take workers with her to start a new colony (Tschinkel 2006). Such strategy does not allow a rapid spread but increase survival rates of queens and colonies. Sometimes, an entire colony can disperse by rafting/floating on water, e.g. after flooding of its habitat (e.g. Adams et al. 2011). The question is scored "moderate" because it is likely to spread more slowly by natural means than by human assistance.
2.2. How important is the expected spread of this organism in Europe by human assistance? (Please list and comment on each of the mechanisms for human-assisted spread) and provide a description of the associated commodities.	**major**	**high**	Human assisted pathways of spread are the agricultural and horticultural trade of plants, plant materials, and soil/substrate as well as other movements of commodities.
2.2a. List and describe relevant pathways of spread.	a) Transport-		

Where possible give detail about the specific origins and end points of the pathways. For each pathway answer questions 2.3 to 2.9 (copy and paste additional rows at the end of this section as necessary).	Contaminant (Contaminant nursery material) b) Transport-Stowaway (Container/bulk, including road transport, sea freight, airfreight, train, etc.) c) Unaided (Natural dispersal)		
Pathway name:	a) Transport-Contaminant (Contaminant nursery material)		
2.3a. Is spread along this pathway intentional (e.g. the organism is released at distant localities) or unintentional (the organism is a contaminant of imported goods)?	**unintentional**	**very high**	
2.4a. How likely is it that large numbers of the organism will spread along this pathway from the point(s) of origin over the course of one year?	**very likely**	**high**	Within Europe, movements of potted plants are unrestricted. Soil/substrate in potted plants is a favourite media for nesting (see entry section above). Thus, newly founded nests or parts of fully developed nests could easily be moved. Other horticultural material such as mulch, hey and other plant material can harbour ant nests. Polygynous nests include many queens and may contain thousands of workers. Ant nests might get onto the pathway in large numbers as contaminant of horticultural materials including soil. The likelihood of reinvasion after eradication is identical to the likelihood of introduction in the first place.
2.5a. How likely is the organism to survive during passage along the pathway (excluding management practices that	**likely**	**high**	Once sealed in a newly-founded nest, a queen is able to survive 13 to 95 days on her own reserves, i.e.

would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.			much longer than before nest establishment (Markin et al. 1972; Porter 1988). Likelihood of survival is high, nevertheless will decrease with increasing travel duration. Multiplication of a colony during spread within the EU cannot be ruled out, but is rather unlikely.
2.6a. How likely is the organism to survive existing management practices during spread?	**likely**	**high**	Horticultural plants and products and soils/substrates are usually not treated before translocation within the EU.
2.7a. How likely is the organism to spread in Europe undetected?	**likely**	**high**	Fully developed nests are quite visible. In contrast, newly-founded nests with few queen(s) and workers can easily travel undetected in soil or other horticultural products.
2.8a. How likely is the organism to be able to transfer to a suitable habitat or host during spread?	**very likely**	**high**	Potted plants and plant materials are often planted or stored in or close to highly suitable habitats, such as gardens, parks, road sides, etc. It is expected that spread facilitates occurrences in suburban and urban habitats.
2.9a. Estimate the overall likelihood of spread into or within the Union based on this pathway?	**very likely**	**high**	We consider this pathway as the most likely pathway of spread of *S. invicta* within Europe.
Pathway name:	b) Transport-Stowaway (Container/bulk, including road transport, sea freight, airfreight, train, etc.)		
2.3b. Is spread along this pathway intentional (e.g. the organism is released at distant localities) or unintentional (the organism is a contaminant of imported goods)?	**unintentional**	**very high**	Virtually any article of commerce can host hitchhiking ants within nests of all sizes and ages, including newly-founded and fully developed nests. There are very many transported items (e.g. vehicles (incl. used car parts), machinery, building material, agricultural equipment packaging materials, bark, aquaculture material, used electric equipment, non-agricultural soil, sand, gravel) that are suitable to carry nests and are grouped here together.
2.4b. How likely is it that large numbers of the organism will spread along this pathway from the point(s) of origin over the course of one year?	**very likely**	**high**	There are very limited data on ant nests translocated within the EU. Polygynous nests include many queens and may contain thousands of workers. Ant nests might get onto transported items in large numbers as

			stowaways. The likelihood of reinvasion after eradication is identical to the likelihood of introduction in the first place.
2.5b. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.	**likely**	**high**	Once sealed in a newly-founded nest, a queen is able to survive 13 to 95 days on her own reserves, i.e. much monger than before nest establishment (Markin et al. 1972; Porter 1988). This is sufficient to survive longer trips within Europe. Likelihood of survival is high, nevertheless will decrease with increasing travel duration. Multiplication of a colony during spread within the EU cannot be ruled out, but is rather unlikely.
2.6b. How likely is the organism to survive existing management practices during spread?	**likely**	**high**	Most potential commodities that can carry ants or nests are not managed.
2.7b How likely is the organism to spread in Europe undetected?	**likely**	**high**	Fully developed nests are quite visible. In contrast, newly-founded nests with few queen(s) and workers can easily travel undetected in most potential transported items.
2.8b. How likely is the organism to be able to transfer to a suitable habitat or host during spread?	**very likely**	**high**	Several of the potential commodities and items in which nests can hide can be transported to suitable outdoor habitats since the ant particularly likes disturbed soils, which are found everywhere, specifically in urban and semi-urban habitats.
2.9b. Estimate the overall likelihood of spread into or within the Union based on this pathway?	**very likely**	**high**	Given the high numbers and types of commodities and items that can be associated with *S. invicta*, this pathway can be considered as having a high likelihood of spread within the EU.
Pathway name:	c) Unaided (Natural dispersal)		
2.3c. Is spread along this pathway intentional (e.g. the organism is released at distant localities) or unintentional (the organism is a contaminant of imported goods)?	**unintentional**	**very high**	
2.4c. How likely is it that large numbers of the organism will spread along this pathway from the point(s) of origin	**moderately likely**	**medium**	Spread by nuptial flights can occur throughout the year in subtropical climates, and likely will be

over the course of one year?			restricted to the summer months in the risk assessment area; it will include small numbers of alates, while budding usually includes a larger number of queens and workers. Colonies can also spread through flood water (Hung and Vinson 1978). The likelihood of reinvasion after eradication is identical to the likelihood of introduction in the first place.
2.5c. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.	**very likely**	**very high**	Likelihood of survival during unaided spread is high. Alate ants do not multiply during spread but budding colonies do.
2.6c. How likely is the organism to survive existing management practices during spread?	**very likely**	**very high**	Management practices during unaided spread are not currently in place.
2.7c. How likely is the organism to spread in Europe undetected?	**moderately likely**	**high**	Low ant densities (e.g. single queens, small newly-founded nests) often remain undetected for longer periods. However, spread will mainly occur from well-established nests, which be noticeable and spread will be detected earlier.
2.8c. How likely is the organism to be able to transfer to a suitable habitat or host during spread?	**likely**	**very high**	Queen ants can fly or be taken by the wind up to 16 km, (Hung and Vinson 1978) and will likely find suitable habitats (e.g. humid or irrigated habitats).
2.9c. Estimate the overall likelihood of spread into or within the Union based on this pathway?	**very likely**	**very high**	*Solenopsis invicta* will spread unaided to all suitable habitats within its suitable climatic range. Alate females can fly up to 16 km and colonies can also be occasionally transported by water flood. However, as with most invasive insects, long distance spread will be more often due to accidental transportations by humans. There are a number of intrinsic and extrinsic factors that influence spread including availability of disturbed habitats and morphology of the queens

			(King and Tschinkel 2006).
End of pathway assessment, repeat as necessary.			
2.10. Within Europe, how difficult would it be to contain the organism?	**very difficult**	**medium**	It will probably be very difficult to contain the species by human means. Its spread will be constrained by climate and habitat suitability. If *S. invicta* become established in a European region, quarantine measures could be put in place to restrict the risk of long-distance spread, e.g. through nursery stock, as in USA (USDA 2015).
2.11. Based on the answers to questions on the potential for establishment and spread in Europe, define the area endangered by the organism.	Establishment and spread in the Mediterranean region is likely, at least in humid and irrigated habitats. Beyond that, establishment in the Macaronesian region is also likely.	**high**	See Ch2 and Ch5 of the Chapeau and Q1.13.
2.12. What proportion (%) of the area/habitat suitable for establishment (i.e. those parts of Europe were the species could establish), if any, has already been colonised by the organism?	**0-10**	**very high**	The species is not yet established in Europe.
2.13. What proportion (%) of the area/habitat suitable for establishment, if any, do you expect to have been invaded by the organism five years from now (including any current presence)?	**0-10**	**high**	Even if it arrives in the next years it will probably not spread very fast, based on previous experiences in invaded areas. For example, Hung and Vinson (1978) measured that *S. invicta* has spread by 48 km /year in Texas between 1957 to 1977. However, Texas is eco-climatically more suitable than Europe (Sutherst and Maywald 2005), which surely influences spread potential.
2.14. What other timeframe (in years) would be appropriate to estimate any significant further spread of the organism in Europe? (Please comment on why this	**40**	**low**	According to Bertelsmeier et al. (2015), under predicted climate change in 2080, the proportion of suitable area for establishment will increase, but still

timeframe is chosen.)			not exceed 10% of the area in Europe. Repeated introductions into Europe via different pathways and without management in place increases likelihood of entry, but is highly unpredictable. A significant further spread might occur in the decades to come, but is highly uncertain.
2.15. In this timeframe what proportion (%) of the endangered area/habitat (including any currently occupied areas/habitats) is likely to have been invaded by this organism?	**0-10**	**low**	The species probably will not spread very widely in the EU and remain restricted to climatically preferred habitats in the Mediterranean region.
2.16. Estimate the overall potential for spread in relevant biogeographical regions under current conditions for this organism in Europe (using the comment box to indicate any key issues).	**moderately**	**medium**	Based on observations in North America and the lower ecoclimatic suitability in Europe (see Q1.13), we can estimate that it will spread to all potentially infested biogeographical regions, but possibly slower than in North America. Its spread will occur mainly through human transport but its distribution will be indirectly constrained by climate and habitat suitability.
2.17. Estimate the overall potential for spread in relevant biogeographical regions in foreseeable climate change conditions	**likely**	**low**	Climate change will not increase the potential or rapidity of spread directly, but may facilitate population growth with subsequently increasing potential for spread and widen the distribution range.

MAGNITUDE OF IMPACT

Important instructions:

- Questions 2.18-2.22 relate to environmental impact, 2.23-2.25 to impacts on ecosystem services, 2.26-2.30 to economic impact, 2.31-2.32 to social and human health impact, and 2.33-2.36 to other impacts. These impacts can be interlinked, for example a disease may cause impacts on biodiversity and/or ecosystem functioning that leads to impacts on ecosystem services and finally economic impacts. In such cases the assessor should try to note the different impacts where most appropriate, cross-referencing between questions when needed.
- Each set of questions above starts with the impact elsewhere in the world, then considers impacts in Europe separating known impacts to date (i.e. past and current impacts) from potential future impacts (including foreseeable climate change).
- Assessors are requested to use and cite original, primary references as far as possible.

QUESTION	RESPONSE	CONFIDENCE	COMMENTS
Biodiversity and ecosystem impacts			
2.18. How important is impact of the organism on biodiversity at all levels of organisation caused by the organism in its non-native range excluding the Union?	**major**	**high**	*Solenopsis invicta* is considered by the International Union for Conservation of Nature (IUCN) one of the "World's 100 worst" invasive alien species (Lowe et al. 2004). It is also the most studied invasive insect for its environmental impact, accounting, until 2007, for 18% of all primary research publications in this field (Kenis et al. 2009). Wang et al. (2013) provide an extensive review of studies on the environmental impact of the ant since its invasion in China. Environmental impacts caused by the ant in the invaded ranged excluding the Union are multiple: -Impact on fauna: In southern North America, it threatens several arthropods, molluscs, reptiles, birds, amphibians and mammals by direct predation, competition or stinging (see review by Holway et al. (2002) and more recent studies such as King and Tschinkel (2008); Allen et al. (2016)). In particular, it

			has been shown to displace or reduce populations of native and invasive ants (including the Argentine ant) (McGlynn 1999; Holway et al. 2002; King and Tschinkel 2008). It also attacks beneficial insects such as parasitoids and predators (Eubanks et al. 2002; Ness 2003). It must be noted, however, that data on direct effects on long term population declines of animals are largely lacking, even for impact on native ants. *Solenopsis invicta* mainly occupies niches in highly disturbed habitats and, in such situations, it is difficult to distinguish between the effects of disturbance and the effects of *S. invicta* on other ants (King and Tschinkel 2006). The native fauna is also indirectly affected through the intensive use of pesticides needed to control the pest (e.g. Mokkarala 2002). -Impact on plants: the impact on wild plants has been less studied than that on animals or cultivated plants. However, the flora can also be affected through various mechanisms, such as changes in soil properties (Lafleur et al. 2005), predation or tending of plant pests, direct seed predation and competition with native ant dispersers (Ness and Bronstein 2004). However, *S. invicta* may also facilitate seed dispersal (Stuble et al. 2010). -Alteration of ecosystem functions: Nest building and foraging activities of *S. invicta*, affect physical and chemical soil properties and strongly enhances plant growth through the increase of $NH4^+$ (Lafleur et al. 2005). It also affects mutualistic interactions between plants and insects by reducing numbers of plant mutualists that protect the plant or disperse plant seeds (Ness and Bronstein 2004). It is likely that impact on ecosystem functions may be locally major and similar

			to that observed in presently invaded areas elsewhere.
2.19. How important is the impact of the organism on biodiversity at all levels of organisation (e.g. decline in native species, changes in native species communities, hybridisation) currently in the different biogeographical regions or marine sub-regions where the species has established in Europe (include any past impact in your response)?	N/A		Because the species is not present in Europe, there is no current impact on biodiversity and related ecosystem services.
2.20. How important is the impact of the organism on biodiversity at all levels of organisation likely to be in the future in the different biogeographical regions or marine sub-regions where the species can establish in Europe?	**major**	**low**	It is likely that, if *S. invicta* establishes and spreads in the Mediterranean region, the impact on native biodiversity, in particular on arthropods, molluscs and small vertebrates may be locally major and similar to that observed in presently invaded areas elsewhere.
2.21. How important is decline in conservation value with regard to European and national nature conservation legislation caused by the organism currently in Europe?	N/A		Because the species is not present in Europe, there is no current impact on the conservation value of native species or habitats.
2.22. How important is decline in conservation value with regard to European and national nature conservation legislation caused by the organism likely to be in the future in Europe?	**moderate**	**low**	Although *S. invicta* can inhabit a wide range of habitats, in invaded regions it particularly dominates highly disturbed habitats, such as forests edge, newly deforested areas, road sides, agricultural areas included irrigated soils, gardens, etc. (Morrison et al 2004; Ness and Bronstein 2004). Therefore, many natural habitats of high conservation value may not be threatened by the ant. However, some open natural habitats in the Mediterranean region may well be suitable, in particular those with permanent water supply.
Ecosystem Services impacts			
2.23 How important is the impact of the organism on provisioning, regulating, and cultural services in its non-native range excluding the Union?	**major**	**high**	Provisioning-Nutrition: *S. invicta* damages cultivated field crops by feeding on the seeds, seedlings and developing fruit (see Qu. 2.18). It also negatively affects cattle farming (Teal et al. 1999). Regulating-Seed dispersal: *S. invita* may interfere with seed dispersal of native ant species and directly predate (and therefore reduce) amount of seeds. However, *S. invicta* may also facilitate seed dispersal (Stuble et al.

			2010). Regulating-Pest and disease Control: *S. invicta* may interfere with beneficial insects that exert biocontrol activities in modified habitats. Cultural-Physical use of landscapes: *S. invicta* is a social nuisance in infested areas. Public areas such as parks and recreational areas may become unsafe for children and people have modified their behaviour to avoid the nuisance (Schinkel 2006).
2.24. How important is the impact of the organism on provisioning, regulating, and cultural services currently in the different biogeographic regions or marine sub-regions where the species has established in Europe (include any past impact in your response)?	**N/A**		Because the species is not present in Europe, there is no current impact on ecosystem services.
2.25. How important is the impact of the organism on provisioning, regulating, and cultural services likely to be in the different biogeographic regions or marine sub-regions where the species can establish in Europe in the future?	**major**	**low**	It is likely that, if *S. invicta* finds suitable habitats and climates for its development in the Mediterranean region, the impact on ecosystem services may be locally major and similar to that observed in presently invaded areas. But its extent is very difficult to estimate considering the uncertainty related to habitat/climatic suitability.
Economic impacts			
2.26. How great is the overall economic cost caused by the organism within its current area of distribution, including both costs of damage and the cost of current management	**massive**	**high**	Various estimates of economic costs due to *S. invicta* in USA have been published, which range from half a billion to several billion dollars per year (Pimentel et al. 2000, Williams et al. 2001, Morrison et al. 2004). Some more specific accounts exist for regions and impact categories. For example, as cited in CABI (2017): "In 1998, the average household cost for imported fire ant problems per Texas household in urban areas was US $150.79, with US $9.40 spent on medical care. The total annual metroplex (Austin, Dallas, Ft. Worth, Houston and San Antonio) expenditures for medical care costs

			was 9% or US $47.1 million of the US $526 million total expenditure cost due to *S. invicta* (Lard et al. 2002)". In Australia, the Australian Bureau of Agriculture Resources Economics has calculated that costs due to *S. invicta* in rural industries have amounted to more than AU$ 6.7 billion over 30 years (ISSG 2017). Other regions have made estimations for potential economic costs in case of *S. invicta* invasion. For Hawaii, it was estimated that the impact on various economic sectors would be around US $211 million per year (Gutrich et al. 2007). Economic costs in invaded areas are mainly related to three impact categories: -Impact on agriculture: *S. invicta* can directly damage crops such as corn, sorghum, okra, potatoes and sunflowers by feeding on the seeds, seedlings and developing fruit (Stewart and Vinson 1991; CABI 2017). The impact may also be indirect through the tending of homopteran pests (aphids, scale insects, etc.), which they protect against natural enemies to collect honeydew. However, it must be noted that *S. invicta* also preys on plant pests and may provide benefits to crops. The ant also affects livestock by stinging particularly very young, old or confined animals. The ants move to moist areas of the body (eyes, genitals), the yolk of hatching birds and wounds, and begin stinging when disturbed. The stings result in injury such as blindness, swelling or death (CABI 2017). Finally, the ant can also affect the agriculture sector by

			stinging workers in the field and affecting agricultural equipment (see below). -Health impacts: *S. invicta* can sting people and may cause an allergic reaction that requires medical care and, sometimes, causes anaphylaxis. See social impact below for a description of the medical issue in south-eastern USA. -Impacts on infrastructure and equipment: Ants and their mounds damage roads and electrical equipment. Also domestic electrical equipment may be damaged such as computers, swimming pool pumps, cars or washing machines. Colonies move into buildings or vehicles seeking favourable nesting sites, particularly during flooding and very hot, dry conditions. Fire ant foraging and nesting activities can result in the failure of many types of mechanical (such as hay harvesting machinery and sprinkler systems) and electrical equipment (including air conditioner units and traffic box switching mechanisms) (CABI 2017).
2.27. How great is the economic cost of damage* of the organism currently in the Union (include any past costs in your response)? *i.e. excluding costs of management	N/A		Because the species is not present in Europe, there is no current cost of damage.
2.28. How great is the economic cost of damage* of the organism likely to be in the future in the Union? *i.e. excluding costs of management	**major**	**low**	It is likely that, if *S. invicta* establish and spread in the Mediterranean region, the economic impact may be locally major and similar to that observed in presently invaded areas elsewhere. In the risk assessment for the Netherlands, Noordwijk (2010) also mentions potential 'indirect' effects caused by probable import restrictions if fire ants become established indoors in the Netherlands. Many countries,

			including the countries in the Mediterranean region, are susceptible for fire ants establishments. These countries will have strict regulations on imports of certain goods from infested countries. If the Netherlands harbours fire ants, this will have serious consequences on plant (material) export trade in Europe and worldwide.
2.29. How great are the economic costs associated with managing this organism currently in the Union (include any past costs in your response)?	N/A		Because the species is not present in Europe, there is no current cost of management.
2.30. How great are the economic costs associated with managing this organism likely to be in the future in the Union?	**major**	**medium**	It is likely that, if *S. invicta* establishes and spreads in the Mediterranean region, the management costs may be locally major, and similar to that observed in presently invaded areas elsewhere.
Social and human health impacts			
2.31. How important is social, human health or other impact (not directly included in any earlier categories) caused by the organism for the Union and for third countries, if relevant (e.g. with similar eco-climatic conditions).	**major**	**high**	*Solenopsis invicta* is a social nuisance in infested areas. Public areas such as parks and recreational areas may become unsafe for children and people have modified their behaviour to avoid the nuisance (CABI 2017). Ants also enter buildings, destroying various domestic equipment. *Solenopsis invicta* significantly affects human health. In south-eastern USA, an estimated 14 million people are stung annually (CABI 2017). A survey in Texas showed that 79% of inhabitants have been stung by the ant in the year of the survey (Drees 2000). While, for most people, the effect of stings is relatively minor, albeit painful, some people are hypersensitive to a protein contained in the venom and, for them, a sting can lead to an anaphylactic shock. Anaphylaxis occurs in 0.6 to 6% of persons who are stung and can be lethal. Several deaths are reported each year in south-eastern USA (deShazo et al. 1999). A survey in South Carolina showed that 0.94% of the people seek medical attention for *S. invicta* stings and 0.02% are treated for

			anaphylaxis (Caldwell et al. 1999).
2.32. How important is social, human health or other impact (not directly included in any earlier categories) caused by the organism in the future for the Union.	**major**	**medium**	It is likely that, if *S. invicta* establish and spread in the Mediterranean region, the social impact, including health impact, may be locally major, and similar to that observed in presently invaded areas elsewhere.
Other impacts			
2.33. How important is the impact of the organism as food, a host, a symbiont or a vector for other damaging organisms (e.g. diseases)?	**minimal**	**medium**	*Solenopsis invicta* is not known for being used as food or feed, being a host or vector of other damaging organisms.
2.34. How important might other impacts not already covered by previous questions be resulting from introduction of the organism? (specify in the comment box).	**N/A**		No other impacts were found.
2.35. How important are the expected impacts of the organism despite any natural control by other organisms, such as predators, parasites or pathogens that may already be present in Europe?	**major**	**medium**	There are no specific natural enemies of *Solenopsis* spp. in Europe. Thus, only generalist natural enemies of ants may affect the ant and these are highly unlikely to regulate (control) populations.
2.36. Indicate any parts of Europe where any of the above impacts are particularly likely to occur (provide as much detail as possible).	Mediterranean region, but see comments.	**low**	The species has a major to massive environmental, economic and social impacts elsewhere in the world. However, the transferability to Europe is hindered by uncertain data on habitat/climatic suitability that may limit the geographic area that is most favourable to the insect. Similar impacts may occur locally in Southern Europe in favourable environments, where humidity is adequate, e.g. in direct contact with permanent water bodies and in irrigated areas.

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
3.1. What aspects of climate change, if any, are most likely to affect the risk assessment for this organism?	increase of temperatures, changes in rainfall pattern	**low**	In their study on ant invasions under climate change, Bertelsmeier et al. (2015) predicts that the potential distribution of *S. invicta* will increase in all regions, including in Europe.
3.2. What is the likely timeframe for such changes?	50 years	**low**	
3.3. What aspects of the risk assessment are most likely to change as a result of climate change?	distribution range, likelihood of establishment	**low**	Establishment potential may be enhanced by climate change, i.e. more areas in Europe will be suitable for *S. invicta* invasion (Beltelsmeier et al. 2014) and, indirectly, if more areas are suitable for the ant, the magnitude of impact at continental and regional level will increase.
ADDITIONAL QUESTIONS - RESEARCH			
4.1. If there is any research that would significantly strengthen confidence in the risk assessment please summarise this here.	**yes**	**very high**	The main uncertainty in this risk assessment is the availability of suitable habitats and the tolerance and adaptability of *S. invicta* to current and foreseeable European climate. There is little doubt that the species is able to establish and spread in some areas in the Mediterranean region, but it is unclear if impact will remain at the local levels or if the species has the potential to multiply and colonize larger territories in the EU.

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ANNEX I - Scoring of Likelihoods of Events

(taken from UK Non-native Organism Risk Assessment Scheme User Manual, Version 3.3, 28.02.2005)

Score	Description	Frequency
Very unlikely	This sort of event is theoretically possible, but is never known to have occurred and is not expected to occur	1 in 10,000 years
Unlikely	This sort of event has not occurred anywhere in living memory	1 in 1,000 years
Possible	This sort of event has occurred somewhere at least once in recent years, but not locally	1 in 100 years
Likely	This sort of event has happened on several occasions elsewhere, or on at least one occasion locally in recent years	1 in 10 years
Very likely	This sort of event happens continually and would be expected to occur	Once a year

ANNEX II - Scoring of Magnitude of Impacts

(modified from UK Non-native Organism Risk Assessment Scheme User Manual, Version 3.3, 28.02.2005)

Score	**Biodiversity and ecosystem impact**	**Ecosystem Services impact**	**Economic impact (Monetary loss and response costs per year)**	**Social and human health impact**
	Question 2.18-22	*Question 2.23-25*	*Question 2.26-30*	*Question 2.31-32*
Minimal	Local, short-term population loss, no significant ecosystem effect	No services affected[1]	Up to 10,000 Euro	No social disruption. Local, mild, short-term reversible effects to individuals.
Minor	Some ecosystem impact, reversible changes, localised	Local and temporary, reversible effects to one or few services	10,000-100,000 Euro	Significant concern expressed at local level. Mild short-term reversible effects to identifiable groups, localised.
Moderate	Measureable long-term damage to populations and ecosystem, but little spread, no extinction	Measureable, temporary, local and reversible effects on one or several services	100,000-1,000,000 Euro	Temporary changes to normal activities at local level. Minor irreversible effects and/or larger numbers covered by reversible effects, localised.
Major	Long-term irreversible ecosystem change, spreading beyond local area	Local and irreversible or widespread and reversible effects on one / several services	1,000,000-10,000,000 Euro	Some permanent change of activity locally, concern expressed over wider area. Significant irreversible effects locally or reversible effects over large area.
Massive	Widespread, long-term population loss or extinction, affecting several species with serious ecosystem effects	Widespread and irreversible effects on one / several services	Above 10,000,000 Euro	Long-term social change, significant loss of employment, migration from affected area. Widespread, severe, long-term, irreversible health effects.

[1] Not to be confused with „no impact“.

ANNEX III - Scoring of Confidence Levels

(modified from Bacher et al. 2017)

Confidence level	Description
Low	There is no direct observational evidence to support the assessment, e.g. only inferred data have been used as supporting evidence *and/or* Impacts are recorded at a spatial scale which is unlikely to be relevant to the assessment area *and/or* Evidence is poor and difficult to interpret, e.g. because it is strongly ambiguous *and/or* The information sources are considered to be of low quality or contain information that is unreliable.
Medium	There is some direct observational evidence to support the assessment, but some information is inferred *and/or* Impacts are recorded at a small spatial scale, but rescaling of the data to relevant scales of the assessment area is considered reliable, or to embrace little uncertainty *and/or* The interpretation of the data is to some extent ambiguous or contradictory.
High	There is direct relevant observational evidence to support the assessment (including causality) *and* Impacts are recorded at a comparable scale *and/or* There are reliable/good quality data sources on impacts of the taxa *and* The interpretation of data/information is straightforward *and/or* Data/information are not controversial or contradictory.
Very high	There is direct relevant observational evidence to support the assessment (including causality) from the risk assessment area *and* Impacts are recorded at a comparable scale *and* There are reliable/good quality data sources on impacts of the taxa *and* The interpretation of data/information is straightforward *and* Data/information are not controversial or contradictory.

ANNEX IV - Species Distribution Models

The following climate models have been considered in the risk assessment. See Q. 1.13. for explanations.

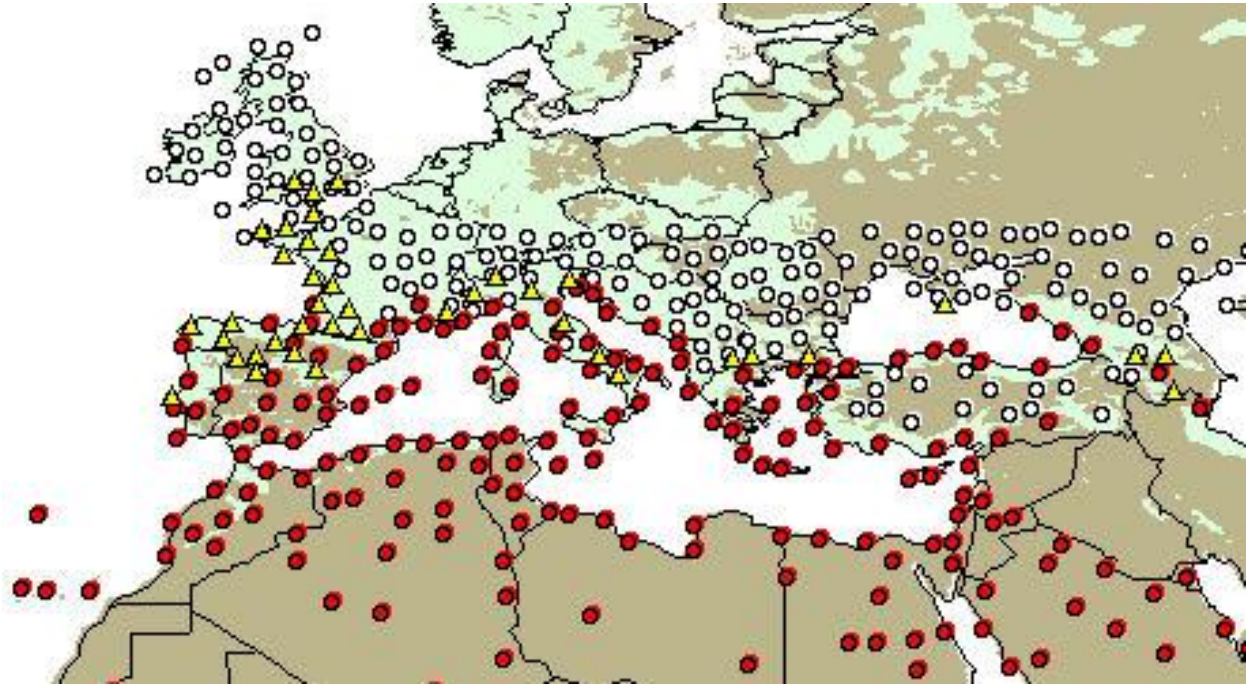

Fig. A1. Potential range of *Solenopsis invicta* in Europe, the Middle East and North Africa from Morrison et al. (2004). Symbols represent potential reproduction: full circle: certain; triangle: possible; empty circle: unlikely. Background represents precipitation: green: adequate; brown: inadequate.

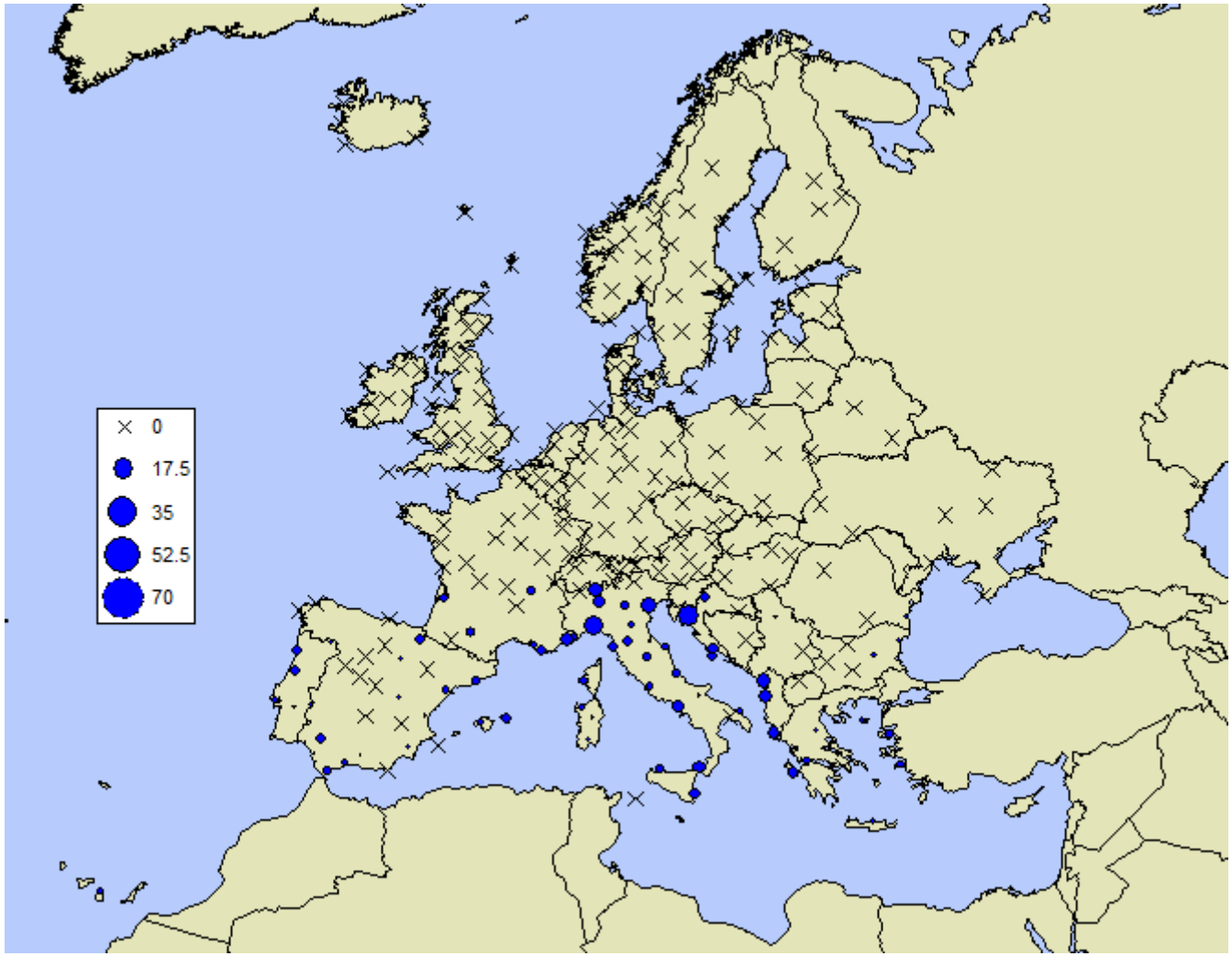

Fig. A2. Ecoclimatic index (EI) for *Solenopsis invicta* using the original CLIMEX parameters from Sutherst and Maywald (2005). Note the differences with the modified version included in the CLIMEX software version 4 (Kriticos et al 2015) shown in Fig. A3.

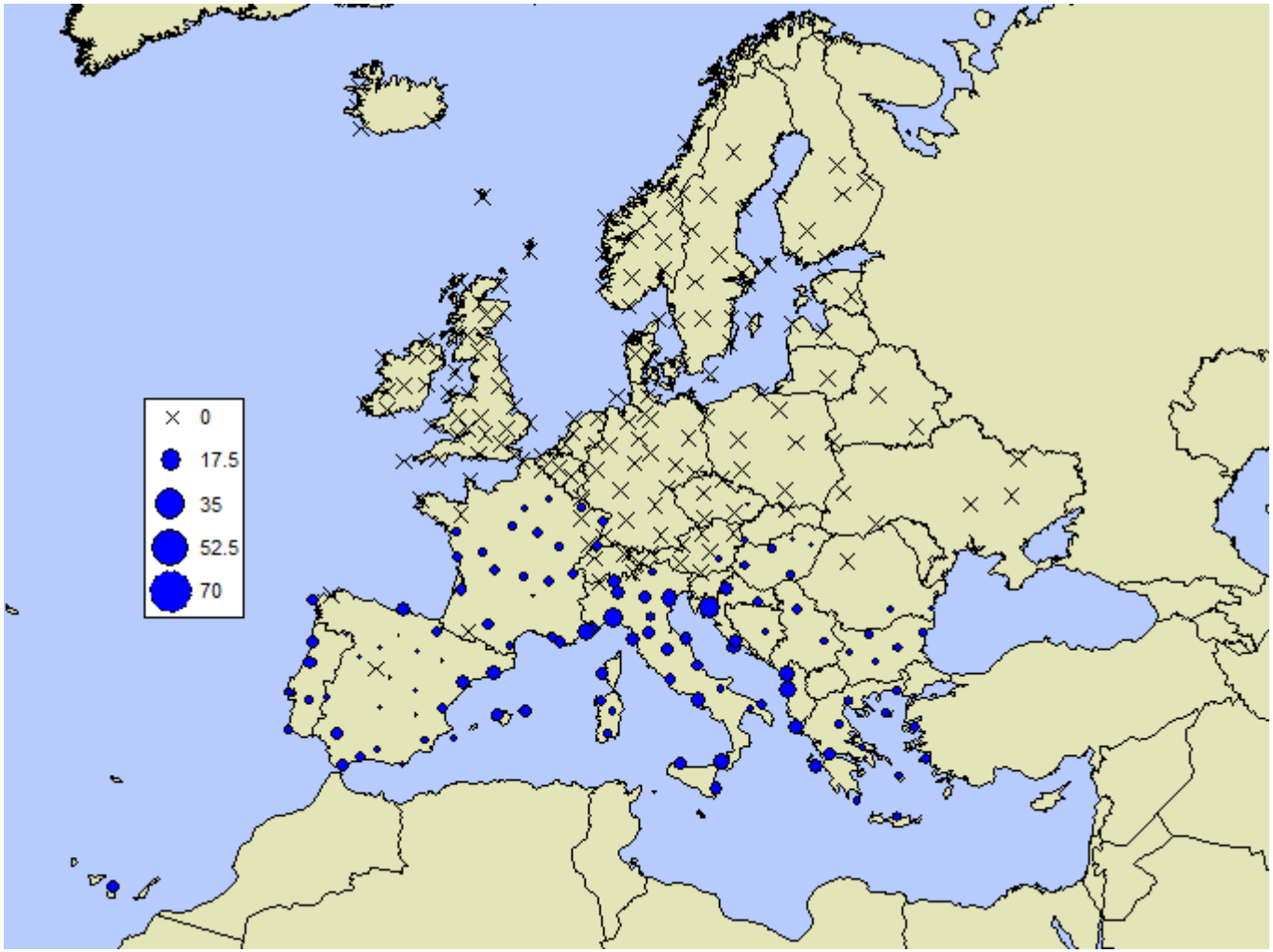

Fig. A3. Ecoclimatic index for *Solenopsis invicta* using CLIMEX parameters from the *S. invicta* parameters included in the CLIMEX software version 4 (Kriticos et al 2015), modified from Sutherst and Maywald (2005). Note differences with Fig. A2.

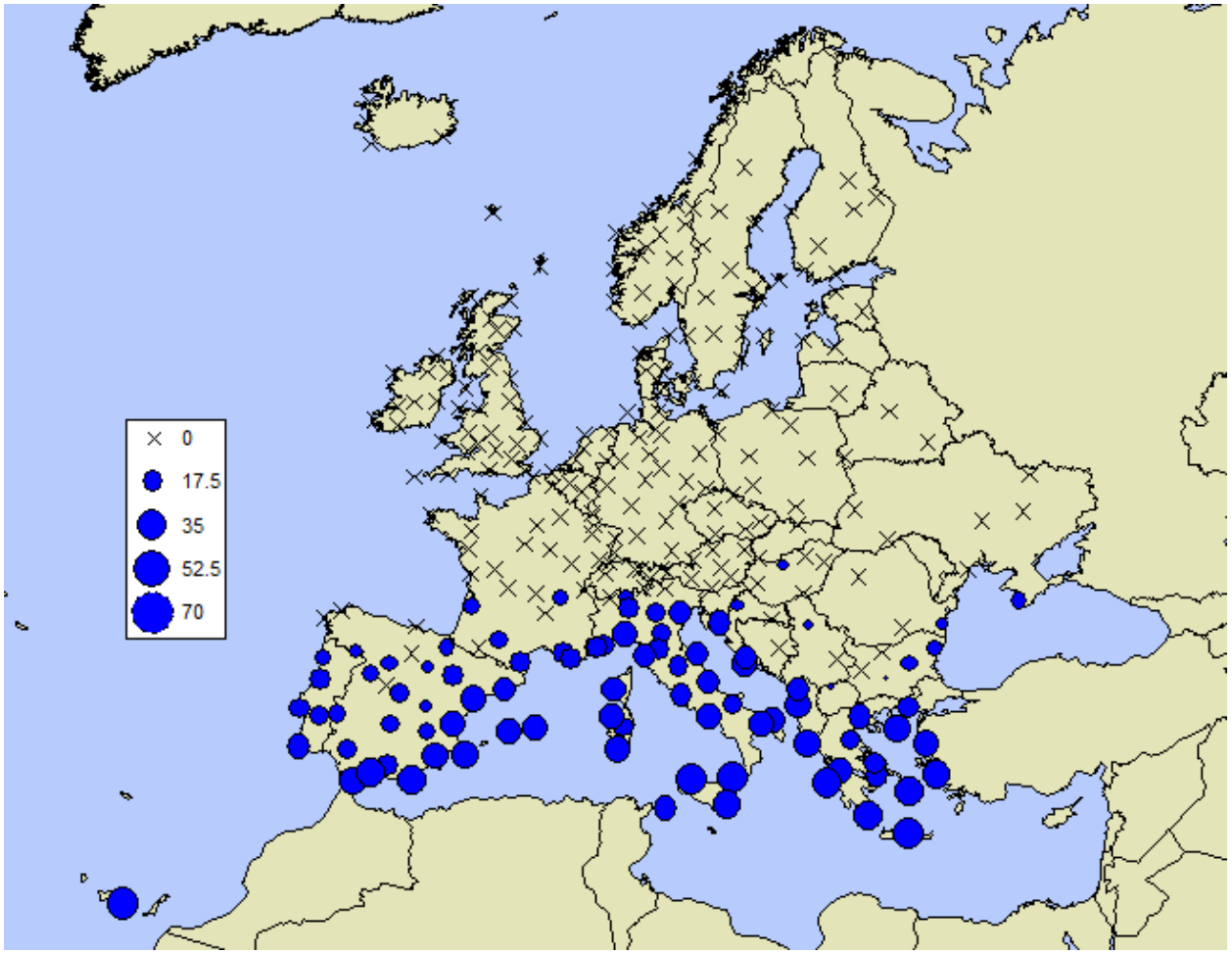

Fig. A4. Ecoclimatic index for *Solenopsis invicta* using the original CLIMEX parameters from Sutherst and Maywald (2005) (as in Fig. A2) with irrigation (30mm/week or 4.3mm/day, al seasons).

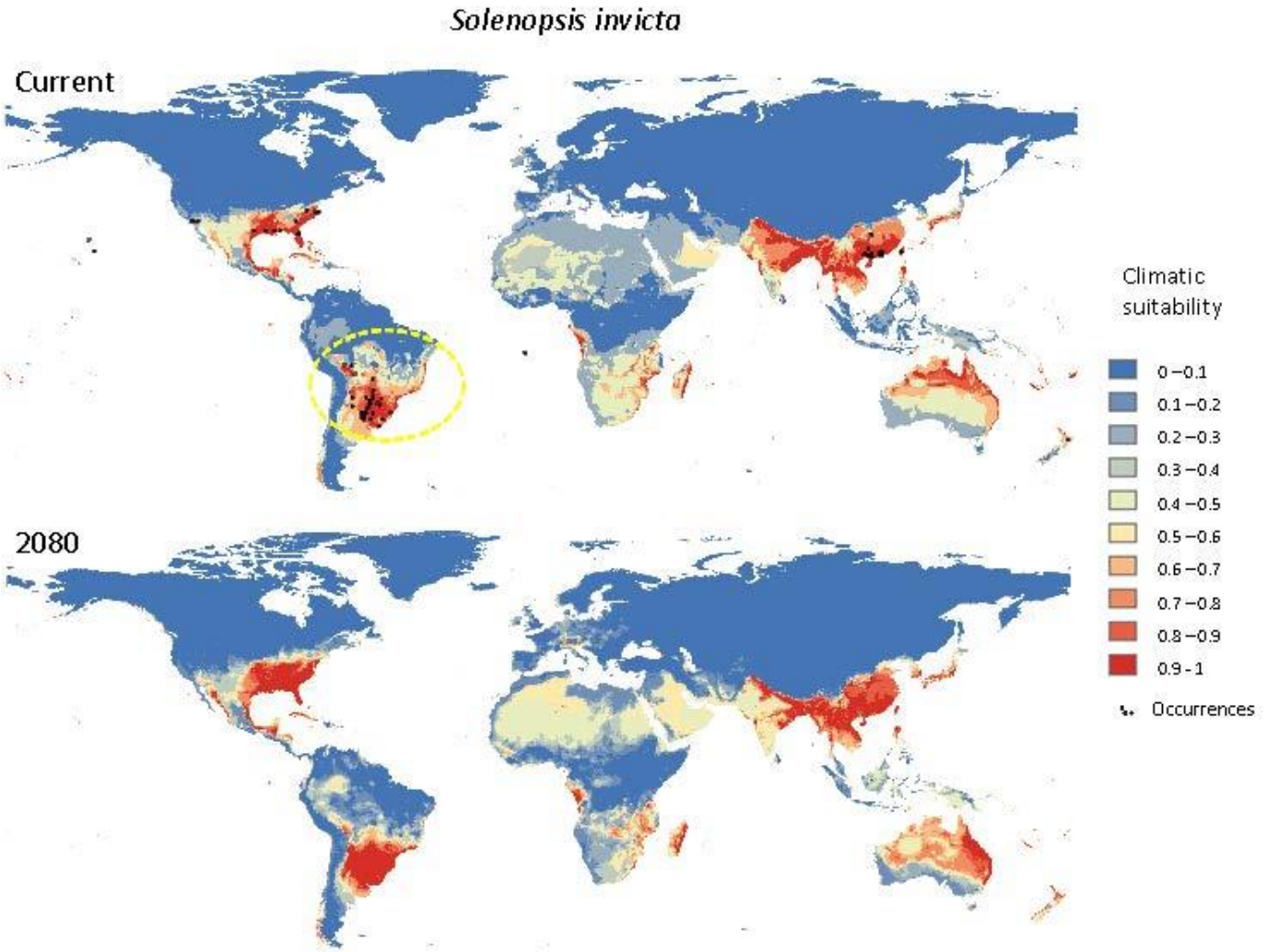

Fig. A5. World climatic suitability of *Solenopsis invicta* in current climate and 2080, from Bertelsmeier et al. (2015).

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