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

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Pest risk assessment for ***Andropogon virginicus***

2018
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This pest risk analysis 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: *Andropogon virginicus* Maliko Gulch, Maui, Hawaii (Forest and Kim Starr)

The pest risk assessment for *Andropogon virginicus* 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

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Review Process

- This PRA on *Andropogon virginicus* was first drafted by Oliver L. Pescott

- The PRA was evaluated under an expert working group at the EPPO headquarters between 2017-01-16/20

The PRAs have been reviewed by:

(1) The EPPO Panel on Invasive Alien Plants (2017)
(2) The EPPO PRA Core members (2017)
(3) The EU Scientific Forum (2018)

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

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Summary of the Express Pest risk assessment for *Andropogon virginicus* L.

PRA area: EPPO region

Describe the endangered area:
The endangered area is mostly focused on the Atlantic (South west France) and the Black Sea biogeographical regions (including parts of Russia and Georgia). Based on the current distribution modelling of the species, there is further potential for establishment in these regions and in the Continental, Mediterranean and Anatolian biogeographical regions (see Appendix 1 and 2).

The highest potential for establishment is in continental areas of northern Italy and Slovenia, the east coastline of the Adriatic Sea (Croatia), the west coast of France bordering Spain. The east coast of the Black Sea (including parts of Russia and Georgia) also has a high potential for establishment. Limited areas of south east Turkey are marginally suitable for establishment.

Main conclusions
Andropogon virginicus poses a high phytosanitary risk (including biodiversity and ecosystem services) to the endangered area with a moderate uncertainty. Within the EPPO region, the species occurs in France, Georgia and Russia. Populations of the species have increased and spread in France. Following the first record in the eastern Black Sea area in 1947, the species is now reported from sites spanning over 600 km.

The likelihood of new introduction occurring via seed imports is moderate as the species is sold within the EPPO region. New introductions via the import of hay are assessed as moderate with a high uncertainty. Introduction as a contaminant via other pathways (contaminant of machinery and equipment, and a contaminant of tourists), is rated as low with a high uncertainty.

Entry and establishment
Within the EPPO region, the species occurs in France, Georgia and Russia. Natural areas most at risk of invasion by this species within the PRA area are grasslands, inland wetlands, heathlands and forests. Apart from the latter, *A. virginicus* has been recorded in the aforementioned habitats in the PRA area (Granereau and Verloove, 2010; Mironova, 2013; Royaud, 2010).

The pathways identified are:

Plants for planting: Moderate likelihood of entry

Contaminant of Hay imports: Moderate likelihood of entry

Contaminant of machinery and equipment: Low likelihood of entry

Contaminant of tourists: Low likelihood of entry

Potential impacts in the PRA area
Although present in the EPPO region, there are no reported studies that have evaluated the ecological or economic impact of *A. virginicus* in the region. However, due to the aggressive spread of the species in natural areas in Georgia, and around the Black Sea, and due to the rapid expansion of the plant in France, the Expert Working Group (EWG) considers that the potential impacts in the EPPO region will be in part similar to that seen in the current area of distribution. This is further emphasised by the fact that when *A. virginicus* invades an area it forms dense monospecific stands and this has been observed in the PRA area (Granereau and Verloove, 2010).

A. virginicus may invade habitats on mesic soils which could introduce fire to previously low fire systems (EWG opinion). If *A. virginicus* invades areas with nutrient poor soils, impacts are likely to be significant within the PRA area where habitats of conservation importance are often nutrient

poor. At present, fire risk is a serious problem in the Mediterranean but also in heathland and dune systems in the Atlantic biogeographical region (e.g. the Netherlands). Adding a species that increases the risk or intensity of fire and even benefits from fire does pose a serious risk to biodiversity and associated ecosystem services provided by these natural areas.

The EWG consider the potential impacts in the PRA area will be moderate with a high uncertainty for ecosystem services and socio-economic impacts and moderate with a moderate uncertainty for biodiversity impacts. The text on impacts in the PRA area relates equally to EU Member States and non-EU Member States in the EPPO region.

Climate change

The likelihood of establishment will increase within the PRA area as a result of climate change. The area conducive for establishment will increase with larger areas of the Atlantic, Black Sea, Continental and Mediterranean biogeographical regions becoming suitable for establishment. Much of central Europe was predicted to become suitable for the species (2070 RCP 8.5), including parts of the EU: eastern France, Croatia, southern Germany, Austria, Slovenia, and the wider EPPO region: northern Switzerland, , Bosnia and Herzegovina, Montenegro, western Serbia, Kosovo and Albania. This was mainly driven by a projected increase in temperature of the warmest quarter (i.e. summer). Human assisted spread may increase with more areas available to grow the species. Natural spread will increase as a result of climate change. More habitats and regions may favour the establishment of *A. virginicus* and thus the climatically suitable area will increase. Higher temperatures and less precipitation could lead to a higher risk of fires, which may favour the initiation of a grass fire cycle. Therefore potentially, the impact on biodiversity and ecosystem services will increase from moderate to high with a high uncertainty. The influence of projected climate change scenarios has not been taken into account in the overall scoring of the risk assessment based on the high levels of uncertainty with future projections.

The results of this PRA show that *Andropogon virginicus* poses high risk to the current and projected endangered area (Atlantic, Black Sea, Continental and Mediterranean biogeographical regions) with a moderate uncertainty.

Phytosanitary risk (including biodiversity and ecosystem services) for the *endangered area* (current/future climate) **Pathways for entry** Plants for planting: Moderate/Moderate Contaminant of Hay imports: Moderate/Moderate Contaminant of machinery and equipment: Low/Low Contaminant of tourists: Low/Low Likelihood of establishment in natural areas: High/High Likelihood of establishment in managed areas: High/High Spread: High/High ***Impacts (potential: PRA area)*** Biodiversity and environment: Moderate/High Ecosystem services: Moderate/High	High X	Moderate	Low

Socio-economic: Moderate/High			
Level of uncertainty of assessment (current/future climate) **Pathways for entry** Plants for planting: High/High Import of hay: High/High Contaminant of machinery and equipment: High/High Contaminant of tourists: High/High Likelihood of establishment in natural areas: Low/High Likelihood of establishment in managed areas: Low/High Spread: Low/High ***Impacts (PRA area)*** Biodiversity and environment: Moderate/High Ecosystem services: High/High Socio-economic: High/High	High	Moderate X	Low

Other recommendations:

- The Expert Working Group considers that it may be possible to eradicate the French population of the species and this should be attempted as soon as possible,
- Surveys should be conducted to confirm the current distribution and status of the species within the endangered area,
- Data sharing should be encouraged across the EPPO region,
- Contact land-managers and local botanists, where the species occurs, to attain further information on all aspects of the species biology,
- Voucher specimens from populations within the EPPO region should be lodged with herbaria.

Express Pest risk assessment:

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***Andropogon virginicus* L.**

Prepared by:

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Date: 7th January 2017

Stage 1. Initiation

Reason for performing the PRA:

Andropogon virginicus was added to the EPPO Alert List in 2011 and transferred to the Observation List of invasive alien plants in 2014 following a prioritization assessment (EPPO, 2014a). *Andropogon virginicus* (*Poaceae*) is a perennial grass native to North and Central America. This species has been introduced into several continents; for example it has naturalized in Australia, New Zealand, Japan, and the Republic of Korea; it is also well known for its reported effects on the fire regime of seasonal submontane woodlands in Hawaiʻi, where it is also non-native. Prior to 2006, the only report from the EPPO region was in Georgia and Russia. In 2006, it was first found in France in a military camp (‘Camp du Poteau’ – located partly in Gironde and Landes departments), and then nearby in 2008 at a nature reserve in Landes. Because the population of *A. virginicus* has multiplied significantly in one of the infested areas in France (from 2 to 500 plants in two years at the nature reserve site in Landes) and the species is considered to be invasive in other parts of the world, the French NPPO suggested adding *A. virginicus* to the EPPO Alert List. *Andropogon virginicus* was also assessed under an all-taxa horizon scanning exercise designed to help prioritise risk assessments for the “most threatening new and emerging invasive alien species” in Europe (Roy *et al.*, 2015); it was rated as a “high” priority for risk assessment. Climate modelling has shown that the species has the potential to establish in more regions in the EPPO region (including EU member States) than it currently occurs (Appendix 1). There is further potential for establishment the Continental, Mediterranean and Anatolian biogeographical regions (Appendix 1 and 2).

In 2016, the species was prioritized (along with 36 additional species from the EPPO List of Invasive Alien Plants and a recent horizon scanning study[1]) for PRA within the LIFE funded project “Mitigating the threat of invasive alien plants to the EU through pest risk analysis to support the Regulation 1143/2014’. *Andropogon virginicus* was one of 16 species identified as having a high priority for PRA (Tanner et al., 2017).

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 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.

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

All information relating to EU Member States is included in the Pest risk assessment and information from the wider EPPO region only acts to strengthen the information in the PRA document. The PRA defines the endangered area where it lists all relevant countries within the endangered area, including EU Member States. The distribution section lists all relevant countries in the EPPO region (including by default those of EU Member States and biogeographical regions which are specific to EU member States). Habitats and where they occur in the PRA are defined by the EUNIS categorization which is relevant to EU Member States. Pathways are defined and relevant to the EU Member States and the wider EPPO Member countries, and where the EWG consider they may differ between EU Member States and non-EU EPPO countries, this is stated. The establishment and spread sections specifically detail EU Member States. When impacts are relevant for both EU Member States and non-EU EPPO countries this is stated 'The text within this section relates equally to EU Member States and non-EU Member States in the EPPO region'. Where impacts are not considered equal to EU Member States and non-EU Member States this is stated and further information is included specifically for EU member States. For climate change, all countries (including EU Member States) are detailed.

Stage 2. Pest risk assessment

1. Taxonomy: *Andropogon virginicus* L. (Kingdom *Plantae*; Division *Tracheophyta*; Class *Magnoliopsida*; Order *Poales*; Family *Poaceae*; Tribe *Andropogoneae*; Section *Leptopogon*; Genus *Andropogon*). (Integrated Taxonomic Information System, accessed 7 January 2017).

EPPO Code: ANOVI

Common names: broomsedge; broomsedge bluestem; yellowsedge bluestem; yellow bluestem; whisky grass; sedge grass; beardgrass; sage grass; deceptive bluestem; old-field broomstraw; broomstraw; smooth bluestem; Russia: андропогон виргинский; Republic of Korea: Na-do-sol-sae (나도솔새); Japan: メリケンカルカヤ.

Note: The current PRA assesses the species *A. virginicus* L.; however, Campbell (1983a) defined the following taxa as comprising the "virginicus complex": *A. arctatus* Chapm., *A. brachystachyus* Chapm., *A. floridanus* Scribn., *A. glomeratus* (Walter) Britton, Sterns & Poggenb., *A. gyrans* Ashe., *A. longiberbis* Hack., *A. liebmannii* Hack., *A. tracyi* Nash and *A. virginicus* L. (all still accepted at the species level with these names by Campbell, 2003). The complex is considered a critical one i.e. taxonomically challenging, with slight morphological differences separating taxa. As such, although the PRA is for *A. virginicus* L., occasionally the text will consider relevant information for other species within the complex, particularly where these appear likely to have been misidentified for *A. virginicus*, or where there is explicit doubt about the identity of observed or studied plants. Of particular interest are *A. glomeratus* and *A. gyrans*, which are, besides *A. virginicus*, the most widespread species of the complex in the USA. They are also the two other species identified as weedy by Campbell (1983a), and which have native ranges extending outside of the USA (note that *A. longiberbis* is reported to be native in the Bahamas; Campbell, 2003). This PRA follows the nomenclature and taxonomy of Campbell (2003); note that Campbell (2003) is the section on Andropogon from the *Flora of North America*, probably the most authoritative treatment of this genus available at the current time. *Andropogon glomeratus* has been highlighted as a potential invasive species in Mexico (though the species is native to this country (Sanchez-Ken et al., 2012). The EWG is not aware of additional information on the invasiveness of other species in the complex.

Two recent publications relating to sightings of this species (Granereau & Verloove, 2010; Royaud, 2010) use the formulation *Andropogon virginicus sensu lato* to refer to the virginicus complex of Campbell (1983a); such a formulation may be best avoided, given that Campbell (1983a, 2003) does not explicitly equate the complex with a single broad species concept, and that historical authors of Floras do not appear to have done so either (Franz *et al.*, 2014). Granereau & Verloove (2010) indicate that the plants they have observed are probably referable to *A. virginicus* L., although they also raise the possibility that, due to the critical nature of the virginicus complex, and the fact that both infraspecific and ecotypic variation exist within *A. virginicus*, the presence of other taxa cannot be ruled out.

This PRA considers all publications pertaining to the non-native range of *Andropogon virginicus* as referring to the species in the strict sense of Campbell (2003), unless there is strong evidence to the contrary. Therefore, the PRA is for *Andropogon virginicus* L. *sensu* Campbell (2003)"

Synonymy: From Campbell (1983a):
Synonyms of Andropogon virginicus *L.,*
Holcus virginicus (L.) Steudel; *Sorghum virginicum* (L.) Kuntze
Synonyms of Andropogon virginicus *L. var.* virginicus

Cinna lateralis Walter; *Andropogon dissitiflorus* Michaux; *Andropogon vaginatus* Ell.; *Andropogon tetrastachyus* Ell.; *Andropogon eriophorus* Scheele; *Andropogon curtisianus* Steudel; *Andropogon virginicus* var. *genuinus* Hackel
Synonyms of Andropogon virginicus *L. var.* glaucus
Andropogon virginicus L. var. *dealbatus* Hackel; *Andropogon capillipes* Nash; *Andropogon dealbatus* (C. Mohr ex Hack.) Weakley & LeBlond

The following synonyms are listed by www.theplantlist.com as synonyms of *A. virginicus* in a broad sense".
Andropogon virginicus var. *abbreviatus* (Hack.) Fernald & Griscom
Andropogon virginicus var. *corymbosus* (Hack.) Fernald & Griscom
Andropogon virginicus var. *dealbatus* Hack.
Andropogon virginicus var. *decipiens* C.S.Campb.
Andropogon virginicus var. *glaucopsis* (Elliott) Hitchc.
Andropogon virginicus var. *glaucus* Hack.
Andropogon virginicus var. *graciliformis* León
Andropogon virginicus f. *hirsutior* (Hack.) Fernald & Griscom
Andropogon virginicus var. *hirsutior* (Hack.) Hitchc.
Andropogon virginicus subsp. *leucostachyus* (Kunth) Hack.
Andropogon virginicus var. *stenophyllus* (Hack.) Fernald & Griscom
Andropogon virginicus f. *tenuispatheus* (Nash) Fernald
Andropogon virginicus var. *tenuispatheus* (Nash) Fernald & Griscom
Andropogon virginicus var. *tetrastachyus* (Elliott) Hack.
Andropogon virginicus var. *vaginatus* (Elliott) Alph.Wood
Andropogon virginicus var. *virginicus*
Andropogon virginicus f. *virginicus*

Plant type: Perennial grass

Related native species in the EPPO region: *Andropogon distachyos* L. (Tutin et al., 1980)

Related non-native species in the EPPO region: *Andropogon gerardii* records for France (as *A. provincialis* Lam.)and Sweden, *Andropogon glomeratus* just 1 old garden collected specimen from Belgium in the Natural History Museum Maastricht (NL), *Schizachyrium scoparium* 1 record as casual from NL (GBIF, 2017).

Related species in trade in the EPPO region: *A. capillipes* Nash., *A. gerardii* Vitman, *A. glomeratus* (Walter) Britton, Sterns & Poggenb., *A. hallii* Hack., *A. ternarius* Michx. and *Schizachyrium scoparium* (Michx.) Nash, *A. longiberbis* Hackel. (Drake, 1994).

2. Pest overview

Introduction

Andropogon virginicus is a perennial grass native to North (eastern and south-eastern North America), Central and South America. It is a densely-tufted grass with a height range of 40-210 cm (Campbell, 2003); under the Raunkiaer life-form system it is a hemicryptophyte (Uchytil, 1992) (Appendix 3, see figures 1, 2 and 3). Seed production can be high (around 1,800 seeds per plant); the presence of cleistogamy (non-opening florets that self-fertilise) and the high seed production means that populations can increase rapidly. *Andropogon virginicus* has been introduced and is naturalized in Australia, Georgia, New Zealand, western North America, the Republic of Korea, Russia and Japan (see section 6 for associated references for countries). Prior to 2006, the only reports from the EPPO region were in Georgia and the Russian Federation (Mironova, 2013). In 2006 the species was found in France in a military camp; soon after, in 2008, a nearby site was located in the National Reserve of Hunting and Wildlife of Arjuzanx (in Landes; Royaud, 2010). At this site the population appears to be increasing: Royaud (2010) reported an increase in the population from two plants in 2008 to 500 in December 2010. *Andropogon virginicus* is expanding in the South-west of France where it colonizes acidic regions as Landes, Gironde and Pyrénées-Atlantique departments.

Reproduction

Reproduction in *A. virginicus* is sexual, although inbreeding is not unusual due to cleistogamous florets (i.e. flowers that do not open to allow cross-pollination). Chasmogamy (i.e. flowers that do open to allow cross-pollination) is reported to vary from around 40 to 100 % across described varieties and forms within the species (see **Identification** below); Campbell (1982, 1983a) gives a figure of around 50 % chasmogamy for the reportedly weedier subtaxa within *A. virginicus*, a trait which he links to their success as weeds. Note that some sources (e.g. CABI, 2016a) do not make this distinction between taxa, thus giving the unwarranted impression that the species is always predominantly chasmogamous. Chasmogamous florets are wind-pollinated, as is true for most grasses.

Gibson & Risser (1982) reported individual seed weights of between 1.00 and 3.39 milligrams across various environmental conditions in a greenhouse transplant experiment, and of between one and three flowering stems per ramet. Voight (1959) noted that each flowering stem could have as many as 50 racemes (see **Identification** below), with each raceme having 8-12 spikelets; this suggests an upper limit of around 1800 seeds per plant (assuming three flowering stems per ramet). Seeds are wind-dispersed, with the dispersules having a high terminal velocity equivalent to *Taraxacum* (Campbell, 1983b); livestock or humans may also transport dispersules given the pubescent rames (Campbell, 2003). Drake (1998) found that *A. virginicus* was the commonest grass species in seed rain traps in invaded *Metrosideros polymorpha* forest on Hawai'i, indicating that the combination of seed production and dispersal potential is likely to lead to high rates of spread.

The species flowers from September to October in the southern and mid-Atlantic United States (Weakley, 2015), and in Hawaiʻi flowering has been found to be stimulated in the autumn by shortening daylight (Sorenson, 1991). Flowering begins when plants are 2 or 3 years old, and continues thereafter (Keever, 1950; Golley, 1965); individual plants reportedly "have an average lifespan of 3-5 years and […] all plants [… die] within 7 years" (GISD, 2017). Seeds of *A. virginicus* have been found to form persistent seed banks in forests in Japan, although at a relatively low density (14 seeds m^{-2}; Naka & Yoda, 1984); higher densities have been found elsewhere, for example, a mean of 286 seeds m^{-2} on granitic outcrops, Georgia, USA (Houle & Phillips, 1988). The seeds "readily establish on exposed soil" (Uchytil, 1992), and require a period of cold before they will germinate (Burrows, 1990).

Andropogon virginicus is also a fire-adapted species (similar to other species in the *Andropogon* complex), accumulating dead material which promotes fires, leading to increases in its abundance (Weber, 2003); it may therefore be able to permanently change the fire regime of an ecosystem. Hughes *et al.* (1991) report that *A. virginicus* can resprout within 96 hours of a fire (see also **Habitat and environmental requirements**). Uchytil (1992), in the USDA Fire Effects Information System, does classify the species as both a "fire survivor and an off-site colonizer", i.e. strategies relating to its ability to resprout and to readily colonise bare soil after a fire.

Habitat and environmental requirements

Andropogon virginicus invades a wide variety of habitats from disturbed to relatively intact habitats including ruderal areas, wetlands, open pastures, grasslands, and open woodlands (Appendix 3, see figure 2). The success of the species in invading a diversity of habitats could be attributed to multiple ecological strategies (see Xavier and D'Antonio, 2016). Campbell (2003) describes the habitats of the three named varieties of *A. virginicus*. For *A. virginicus* var. *decipiens* C.S. Campb. listed habitats include "flatwoods [open pine forest or savannah], scrublands, and disturbed sites, such as roadsides and cleared timberlands, of the south eastern coastal plain [of the USA]". For *A. virginicus* var. *glaucus* Hack., the given habitats are "moist or dry soils of the coastal plain, from southern New Jersey to eastern Texas. For the widespread nominal variety, var. *virginicus*, denoted as "weedy" by Campbell (2003), the listed habitats include "openings in mature vegetation created by disturbance" and "poorly drained soils of pond margins, swales, and cutover flatwoods".

Weber (2003) states that the species is an indicator of acid soil, and gives "prairies" as the main habitat. The species also tolerates extremely nutrient poor soils in Australia, burnt areas and grassland and has a low requirement for phosphorus (Weber, 2003). Although it is also found on more fertile soils, its abundance decreases as competition increases; indeed, the species has often been used as an exemplar of a mid-successional species (Bazzaz, 1968, 1975, 1990). See Section 7 for a detailed list of habitats from across the range of the species.

Fire is an important part of the species' ecology, both within its native (Uchytil, 1992; Irving, 1983) and invaded ranges (e.g. Hughes *et al.*, 1991) where the species depends on frequent disturbance to maintain itself (Lemon, 1949; Lewis & Harshbarger, 1976; White *et al.*, 1991; Uchytil, 1992). Hughes *et al.* (1991) state that *A. virginicus* is one of several non-native grasses in Hawai'i that are excellent fire promoters, given their high dead:live biomass ratio, ability to burn at high relative humidity and high fuel moisture. Overall then, it is worth noting that this species is fire-promoting, with the potential for positive feedbacks, but that controlled burning at a particular time of year and frequency may also reduce the species' abundance (e.g. Butler *et al.*, 2002).

Identification

Andropogon virginicus is an herbaceous, perennial, warm season (C_4) grass. It has a cespitose (i.e. densely tufted) growth form, and a height range of 40-210 cm (Campbell, 2003); under the Raunkiaer life-form system it is a hemicryptophyte (Uchytil, 1992).. The culms are typically branched distally, with light-green to reddish brown colouration (Weber, 2003). The leaf-sheaths are long-ciliate, with a tuberculate (scabrous) surface. The ligules are yellow to brownish and membranous, 0.2-1 mm, with cilia 0.2-1.3 mm (Campbell, 2003). Leaf blades reach up to 52 cm, and are 1.7-6.5 mm wide. These blades are variably hairy, with Campbell (2003) reporting them "smooth and glabrous or sparsely to densely pubescent with spreading hairs". Weber (2003) reports that the "[i]nflorescences are racemes of 2-4 cm length containing spikelets of 3-4 mm length. [And that f]lowers are either sessile and bisexual or stalked and male." This is, however, a rather simplified description: Barkworth (2003) lays out four pages defining the terms used to describe the "great structural diversity" of inflorescences found within the *Andropogoneae* tribe. Campbell (2003) should be consulted for guidance on distinguishing between the nine species and their varieties within the *A. virginicus* complex (defined in Campbell, 1983; and see **Taxonomy** above).

Andropogon as a genus can be separated from the closely related genus *Schizachyrium* by the cupulate tips of its rame internodes, the convex lower glumes, and the presence of veins between the keels of the lower glumes (Wipff, 2003). *Schizachyrium* has historically been included in *Andropogon* (Hitchcock, 1951).

Symptoms (Impacts)

As a non-native invasive species, *A. virginicus* is generally considered to "[alter] successional processes, [change] fire regimes, [cause] erosion, and [alter] hydrology" (CABI, 2016a). Most, if not all, of the supporting evidence for these impacts come from studies of invaded areas in Hawai'i (Mueller-Dombois, 1972; Hughes *et al.*, 1991). Although there can be no doubt that *A. virginicus* plays an important role in the fire regimes of some ecosystems (Uchytil, 1992; Parsons and Cuthbertson, 2001; Queensland Government, 2016), the nature of its impacts, in isolation from other non-native species, is less clear in Hawai'i, even though the systems studied have become well-known. This makes the attribution of importance of *A. virginicus* in Hawai'i, where impacts on fire regime are considered, rather ambiguous: *Andropogon virginicus* may have the same impacts in isolation, but in a community of non-native grasses, it appears to be *S. condensatum*, and, particularly latterly, *Melinis minutiflora* P.Beauv., that are by far the dominant species in the main area studied in the Volcanoes National Park (Hughes *et al.*, 1991; D'Antonio *et al.*, 2011). It should also be stated that the impacts on erosion are inferred by Mueller-Dombois (1972, 1973), rather than measured or monitored, and that therefore it is hard to say with much certainty that the invasion of *A. virginicus*, or any related taxon, is directly linked to increased soil erosion in Hawai'i.

Pot-based experimental work by Rice (1972) demonstrated allelopathic effects on the seedlings of the native North American species *Amaranthus palmeri*, *Bromus japonicus*, *Aristida oligantha*, and *Schizachyrium scoparium* (syn. *Andropogon scoparius*). Inhibitory effects on nitrogen-fixing bacteria were also found.

Within its native range, *A. virginicus* is a significant weed of pasture (forageland), due to it being less palatable than other grasses, and is stated to have "invaded millions of acres of pastureland across the southeastern USA" (e.g. Butler *et al.*, 2006). Research into controlling it as a weed of such systems has been conducted (e.g. Butler *et al.*, 2002, 2006). Uchytil (1992) states that "nearly pure stands can persist on soils low in nitrogen or phosphorus as a result of competition and allelopathy." Parsons and Cuthbertson (2001) also note impacts on pasture productivity in Australia.

Existing PRAs

Australia: This risk assessment predicts the likelihood of invasions of *A. virginicus* in Australia and Hawaiʻi. The risk assessment for Australia scored *A. virginicus* as 13, indicating that the species should be rejected for import (PIER 2001). The species has also been assessed using the Victorian Weed Risk Assessment (The State of Victoria, 1996-2017).

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

Russia: The Russian Federation PPO performed a prioritization report assessment on *A. virginicus* which concluded that this species has a high spread potential and high potential environmental impact and therefore should be included in the List of Invasive Alien Plants (Mironova, 2013; EPPO, 2014b).

USA (Hawaiʻi): The risk assessment for Hawaiʻi scored *A. virginicus* as 20, indicating that the species poses a high risk of becoming a problematic invader (PIER 2010). It has reportedly been placed on the exclusion list by French Polynesia because of this assessment (CABI, 2016a).

Socio-economic benefits

This species is generally considered to be of low economic value. *Andropogon virginicus* is sold by nurseries promoting native species gardening in the USA (e.g. http://www.northcreeknurseries.com/plantName/Andropogon-virginicus-). A named cultivar ('Silver Beauty') exists for horticulture (USDA, 2009). There is evidence that the species is sold within the EPPO region, in particular the EU https://www.jelitto.com/de/Saatgut/Ziergraeser/ANDROPOGON+virginicus+Portion+en.html, and www.siergras.nl/Siergras_soorten/kenmerk/kenmerk/8/Andropogon_virginicus however again, the species is considered low economic value to the horticulture industry (Expert Working Group (EWG) opinion).

It is frequently mentioned as a low value forage species in North America, and is therefore undesirable when it invades pastures, outcompeting other vegetation of greater value as fodder (Griffin *et al.*, 1988; Butler *et al.*, 2002). Nutritional quality is greatly increased by prescribed burning, presumably due to the higher nutritional value of young shoots (Uchytil, 1992). Campbell

(1983) states that "[t]he only direct economic value of the plants is in their leaves and stems, which have long been used for dyeing fabric and for brooms". There is no evidence that the species is used as a forage species within the EPPO region.

The plant is promoted for landscaping in the USA, and there may be interest in growing plants for similar purposes in the EPPO region (EWG opinion).

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

Some taxa within the *A. virginicus* complex (e.g. *A. glomeratus* var. *glaucopsis* (Elliott) Mohr) may act as vectors for maize dwarf mosaic virus and sugarcane mosaic virus (Rosenkranz, 1987). Switchgrass (*Panicum virgatum* L., a biofuel crop) mosaic virus has also been found in *A. virginicus* L. (Agindotan *et al.*, 2013). Both maize dwarf mosaic virus and sugarcane mosaic virus are found in the EPPO area (CABI, 2016b,c); switchgrass mosaic virus is a recently identified virus, related to maize rayado fino virus (Agindotan *et al.*, 2013), and does not appear to have been identified in the EPPO area. Note that, in general, perennial grasses have been found to be major sources of inoculum for the transmission of viruses in agroecosystems (e.g. Knoke *et al.*, 1983, for the maize-maize dwarf mosaic virus-Johnson grass (*Sorghum halepense* L.) pathosystem).

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

5. Regulatory status of the pest

Australia: Although some local governments aim to reduce population sizes of *A. virginicus* (e.g. in Brisbane, where it is a low priority environmental weed, http://weeds.brisbane.qld.gov.au/weeds/whisky-grass), it is not currently controlled at the national level in Australia (Queensland Government, 2016). It is also considered to be an "environmental weed" in New South Wales and Queensland (Queensland Government, 2016).

Europe (overall): *Andropogon virginicus* was added to the EPPO "Alert List" in 2011. It was transferred to the EPPO "Observation List" in 2014. The species was evaluated through the EPPO prioritisation scheme in 2016, and was considered to be a high priority for a PRA given its potential for further spread within the EPPO area. *Andropogon virginicus* was also assessed under an all-taxa horizon scanning exercise designed to help prioritise risk assessments for the "most threatening new and emerging invasive alien species" in Europe (Roy *et al.*, 2015) where it was rated as a "high" priority for risk assessment.

French Polynesia: The species is on the quarantine pest list for French Polynesia (e.g. see http://www.biosecurity.govt.nz/node/7067).

New Zealand: The species has been included on many weed lists in New Zealand, and was included in a summary "consolidated list" by Howell (2008). However, it is not currently listed on the country's National Plant Pest Accord (which would prohibit it from sale and commercial propagation and distribution).

USA: *Andropogon virginicus* is on the composite list of weeds of the Weed Science Society of America (http://wssa.net/wssa/weed/composite-list-of-weeds/); however, this does not imply by itself the existence of any regulatory instruments.

USA (Hawaiʻi): *Andropogon virginicus* is on the "List of Plant Species Designated as Noxious Weeds for Eradication or Control Purposes by the Hawaiʻi Department of Agriculture" (https://hdoa.Hawaiʻi.gov/pi/files/2013/01/AR-68.pdf).

South Africa: In South Africa control of the species is enabled by the Conservation of Agricultural Resources (CARA) Act 43 of 1983, as amended, in conjunction with the National Environmental Management: Biodiversity (NEMBA) Act 10 of 2004. Currently *A. virginicus* is listed as a “Prohibited Alien Species” on the NEMBA mandated list of 2014. “[Prohibited alien species are] defined as alien species that are not yet in South Africa, that are known to be invasive and should not be imported into South Africa. If a Prohibited Alien species does occur in South Africa it is automatically listed as a 'Species that requires compulsory control' unless listed otherwise” (NEMBA Act 10 of 2014, www.environment.gov.za).

6. Distribution[2]

Continent	***Distribution*** *(list countries, or provide a general indication , e.g. present in West Africa)*	***Provide comments on the pest status in the different countries where it occurs*** *(e.g. widespread, native, non-native, established….)*	***Reference***
Africa	Absent	-	-
America	North America: Canada (Ontario), Mexico, USA (Alabama, Arkansas, California Connecticut, Delaware, District of Columbia, Florida, Georgia, Hawai'i, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Massachusetts, Michigan, Mississippi, Missouri, New Jersey, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, Tennessee, Texas, Virginia, West Virginia). South and Central America: Bahamas, Belize, Bermuda, Colombia, Costa Rica, Cuba, Dominican Republic, Guatemala, Honduras, Jamaica, Nicaragua, Panama, Puerto Rico, Trinidad and Tobago.	North America: Native with the exception of Hawai'i and California where the species is introduced, established and invasive. South and Central America: Native.	CABI, (2016a); EPPO, (2014b); USDA (2016).
Asia	Japan, Republic of Korea.	Japan: Introduced, established and invasive. Republic of Korea: Introduced and established.	Lee *et al*. (2008); NIES, (2017), Mironova, 2013.
Europe	France, the Russian Federation and Georgia, Biogeographical regions: Atlantic and Black Sea biogeographical regions	Introduced, established and invasive.	EPPO (2014b); Granereau and Verloove (2010); Royaud (2010); Mironova (2013), www.ofsa.fr; Caillon and Lavoue (2016); Royaud (2017).
Oceania	Australia, New Zealand.	Introduced, established and invasive.	EPPO (2014b); Gardner *et al.* (1996).

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

Introduction

Andropogon virginicus (*Poaceae*) is native to North and Central America. This species has been introduced and naturalized in Australia, New Zealand, Japan, and the Republic of Korea. Prior to 2006, the only report from the EPPO region was in Georgia and the Russian Federation. In 2006, *A. virginicus* was found in France in a military camp. See Appendix 5, Figure 1 for a global distribution map.

Africa

Andropogon virginicus is not recorded from Africa.

Americas

The native range of *A. virginicus* spans across much of North and Central America, including islands in the Caribbean. In the United States, *A. virginicus* mainly has an eastern and central native range. The species is also present in California where it is regarded as non-native. It is reported as invasive in Hawai'i where it was first reported in 1924. See Appendix 5, Figure 2.

Asia

In Japan, *A. virginicus* was first recorded around 1940 at Aichi Prefecture in the region of Chūbu, Honshu (NIES, 2017) where it is reported to be an aggressive invader (Enomoto *et al*., 2007). *Andropogon virginicus* is recorded from the Republic of Korea (Lee *et al.*, 2008); the authors give the habitat as "vacant lots near the inhabited areas, forest side".. *A. virginicus* was first recorded in 1947 in Georgia in the Autonomous Republic of Abkhazia near the Lake Bebsyr (Ochamchira (Очамчыра) region). In this area *A. virginicus* is widespread in the natural environment, as well as in ruderal and disturbed land across the low-lying (up to 250 m) part of the country close to the Black Sea (Колаковский, 1986), and is expanding its range in the Caucasus region. The most northern point of its spread is the region of Tuapse town (Туапсе) where in 1996 the population of this species was dominant in the area of a former vineyard on the marine terrace of the bank of the estuary (Зернов *et al.*, 2000). See Appendix 5, Figure 3.

Europe

Andropogon virginicus is established in the EPPO region: France, Georgia and the Russian Federation. In France, *A. virginicus* was found in 2006 in the military camp 'Camp du Poteau' (Landes and Gironde departments; Granereau and Verloove, 2010). *Andropogon virginicus* is in expansion in the South-west of France where it colonizes acidic regions as Landes, Gironde and Pyrénées-Atlantique departments. The plant forms large and dense populations in several areas (few areas colonized in Arjuzanx, Captieux). It is suspected that *A. virginicus* was introduced into the military camp with NATO munitions in the years 1950-1967 (Granereau and Verloove, 2010; EPPO, 2011). It has also been recorded in Arjuzanx (Landes) in 2008, where its population has been observed to have increased (Royaud, 2010). In the Russian Federation, *A. virginicus* is established on the Black Sea coast of the Caucasus (Mironova, 2013). See Appendix 5, Figure 4.

Oceania

Andropogon virginicus has been introduced and is established in Australia and in New Zealand. In Australia, the first report of the species was in 1942 in New South Wales (Gardner *et al*., 1996). It is also recorded from Queensland and Victoria (AVH, 2017). In New Zealand, *A. virginicus* was first recorded by Edgar and Shand (1987) (Gardner *et al*., 1996). The species is recorded as having a scattered distribution in the North Island near Albany Hill (despite seven years of eradication measures) and Warkworth. Gardner *et al*. 1996 also report the species at Northland, at Matai Bay and at Te Paki. CABI (2016a) report that ISSG (ISSG, 2006) record the species from the French Polynesian islands, but this appears to be a misinterpretation of the main PIER webpage for the species (PIER, 2013), and no evidence for the species' presence in French Polynesia appears to exist. See Appendix 5, Figure 5.

7. Habitats and where they occur in the PRA area

Habitat (main)	**EUNIS habitat types**	**Status of habitat (e.g. threatened or protected)**	**Is the pest present in the habitat in the PRA area (Yes/No)**	**Comments (e.g. *major/minor habitats* in the PRA area)**	***Reference***
Grassland	E: Grassland and tall forb	Yes, in part	Yes	Major	Granereau and Verloove, 2010; Mironova, 2013
Forest	G: Woodland, forest and other wooded land G1: Broadleaved deciduous woodland Coniferous forest	Yes, in part		Major	Campbell, 2003; Lee et al., 2008
Inland wetland	D: Mires, bogs and fens	Yes, in part	Yes	Major	Royaud, 2010
Man-made	J: Constructed, industrial and other artificial habitats		Yes	Major	Granereau and Verloove, 2010; Lee et al., 2008; Mironova, 2013
Heathland,	F: Heathland, Scrub and Tundra F4: Temperate shrub heathland	Yes, in part	Yes	Major	Granereau and Verloove, 2010

Andropogon virginicus invades a wide variety of habitats from disturbed to relatively intact habitats including ruderal areas, wetlands, open pastures, grasslands, and open woodlands. Campbell (2003) describes the habitats of the three named varieties of *A. virginicus*. For *A. virginicus* var. *decipiens* C.S. Campb. listed habitats include “flatwoods [open pine forest or savannah], scrublands, and disturbed sites, such as roadsides and cleared timberlands, of the southeastern coastal plain [of the USA]”. For *A. virginicus* var. *glaucus* Hack., the given habitats are “moist or dry soils of the coastal plain, from southern New Jersey to eastern Texas. For the widespread nominal variety, var. *virginicus*, denoted as “weedy” by Campbell (2003), the listed habitats include “openings in mature vegetation created by disturbance” and “poorly drained soils of pond margins, swales, and cutover flatwoods”.

Weber (2003) states that the species is an indicator of acid soil, and gives “prairies” as the main habitat. The species also tolerates extremely nutrient poor soils in Australia, burnt areas and grassland and has a low requirement for phosphorus (Weber, 2003). Although it is also found on more fertile soils, its abundance decreases as competition increases; indeed, the species has often been used as an exemplar of a mid-successional species (Bazzaz, 1968, 1975, 1990).

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

Possible pathway	Pathway: Plants for planting (CBD terminology: Escape from confinement - horticulture)
Short description explaining why it is considered as a pathway	*Andropogon virginicus* is available for commercial purposes (through the horticultural trade) in the USA and within the EPPO region (see http://www.jelitto.com/de/Saatgut/Ziergraeser/ANDROPOGON+virginicus+Portion+en.html). There is no evidence that the species is commonly imported as seed into the EPPO region for horticultural purposes. Seeds of the species are available for sale within the EU.
Is the pathway prohibited in the PRA area?	Seeds of *A. virginicus* are not currently prohibited in the PRA area.
Has the pest already been intercepted on the pathway?	No, to-date *Andropogon virginicus* has not been intercepted.
What is the most likely stage associated with the pathway?	Seeds are the only stage to be moved via this pathway.
What are the important factors for association with the pathway?	Seeds are readily available online for purchase. The plant is promoted for landscaping in the USA (given as a native species http://www.tnipc.org/wp-content/uploads/2016/08/landscaping-east-tn.pdf).
Is the pest likely to survive transport and storage along this pathway?	Yes.
Can the pest transfer from this pathway to a suitable habitat?	Yes, the assumption is that seeds would either be sown directly or grown and then made available as plants for planting in suitable habitats.
Will the volume of movement along the pathway support entry?	There is no evidence that the species is commonly imported as seed into the EPPO region for horticultural purposes. Therefore, it is unlikely that the volume of movement along this pathway will support entry. Although the species is sold within the EPPO region, the number of suppliers (online suppliers) is low. There is no evidence that the species is sold in popular garden centres within the EPPO region.
Will the frequency of movement along the pathway support entry?	There is no evidence that the species is commonly imported as seed into the EPPO region for horticultural purposes. Therefore, it is unlikely that the frequency of movement along this pathway will support entry.

	Although the species is sold within the EPPO region, the number of suppliers (online suppliers) is low. Therefore a moderate rating has been given with a high uncertainty.
Rating of the likelihood of entry	Low ☐ Moderate X High ☐
Rating of uncertainty	Low ☐ Moderate High X

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

Possible pathway *(in order of importance)*	**Pathway: Contaminant of hay imports** (CBD terminology: Transport contamination – transportation of habitat material)
Short description explaining why it is considered as a pathway	Although there is no published evidence of *Andropogon virginicus* being transported as part of hay material from the USA, there is evidence that hay is imported into the EU (see https://apps.fas.usda.gov/gats/default.aspx) and potentially seed material of *A. virginicus* can be included. Grass species have been intercepted via this pathway into other regions with seeds remaining viable (for example into Alaska from the USA, see Conn et al., 2010). In Australia, seeds of *A. virginicus* are also reported to be spread through the movement of hay and livestock (EPPO, 2011).
Is the pathway prohibited in the PRA area?	Regulations on the import of hay into the EPPO region based on animal and plant legislation is unclear.
Has the pest already been intercepted on the pathway?	No, to date *A. virginicus* has not been intercepted along this pathway.
What is the most likely stage associated with the pathway?	Seeds are the most likely stage to be associated with this pathway.
What are the important factors for association with the pathway?	*Andropogon virginicus* grows in pasture habitats in the USA and could become incorporated into plant material used for hay production. Seed can remain viable during packing and transportation of the commodity. Seeds of *A. virginicus* have been found to form persistent seed banks (Baskin and Baskin, 1998).
Is the pest likely to survive transport and storage along this pathway?	Conn et al., 2010 showed that grass seed can remain viable when imported into Alaska from the USA. Although *A. virginicus* was not included (intercepted) in this study, it is likely that seeds of the species can survive in hay bales.
Can the pest transfer from this pathway to a suitable habitat?	Yes, via the spreading of hay material and spread via livestock eating and dispersing seed (through dung).

Will the volume of movement along the pathway support entry?	Yes. Though the volume of hay import into the EPPO region from the USA varies between years. A number of countries import hay from the USA where GB, IT, FR, IE and ES are the largest importers over a 10 year period. (https://apps.fas.usda.gov/gats/default.aspx).
Will the frequency of movement along the pathway support entry?	Yes. Hay is import into the EPPO region from USA regularly over a 5 – 10-year period, with variation between years (https://apps.fas.usda.gov/gats/default.aspx).
Rating of the likelihood of entry	Low Moderate X High ☐ As *Andropogon virginicus* is found widely throughout its native range in North America (in pastures where hay could be collected) a moderate rating has been given.
Rating of uncertainty	Low ☐ Moderate ☐ High **X**

All European biogeographical regions will have the same likelihood of entry and uncertainty scores.

Possible pathway *(in order of importance)*	**Pathway: Contamination of machinery and equipment** **(CBD terminology: transport- stowaway – machinery/equipment)**
Short description explaining why it is considered as a pathway	There is evidence that the species has been associated with this pathway in the past (Granereau and Verloove, 2010). In France, it is suspected that *A. virginicus* was introduced into the military camp with NATO munitions in the years 1950-1967 (EPPO, 2011; Granereau and Verloove, 2010). In Australia, *A. virginicus* is reported as entering the country during World War ll in packing material around vital supplies for members of the U.S. armed forces http://bts.nzpcn.org.nz/bts_pdf/Auck_1996_51_1_31-33.pdf.
Is the pathway prohibited in the PRA area?	No the pathway is not prohibited along this pathway. There is legislation on the cleaning of machinery in Israel and in Norway. In Norway, when used machinery and equipment intended to be used in agriculture, forestry or horticulture is imported, an official statement must accompany the consignment stating that it has been thoroughly cleaned and if necessary disinfected and that it is free from soil, plant remains and contamination from pests. The country exports plant inspection service, or an equivalent official agricultural authority shall issue this certification (Regulations of 1 December 2000 no. 1333 relating to plants and measures against pests). There is no other known compulsory management practice for cleaning agricultural machinery, vehicles or military equipment in the EPPO region. An ISPM 41 Standard (IPPC, 2017) has been adopted

	on 'International movement of used vehicles, machinery and equipment'.
Has the pest already been intercepted on the pathway?	No, but there is circumstantial evidence that in France *A. virginicus* was introduced into the military camp with NATO munitions in the years 1950-1967 (EPPO, 2011; Granereau and Verloove, 2010).
What is the most likely stage associated with the pathway?	Seed is the most likely stage associated with this pathway.
What are the important factors for association with the pathway?	Seed longevity coupled with high seed production at the source.
Is the pest likely to survive transport and storage along this pathway?	The ability of the seed to survive prolonged drying periods highlight the species is likely to survive transport along this pathway. In addition, the seeds are small and can become attached in small crevices – for example tyres. It is only recently, that a ISPM Standard (IPPC, 2017, ISMP 41) has been drafted and adopted on 'International movement of used vehicles, machinery and equipment'. Previous to this, there are no specific biosecurity measures are required for the movement of used vehicles, machinery and equipment'.
Can the pest transfer from this pathway to a suitable habitat?	As much of the equipment or machinery is for potential use in the outdoors, A. *virginicus* would be able to transfer from this pathway to a suitable habitat.
Will the volume of movement along the pathway support entry?	It is unlikely that the volume of movement along this pathway will support entry. However, for the case of the population in France, this pathway is considered the most likely. It is difficult to estimate the volume of machinery and equipment entering the EPPO region.
Will the frequency of movement along the pathway support entry?	Unknown, it is difficult to estimate the frequency of machinery and equipment entering the EPPO region. However, just one event could lead to the entry of the species and establishment in a region.
Rating of the likelihood of entry	Low X Moderate ☐ High ☐
Rating of uncertainty	Low ☐ Moderate High X

All European biogeographical regions will have the same likelihood of entry and uncertainty scores.

Possible pathway *(in order of importance)*	**Pathway: Contaminant of tourists** **(CBD terminology: Transport – stowaway – people and their luggage/equipment)**
Short description explaining why it is considered as a pathway	Material susceptible to be contaminated is: clothing, boot or shoe treads. Other grass species have been shown to be spread by tourists into new areas. For example, in the USA, *Microstegium vimineum* has been shown to become incorporated into clothing and equipment of tourists and spread along trails and into new areas (Miller 2011).
Is the pathway prohibited in the PRA area?	No, currently this pathway is not prohibited in the PRA area and there are more importantly no biosecurity
Has the pest already been intercepted on the pathway?	No, *A. virginicus* has not been intercepted on this pathway.
What is the most likely stage associated with the pathway?	Seeds are the most likely stage of the plant to be associated with this pathway
What are the important factors for association with the pathway?	Seeds are small and the dispersules (= dispersal structure are hairy and can attach readily to clothes and can be included within mud attached to boots. Dispersules are likely to be in close proximity to people / footpaths where they could easily be picked up.
Is the pest likely to survive transport and storage along this pathway?	The ability of the seed to survive prolong drying periods highlight the species is likely to survive transport along this pathway. In addition, the seeds are small and can become attached in small crevices.
Can the pest transfer from this pathway to a suitable habitat?	Dispersules are likely to be in close proximity to people / footpaths where they could easily be picked up.
Will the volume of movement along the pathway support entry?	Though there is no data available, the volume of people travelling internationally is considered to be high. There is an estimated 700 million people crossing international borders as tourists each year (McNeely, 2006). Millions of people visit the EPPO region every year from the USA.
Will the frequency of movement along the pathway support entry?	Flights with travellers from all over the world arrive daily in the EPPO region
Rating of the likelihood of entry	Low X Moderate ☐ High ☐
Rating of uncertainty	Low ☐ Moderate High X

Do other pathways need to be considered?

no **Go to 9**

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

Andropogon virginicus invades a wide variety of habitats from disturbed to relatively intact habitats including ruderal areas, wetlands, open pastures, grasslands, and open woodlands.

Weber (2003) states that the species is an indicator of acid soil, and gives "prairies" as the main habitat. The species also tolerates "extremely nutrient poor soils in Australia, burnt areas and grassland and has a low requirement for phosphorus" (Weber, 2003). Although it is also found on more fertile soils, its abundance decreases as competition increases; indeed, the species has often been used as an exemplar of a mid-successional species (Bazzaz, 1968, 1975, 1990).

Reproduction in *A. virginicus* is sexual. Gibson & Risser (1982) reported between one and three flowering stems per ramet. Voight (1959) noted that each flowering stem could have as many as 50 racemes, with each raceme having 8-12 spikelets; this suggests an upper limit of around 1800 seeds per plant (assuming three flowering stems per ramet).

The species is established in the Atlantic (South west France) and the Black Sea (eastern coastline Georgia and Russia) biogeographical regions (see Appendix 1 and 2) so likelihood of establishment is clearly high and uncertainty is low. Based on the current distribution modelling of the species, there is further potential for establishment in these regions and for established populations in Atlantic, Black Sea, Continental, Mediterranean and Anatolian biogeographical regions. The highest potential for establishment is in continental areas of northern Italy and Slovenia, the east coastline of the Adriatic Sea (Croatia), the west coast of France bordering Spain. The east coast of the Black Sea (including parts of Russia and Georgia) also has a high potential for establishment. Limited areas of south east Turkey are marginally suitable for establishment.

Natural areas most at risk of invasion by this species within the PRA area are grasslands, inland wetlands, heathland and forests. Apart from the latter, *A. virginicus* has been recorded in the aforementioned habitats in the PRA area (Granereau and Verloove, 2010; Mironova, 2013; Royaud, 2010).

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

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

Throughout its invasive range, *A. virginicus* has become established in constructed, industrial and other artificial habitats (see (EPPO, 2011; Granereau and Verloove, 2010). In addition, the species is found in constructed, industrial and other artificial habitats (Granereau and Verloove, 2010; Lee et al., 2008; Mironova, 2013). Managed areas, such as military camps, roadsides and cleared timberlands have been invaded by the species within the current area of distribution (both the USA, Hawaiʻi and the EPPO region). Therefore, due to the known established populations in managed environments, the rating of likelihood of establishment is high with a low uncertainty.

In Georgia *A. virginicus* is widespread in ruderal and disturbed land across the low-lying (up to 250 m) coastal areas of the Black Sea (Колаковский, 1986),

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

11. Spread in the PRA area

Natural spread

Natural spread is likely to be high within the PRA area and throughout its invaded range, *A. virginicus* has been reported as an aggressive invasive (i.e. spreading) (EWG analysis; Колаковский, 1986). Gibson & Risser (1982) reported between one and three flowering stems per ramet. Voight (1959) noted that each flowering stem could have as many as 50 racemes, with each raceme having 8-12 spikelets; this suggests an upper limit of around 1800 seeds per plant (assuming three flowering stems per ramet). Seeds are wind-dispersed, with the dispersules having a high terminal velocity equivalent to *Taraxacum* (Campbell, 1983b); livestock or humans may also transport dispersules given the pubescent rames (Campbell, 2003). Drake (1998) found that *A. virginicus* was the commonest grass species in seed rain traps in invaded *Metrosideros polymorpha* forest on Hawai'i, indicating that the combination of seed production and dispersal potential is likely to lead to high rates of spread. Both the volume of movement and the probability of transfer to a suitable habitat is likely to be supported by spread.

Following the first record in the eastern Black Sea area in 1947, the species is now reported from sites spanning over 600 km (EWG analysis). Populations of the species have increased and spread in France: in 2 years, the population increased from 2 plants to more than 500. The presence of the Common Crane (*Grus grus*) at the Camp de Poteau site in France also means that long-distance dispersal is possible, particularly as the site is reported to be a stop along the Crane's migratory corridor (Granereau & Verloove, 2010). In addition, other animal species may act to spread the species through ingestion and/ or contaminant of fur (EWG opinion). However, there is no evidence of this happening, although it is extremely likely to occur due to the pubescent nature of the species' dispersules.

In Georgia in the Autonomous Republic of Abkhazia near the Lake Bebsyr (Ochamchira (Очамчыра) region), *A. virginicus* is widespread in the natural environment, as well as in ruderal and disturbed land across the low-lying (up to 250 m) maritime part of the country (Колаковский, 1986), and is expanding its range in the Caucasus region.

Human assisted spread

Spread through the contamination of vehicles is possible; humans may also transport the hairy dispersules on their clothes or footwear (Parsons & Cuthbertson, 2001). Seeds of the species are available for sale within the EU and therefore this may be another potential spread method. In Australia, *A. virginicus* has been shown to spread by more than 1 km through the movement of hay material (Sexton 2003). Similar rates of movement are likely within the EPPO region.

In France, in Landes and Gironde, most of the recent occurrences are assumed to be due to the movement of forest machinery. In fact, recently *A. virginicus* seems to be in expansion due to the management of pinewood with machinery.

Based on the current distribution modelling of the species, there is further potential for establishment (spread) in these regions and for established populations in Atlantic, Black Sea, Continental, Mediterranean and Anatolian biogeographical regions.

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

12. Impact in the current area of distribution

12.01 Impacts on biodiversity

Andropogon virginicus stands can be dense, widespread, and highly competitive suggesting the species reduces biodiversity (Uchytil, 1992, CABI, 2017). The species is reported to be able to dominate within the grass layer (Sorenson 1991).

Andropogon virginicus has been documented in Hawaiʻi as negatively impacting biodiversity by outcompeting native species through the promotion of fire and transformation of vegetation from native woodlands to fire-adapted non-native grassland. In dry habitats, it directly competes with the endangered shrub *Tetramolopium remyi*, and the endangered tree *Santalum freycinetianum* var. *lanaiense* [*S. haleakalae* var. *lanaiense*] by competing for space and resources (USFWS, 1995).

On Oahu it threatens the endangered subshrub *Schiedea nuttallii* (USFWS 2009). It is a major threat to the small herb *Portulaca sclerocarpa* on the island of Hawaii and an islet off of Lanai (Shaw et al., 1996). *A. virginicus* is also sympatric with *Pritchardia napaliensis* and *Schiedea apokremnos* in Hawaii and is a potential threat to those species. In conjunction with other non-native grasses in Hawai'i, the species has altered fire regimes in seasonal submontane woodland reducing the abundance of native species (D'Antonio *et al.*, 2000).

In Australia, *A. virginicus* degrades habitat occupied by the Charmhaven apple (*Angophora inopina*, *Myrtaceae*) and may be having a direct impact on the regeneration of the species (Queensland Government, 2016). Also see: http://www.environment.nsw.gov.au/resources/pestsweeds/factsheetExoticPerennialGrasses.pdf. It is also recorded as a weed threat to the Downy wattle (*Acacia pubescens*, *Fabaceae*) (Queensland Government, 2016).

Pot-based experimental work by Rice (1972) demonstrated *A. virginicus* has negative allelopathic effects on the seedlings of the native North American species *Amaranthus palmeri*, *Bromus japonicus*, *Aristida oligantha*, and *Schizachyrium scoparium* (syn. *Andropogon scoparius*). Inhibitory effects on nitrogen-fixing bacteria were also found.

At present there are no known studies on impacts on biodiversity from the EPPO region.

A rating of high impact has been given as the species has clear documented impacts on native species in the current area of distribution. However, due to the lack of scientific studies, a high uncertainty has been given.

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

12.02. Impact on ecosystem services

Ecosystem service	**Does the pest impact on this Ecosystem service?** Yes/No	**Short description of impact**	**Reference**
Provisioning	Yes	*Andropogon virginicus* stands can be dense, covering large areas, and highly competitive suggesting the species compromises (reduces) genetic resources by reducing biodiversity. Due to its competitive nature, the species may have negative economic impacts on forage and timber production in the southeastern US.	(Uchytil, 1992; Balandier *et al*. 2006; Butler *et al*., 2006).
Regulating	Yes	This species impacts a number of regulating services. It is a fire-adapted and fire promoting species that can increase fire frequency which has the effect of influencing natural hazard regulation. Primary production and habitat stability is likely to be altered by *A. virginicus* invasion due to a reduction in infiltration rates. Along with other non-native grasses, the species impacts nitrogen cycling by reducing the abundance of native species.	(Weber 2003, Hughes 1991), Mueller-Dombois (1972), D'Antonio and Vitousek (1992); Mack and D'Antonio, 2003.
Cultural	Yes	No studies have investigated cultural impacts of this species. The aesthetics of natural areas are likely be altered by the transformation of woodlands to grasslands.	EWG opinion

A rating of moderate impact has been given as the species has clear documented impacts on native species in the current area of distribution. However, due to the lack of scientific studies, a moderate uncertainty has been given (EWG opinion).

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

12.03. Socio-economic impact

No studies have investigated the socio-economic impacts of *A. virginicus* invasions. The only economic costs associated with this species are likely to be from its control and when the species degrades pasture land. However, there is almost published information on management costs of this species.

Andropogon virginicus has been found to impact plantation forestry by decreasing soil water content (Balandier *et al*., 2006). In forestry, control or suppression of this species, may be necessary to enable the establishment of the plantation species (Groninger *et al.* 2004).

It is frequently mentioned as a low value forage species in North America, and is therefore undesirable when it invades pastures, outcompeting other vegetation of greater value as fodder (Griffin *et al.*, 1988; Butler *et al.*, 2002). Nutritional quality is greatly increased by prescribed burning, presumably due to the higher nutritional value of young shoots (Uchytil, 1992). Uchytil (1992) states that “nearly pure stands can persist on soils low in nitrogen or phosphorus as a result of competition and allelopathy.” Parsons and Cuthbertson (2001) also note impacts on pasture productivity in Australia.

The EWG consider the socio-economic impacts of *A. virginicus* are high when considering the impact of control, negative economic impacts on plantation forestry and pastures. However, with a lack of quantitative costs, the uncertainty is rated as high.

Andropogon virginicus does not have any known human health implications.

Control methods

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

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

13. Potential impact in the PRA area

Although present in the EPPO region, there are no reported studies that have evaluated the ecological or economic impact of *A. virginicus* in the region. Due to the aggressive spread of the species in natural areas in Georgia, and around the Black Sea, and due to the rapid expanse of the plant in France, the EWG consider that the potential impacts in the EPPO region will be in part similar to that seen in the current area of distribution. This is further compounded by the fact that when *A. virginicus* invades an area it forms dense monospecific stands and this has been observed in the PRA area (Granereau and Verloove, 2010).

Andropogon virginicus may invade habitats on mesic soils which could introduce fire to previously low fire systems (EWG opinion). If *A. virginicus* invades areas with nutrient poor soils, impacts are likely to be significant within the PRA area where habitats of conservation importance are often nutrient poor. At present fire risk is a serious problem in the Mediterranean but also in heathland and dune systems in the Atlantic region (i.e. the Netherlands).. Adding a species that increases the risk or intensity of fire and even benefits from fire does pose a serious risk to biodiversity and associated ecosystem services provided by these natural areas.

In the EPPO region, *Andropogon virginicus* does not have any known human health implications.

The text within this section and section 13.01 -13.03 relates equally to EU Member States and non-EU Member States in the EPPO region.

Andropogon virginicus does not have any known human health implications.

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

13.01. Potential impacts on biodiversity in the PRA area

Andropogon virginicus is already present in the EPPO region, where it is widespread in natural areas. The potential for further spread into grasslands, inland wetlands, heathlands and forests is high, and as the species has been shown to form dense monospecific stands, the potential impact on biological diversity would be similar to that seen in the current area of distribution. Within its invasive range (Australia and Hawaii), negative impacts have been recorded on biological diversity (flora). The species can negatively impact on ecosystem services by being a habitat transformer (provisioning services), where it can increase fire frequencies (regulating), change nutrient cycling (supporting), and degrade the aesthetical value of habitats (cultural).

In France, *A. virginicus* can form large clumps on moorland, habitats conducive to many remarkable species and floristic processions of heritage interest.

The EWG has not identified any rare or protected species which may be impacted on in the PRA area.

A moderate score has been given as the species does show impacts but these have not been quantified within the invaded area. A moderate rating of uncertainty has been given as when the species invades an area it forms dense monospecific stands and this has been observed in the PRA area (Granereau and Verloove, 2010).

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

13.02. Potential impact on ecosystem services in the PRA area

Ecosystem service impacts are indicated already in the PRA area and this is likely to increase with additional spread of the species in the region. *Andropogon virginicus* forms dense, widespread stands which are likely to degrade genetic resources by reducing biodiversity. *Andropogon virginicus* may invade habitats on mesic soils which could introduce fire to previously low fire systems. Therefore a moderate rating has been given for impact but with a high uncertainty due to the lack of scientific data.

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

13.03 Potential socio-economic impact in the PRA area

If the species invades plantation forestry and pasture land in the PRA similar impacts are likely to be seen including a risk of increased fire and habitat degradation. A moderate score has been given for potential socio-economic impacts based on evidence from its native range where it invades pastures and forestry plantations. A high uncertainty reflects that information is lacking within the PRA area on such impacts.

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

14. Identification of the endangered area

The endangered area is mostly focused on the Atlantic (South west France) and the Black Sea biogeographical regions. Based on the current distribution modelling of the species, there is further potential for establishment in these regions and in the Continental, Mediterranean and Anatolian biogeographical regions.

The highest potential for establishment is in continental areas of northern Italy and Slovenia, the east coastline of the Adriatic Sea (Croatia), the west coast of France bordering Spain. The east coast of the Black Sea (including parts of Russia and Georgia) also has a high potential for establishment. Limited areas of south east Turkey are marginally suitable for establishment.

15. Climate change

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

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

Climate projection RCP8.5 (2070)

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

Delete (yes/no) as appropriate

*Temperature **(yes)*** *Precipitation **(yes)*** *$C0_2$ levels **(yes)***

*Sea level rise **(no)*** *Salinity **(no)*** *Nitrogen deposition **(yes)***

*Acidification **(no)*** *Land use change **(yes)*** *Other (please specify)*

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

Are the **pathways** likely to change due to climate change? **(If yes, provide a new rating for likelihood and uncertainty)**	**Reference**
Pathways are unlikely to change as a result of climate change. Plants for planting: Moderate with high uncertainty Contaminant of Hay imports: Moderate with high uncertainty Contaminant of machinery and equipment: Low with high uncertainty Contaminant of tourists: Low with high uncertainty	EWG opinion
Is the **likelihood of establishment** likely to change due to climate change? **(If yes, provide a new rating for likelihood and uncertainty)**	**Reference**
The likelihood of establishment will increase within the PRA area as a result of climate change (for example see Xavier et al., 2016). The area conducive for establishment will increase (see Appendix 1, Figure 7), with larger areas of the Atlantic, Black Sea, Continental, Mediterranean and Anatolian biogeographical regions becoming suitable for establishment (see Appendix 1 and 2). However, the rating for establishment will not increase in the natural or managed environment (both rated as high) but the uncertainty will raise from low to high.	EWG opinion, Appendix 1
Is the magnitude of **spread** likely to change due to climate change? **(If yes, provide a new rating for the magnitude of spread and uncertainty)**	**Reference**
Human assisted spread may increase with more areas available to grow the species. Natural spread will increase as a result of climate change. More habitats and regions may favour the establishment of A. virginicus and thus the area available for spread will increase.	EWG opinion, Appendix 1

However, the rating for spread will not increase (rated as high) but the uncertainty will raise from low to high.	
Will **impacts** in the PRA area change due to climate change? **(If yes, provide a new rating of magnitude of impact and uncertainty for biodiversity, ecosystem services and socio-economic impacts separately)**	**Reference**
Higher temperatures and less precipitation could lead to a higher risk of fires, which may favour the initiation of a grass fire cycle. Therefore potentially, the impact on biodiversity and ecosystem services will increase from moderate to high with a high uncertainty. As ecological impacts increase, it is likely that socio-economic impacts will increase as more effort is placed on control and management of the species. Additionally, more habitat is likely to be invaded and thus economic costs may result from land degradation and reduced crop/pasture yields in areas invaded.	EWG opinion, Appendix 1

16. Overall assessment of risk

Andropogon virginicus poses a high phytosanitary risk (including biodiversity and ecosystem services) to the endangered area with a moderate uncertainty. Within the EPPO region, the species occurs in France, Georgia and Russia. Populations of the species have increased and spread in France. Following the first record in the eastern Black Sea area in 1947, the species is now reported from sites spanning over 600 km.

The likelihood of new introduction occurring via seed imports is moderate. The species is recorded as being sold within the EPPO region by a limited number of suppliers. Newintroductions via the import of hay is recorded as moderate with a high uncertainty. Introduction as a contaminant via other pathways (detailed in pathway section), seems low with a high uncertainty.

Pathways for entry:

Plants for planting

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

Import of hay

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

Contaminant of machinery and equipment

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

Contaminant of tourists

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

Likelihood of establishment in the natural environment in the PRA area

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

Likelihood of establishment in managed environment in the PRA area

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

Spread in the PRA area

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

Impacts
Impacts on biodiversity

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

Impacts on ecosystem services

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

Socio-economic impacts

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

Impacts in the PRA area

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

Although present in the EPPO region, there are no reported studies that have evaluated the ecological or economic impacts of *A. virginicus* in the region. Due to the aggressive spread of the species in natural areas in Georgia, and around the Black Sea, and due to the rapid expanse of the plant in France, the EWG considers that the potential impacts in the EPPO region will be in part similar to that seen in the current area of distribution. This is further compounded by the fact that when *A. virginicus* invades an area it forms dense monospecific stands and this has been observed in the PRA area (Granereau and Verloove, 2010).

Andropogon virginicus may invade habitats on mesic soils which could introduce fire to previously low fire systems (EWG opinion). If *A. virginicus* invades areas with nutrient poor soils, impacts are likely to be significant within the PRA area where habitats of conservation importance are often nutrient poor.

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

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

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

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

17. Uncertainty

An overall moderate uncertainty rating has been given. The distribution of this species in the PRA area may not be well documented, grasses tend to be significantly under-recorded. Much more information is needed on the size of *A. virginicus* infestations and whether they are having an impact. More information is needed on the abundance of the species in the Black Sea region.

Other areas of uncertainty include the modelling of the species. Areas of uncertainty with the modelling include:

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

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

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

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

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Appendix 1 Projection of climatic suitability for *Andropogon virginicus* establishment

Aim

To project the suitability for potential establishment of *Andropogon virginicus* 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 (1970-2000) database (Hijmans *et al.*, 2005) originally at 5 arcminute resolution (0.083 x 0.083 degrees of longitude/latitude) but bilinearly interpolated to a 0.1 x 0.1 degree grid for use in the model. We found little information on the climatic requirements of the species. Therefore, we used four climate variables commonly limiting plant distributions:

- Mean temperature of the warmest quarter (Bio10 °C) reflecting the growing season thermal regime.
- Mean minimum temperature of the coldest month (Bio6 °C) reflecting exposure to frost.
- Mean annual precipitation (Bio12 ln+1 transformed mm), as a measure of moisture availability.
- Precipitation of the driest quarter (Bio17 ln+1 transformed) as a further measure of drought stress.

To estimate the effect of climate change on the potential distribution, equivalent modelled future climate conditions for the 2070s under the Representative Concentration Pathway (RCP) 8.5 were also obtained. This assumes an increase in atmospheric CO_2 concentrations to approximately 850 ppm by the 2070s. Climate models suggest this would result in an increase in global mean temperatures of 3.7 °C by the end of the 21st century (90^{th} percentile range of 2.6 to 4.8 C.). The above variables were obtained as averages of outputs of eight Global Climate Models (BCC-CSM1-1, CCSM4, GISS-E2-R, HadGEM2-AO, IPSL-CM5A-LR, MIROC-ESM, MRI-CGCM3, NorESM1-M), downscaled and calibrated against the WorldClim baseline (see http://www.worldclim.org/cmip5_5m). RCP8.5 is the most extreme of the RCP scenarios, and may therefore represent the worst case scenario for reasonably anticipated climate change.

Species occurrences were obtained from the Global Biodiversity Information Facility (www.gbif.org), supplemented with other sources. GBIF records flagged with significant issues by the rgbif R package were omitted. Other major sources of data included the USGS Biodiversity Information Serving Our Nation (BISON), Berkeley Ecoinformatics Engine, the Integrated Digitized Biocollections (iDigBio), iNaturalist and members of the Expert Working Group. Occurrence records outside of the coverage of the predictor layers (e.g. small island or coastal occurrences) were excluded. The remaining records were gridded at a 0.1 x 0.1 degree resolution for modelling (Figure 1).

In total, there were 2394 grid cells with recorded occurrence of *A. virginicus* available for the modelling (Figure 1).

Figure 1. Occurrence records obtained for *Andropogon virginicus* used in the model.

Species distribution model

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

- The native distribution of *A. virginicus*, i.e. North America, Central America, the Caribbean and Colombia, in which the species is likely to have had sufficient time to cross all biogeographical barriers. However, since the range of *A. virginicus* extends into Canada but no records were obtained from there Canada was excluded; AND
- A relatively small 50 km buffer around all non-native occurrences, encompassing regions likely to have had high propagule pressure for introduction by humans and/or dispersal of the species; AND
- Regions where we have an *a priori* expectation of high unsuitability for the species (see Fig. 3). Absence from these regions is considered to be irrespective of dispersal constraints. Since the northern range margin in Canada was not covered by the data, we specified rules for defining unsuitability based on extreme low temperature:
    - Mean minimum temperature of the coldest month (Bio6) < -20 °C. CABI ISC consider this to be the maximum frost tolerance of the species (CABI, 2016). The coldest location with a presence in our dataset has Bio6 = -12.0 °C.
    - Mean temperature of the warmest quarter (Bio10 °C) < 10 °C, which we assume would be too cold to sustain growth. Only one location with a presence has a temperature lower than this, with the next coldest presence location having Bio10 = 13.6 °C.

Within this sampling region there will be substantial spatial biases in recording effort, which may interfere with the characterisation of habitat suitability. Specifically, areas with a large amount of recording effort will appear more suitable than those without much recording, regardless of the underlying suitability for occurrence. Therefore, a measure of vascular plant recording effort was made by querying the Global Biodiversity Information Facility application programming interface (API) for the number of phylum Tracheophyta records in each 0.1 x 0.1 degree grid cell (Figure 2). The sampling of background grid cells was then weighted in proportion to the Tracheophyte recording density. Assuming Tracheophyte recording density is proportional to recording effort for the focal species, this is an appropriate null model for the species' occurrence.

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

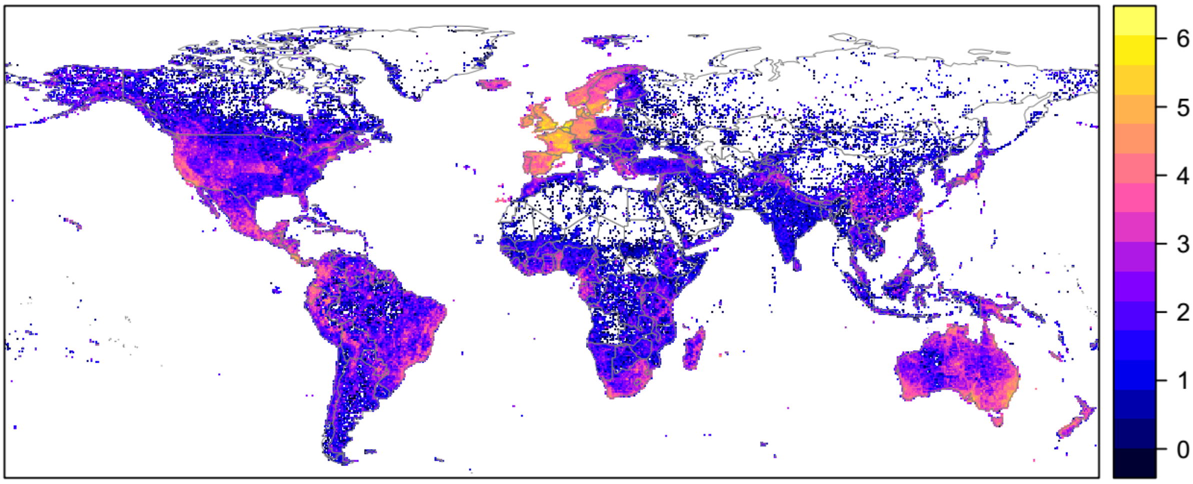

Figure 2. The density of Tracheophyte records held by GBIF, aggregated to a 0.5 x 0.5 degree resolution and log_{10} transformed. These densities were used to weight the sampling of background locations for modelling to account for recording effort biases.

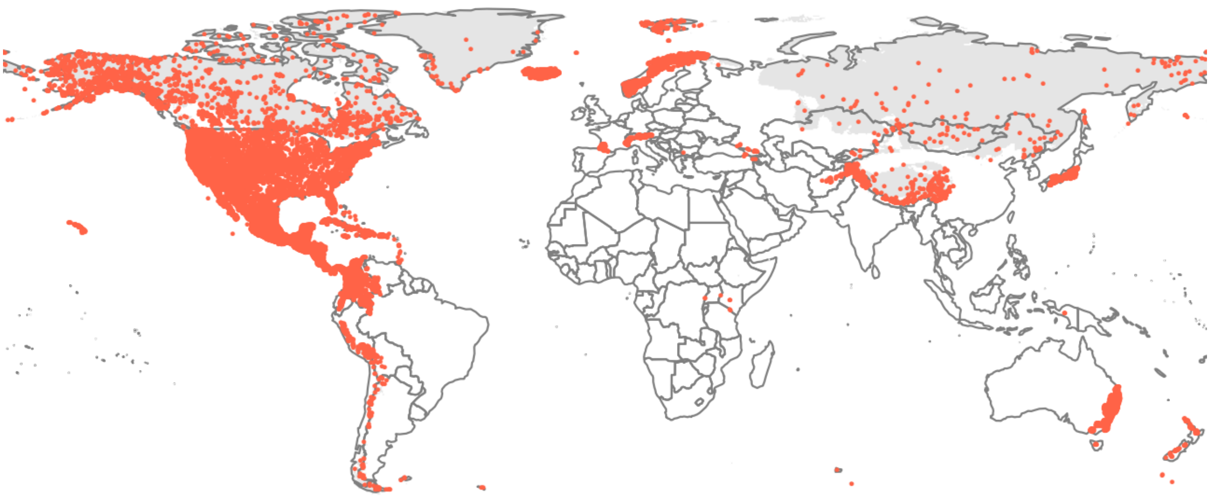

Figure 2. Randomly selected background grid cells used in the modelling of *Andropogon virginicus*, mapped as red points. Points are sampled from across the native range (North and Central America, the Carribbean and Colombia, but excluding Canada), a small buffer around non-native occurrences and from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

Each 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:

- Generalised linear model (GLM)

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

Since the background sample was much larger than the number of occurrences, prevalence fitting weights were applied to give equal overall importance to the occurrences and the background. Variable importances were assessed and variable response functions were produced using BIOMOD2's default procedure. Model predictive performance was assessed by calculating the Area Under the Receiver-Operator 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. This information was used to combine the predictions of the different algorithms to produce ensemble projections of the model. For this, the three algorithms with the lowest AUC were first rejected and then predictions of the remaining seven algorithms were averaged, weighted by their AUC. Ensemble projections were made for each dataset and then averaged to give an overall suitability.

Results
The ensemble model had a better predictive ability (AUC) than any individual algorithm and suggested that suitability for *A. virginicus* was most strongly by the temperature of the warmest quarter (Table 1). As shown in Figure 4 and allowing for variation among the model algorithms, the estimated optimum conditions for occurrence were approximately:

- Mean temperature of the warmest quarter = 27.7 °C (>50% suitability with > 19.8 °C)
- Minimum temperature of the coldest month < 13 °C, but with disagreement among algorithms about the response at very low temperatures.
- Precipitation of driest quarter approximately > 250 mm, but with disagreement among algorithms about the response at very low precipitation.
- Annual precipitation = 1292 mm (>50% suitability for 533 to 2578 mm)

The variation among algorithms in the modelled responses will partly reflect their different treatment of interactions among variables. Since partial plots are made with other variables held at their median, there may be values of a particular variable at which this does not provide a realistic combination of variables to predict from. It also demonstrates the value of an ensemble modelling approach in averaging out the uncertainty between algorithms.

These optima and ranges of high suitability described above are conditional on the other predictors being at their median value in the data used in model fitting, which may also explain some of the variation in responses among algorithms.

Global projection of the model in current climatic conditions (Figure 5) indicates that the major native distribution area in the USA was well defined and predicted to be highly climatically suitable. The major clusters of non-native records in Australia and Japan also fell within regions of moderately high climatic suitability. The model predicts that the climate may permit some further expansion of the species' distributions in Japan but that the niche is largely filled in Australia. Other regions without records of the species, but that are projected to be climatically suitable include Uruguay, Paraguay and the neighbouring parts of Brazil and Argentina as well as south eastern China.

The projection of suitability in Europe and the Mediterranean region (Figure 6) suggest that the existing non-native records in southwest France are in a climatically marginal region. However the records from the Black Sea coastlines of Georgia and Russia are mainly predicted to be highly climatically suitable. Other parts of Europe predicted to have marginal or suitable climates but that are without current records of the species include northern Italy and the eastern Adriatic coastline as far south as Albania. The main limiting factor for the species across Europe appeared to be lower mean temperatures of the warmest quarters than are experienced in the native range.

By the 2070s, under climate change scenario RCP8.5, projected suitability for *A. virginicus* increased in all the European regions predicted to be currently suitable or marginal for the species (Figure 7). Additionally, much of central Europe was predicted to become suitable for the species, including parts of eastern France, northern Switzerland, southern Germany, Austria, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, western Serbia, Kosovo and Albania. This was mainly driven by a projected increase in temperature of the warmest quarter.

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 seven algorithms). Results are the average from models fitted to five different background samples of the data.

Algorithm	**Predictive AUC**	**Variable importance**			
		Minimum temperature of coldest month	**Mean temperature of warmest quarter**	**Annual precipitation**	**Precipitation of driest quarter**
GBM	0.9240	14.1%	56.2%	11.3%	18.3%
ANN	0.9228	25.0%	36.8%	13.5%	24.8%
MaxEnt	0.9198	17.1%	42.9%	16.2%	23.9%
GAM	0.9188	14.2%	51.2%	24.0%	10.6%
MARS	0.9186	19.4%	50.0%	18.1%	12.5%
GLM	0.9162	20.4%	49.6%	18.8%	11.3%
FDA	0.9072	23.7%	45.8%	5.7%	24.8%
CTA	0.9040	19.0%	44.1%	8.0%	29.0%
RF	0.9022	20.5%	38.9%	13.5%	27.1%
MEMLR	0.8594	2.0%	33.7%	21.0%	43.3%
Ensemble	0.9230	19.1%	47.5%	15.4%	18.0%

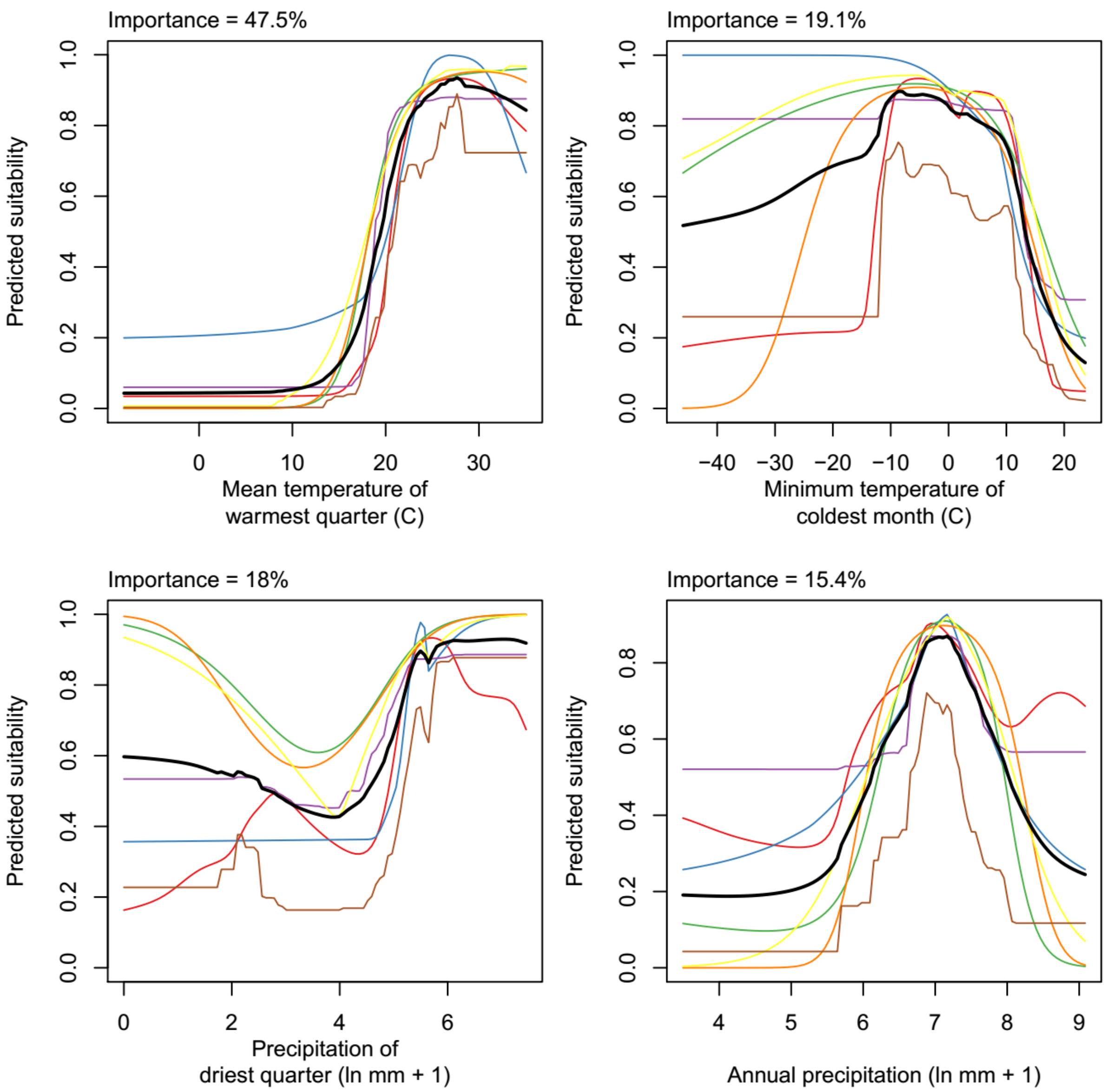

Figure 4. Partial response plots from the fitted models, ordered from most to least important. Thin coloured lines show responses from the seven algorithms, while the thick black line is their ensemble. In each plot, other model variables are held at their median value in the training data. Some of the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

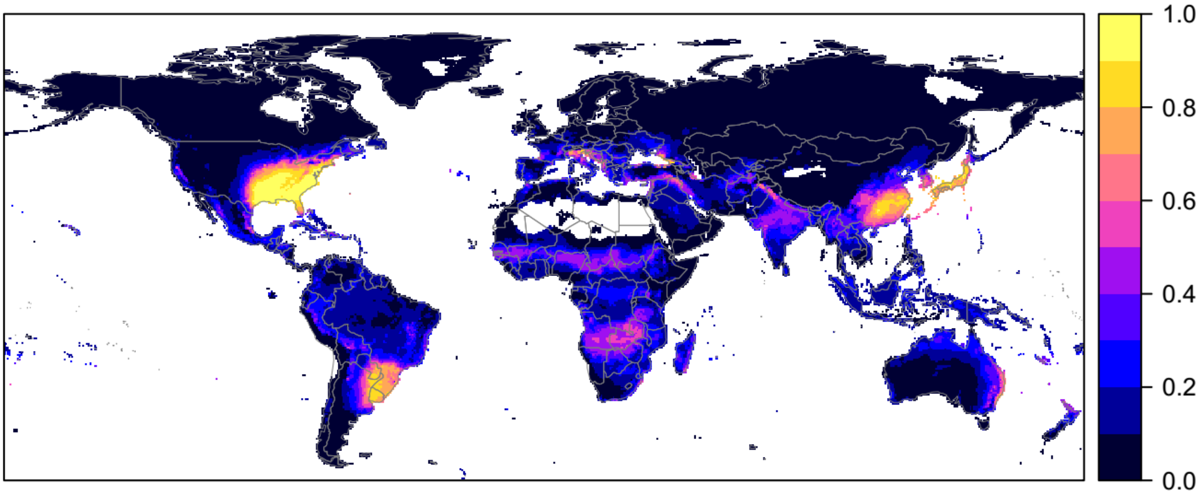

Figure 5. Projected global suitability for *Andropogon virginicus* establishment in the current climate (1960- 1990). For visualisation, the projection has been aggregated to a 0.5 x 0.5 degree resolution, by taking the maximum suitability of constituent higher resolution grid cells. Values > 0.5 may be suitable for the species. The white areas have climatic conditions outside the range of the training data so were excluded from the projection.

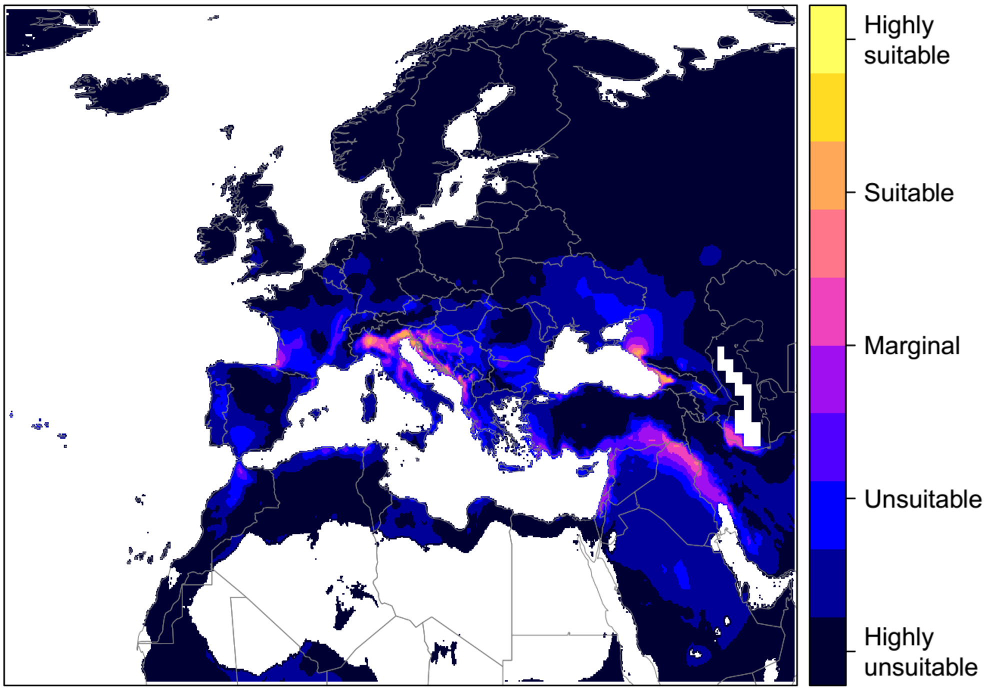

Figure 6. Projected current suitability for *Andropogon virginicus* establishment in Europe and the Mediterranean region. For visualisation, the projected suitability has been smoothed with a Gaussian filter with standard deviation of 0.1 degrees longitude/latitude. The white areas have climatic conditions outside the range of the training data so were excluded from the projection.

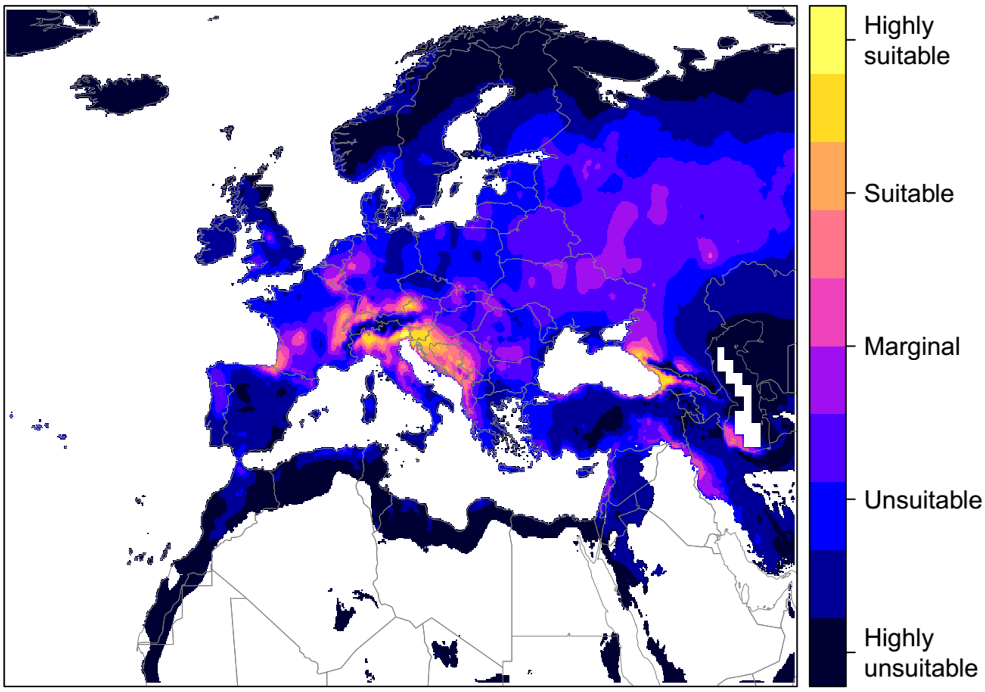

Figure 7. Projected suitability for *Andropogon virginicus* establishment in Europe and the Mediterranean region in the 2070s under climate change scenario RCP8.5, equivalent to Fig. 6.

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

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

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

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

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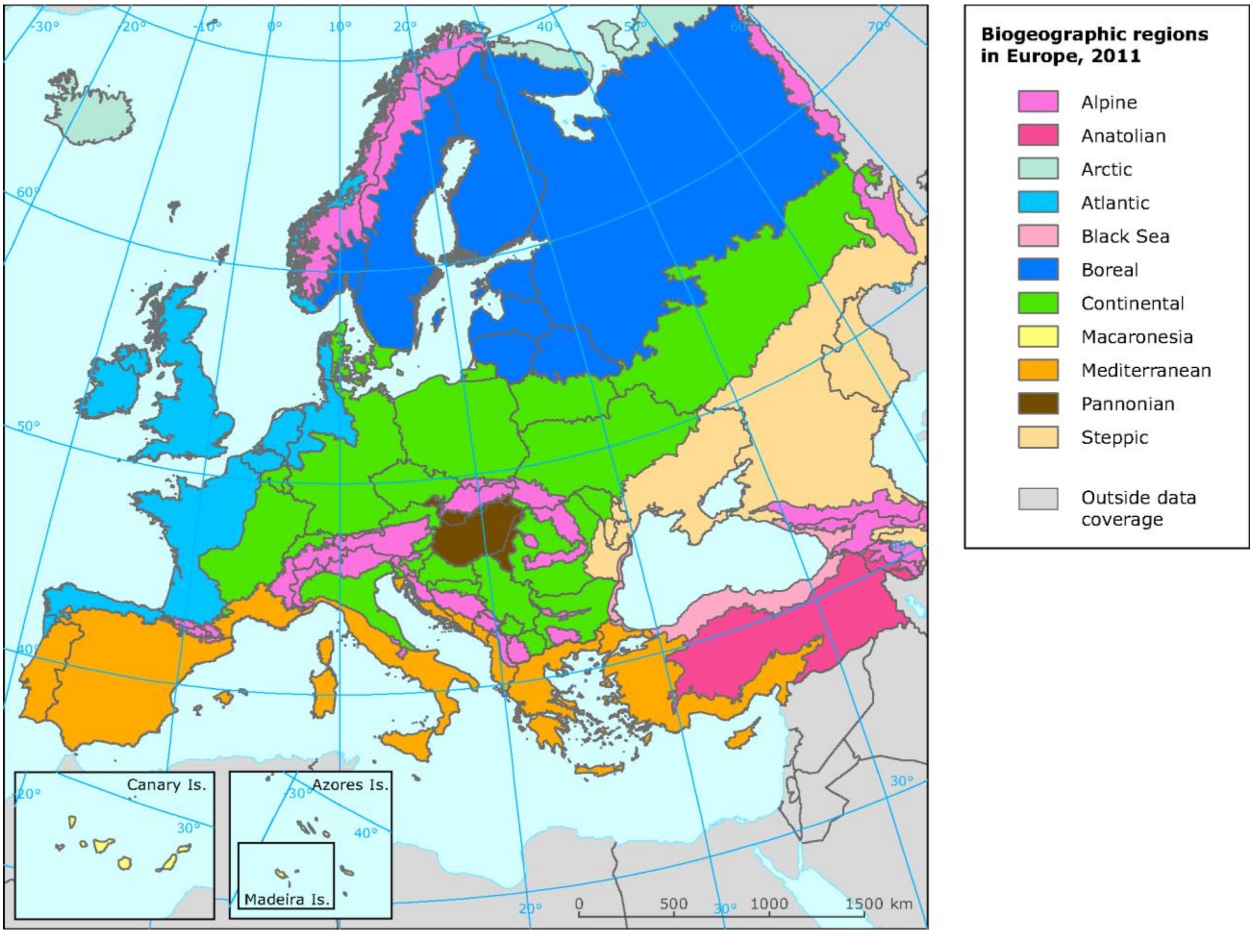
Appendix 2 Biogeographical regions



Appendix 3. Images (for information)

*Andropogon virginicus (*Kapunakea Preserve West Maui, Maui, Hawaii)
Image by Forest & Kim Starr

Andropogon virginicus (HAVO, Hawaii, Hawaii.)
Image by Forest & Kim Starr

Andropogon virginicus (West Maui, Maui, Hawaii.)
Image by Forest & Kim Starr

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

Member States:

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

Biogeographical regions

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

Yes: if recorded, established or invasive or can occur under future climate; – if not recorded, established or invasive; ? Unknown

Appendix 5. Maps of the occurrence of Andropogon virginicus[3]

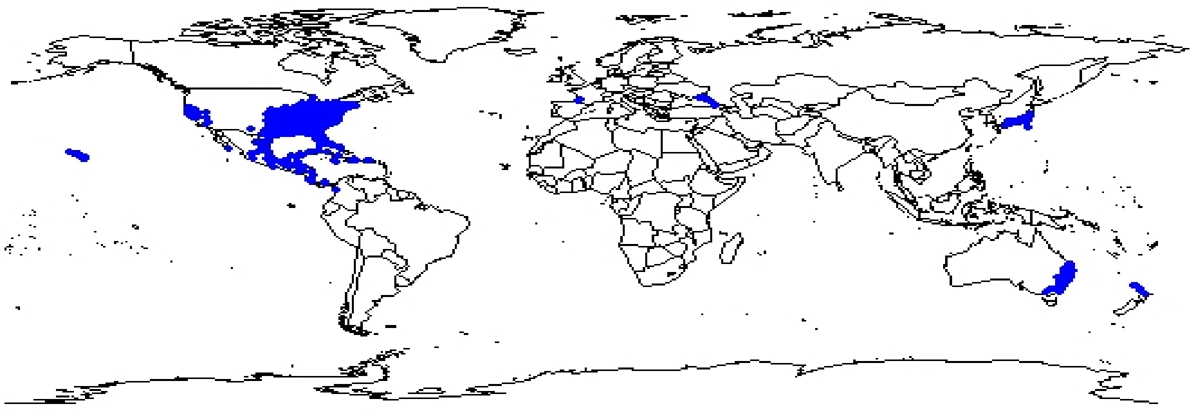


Figure 1. The global distribution of *Andropogon virginicus*

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

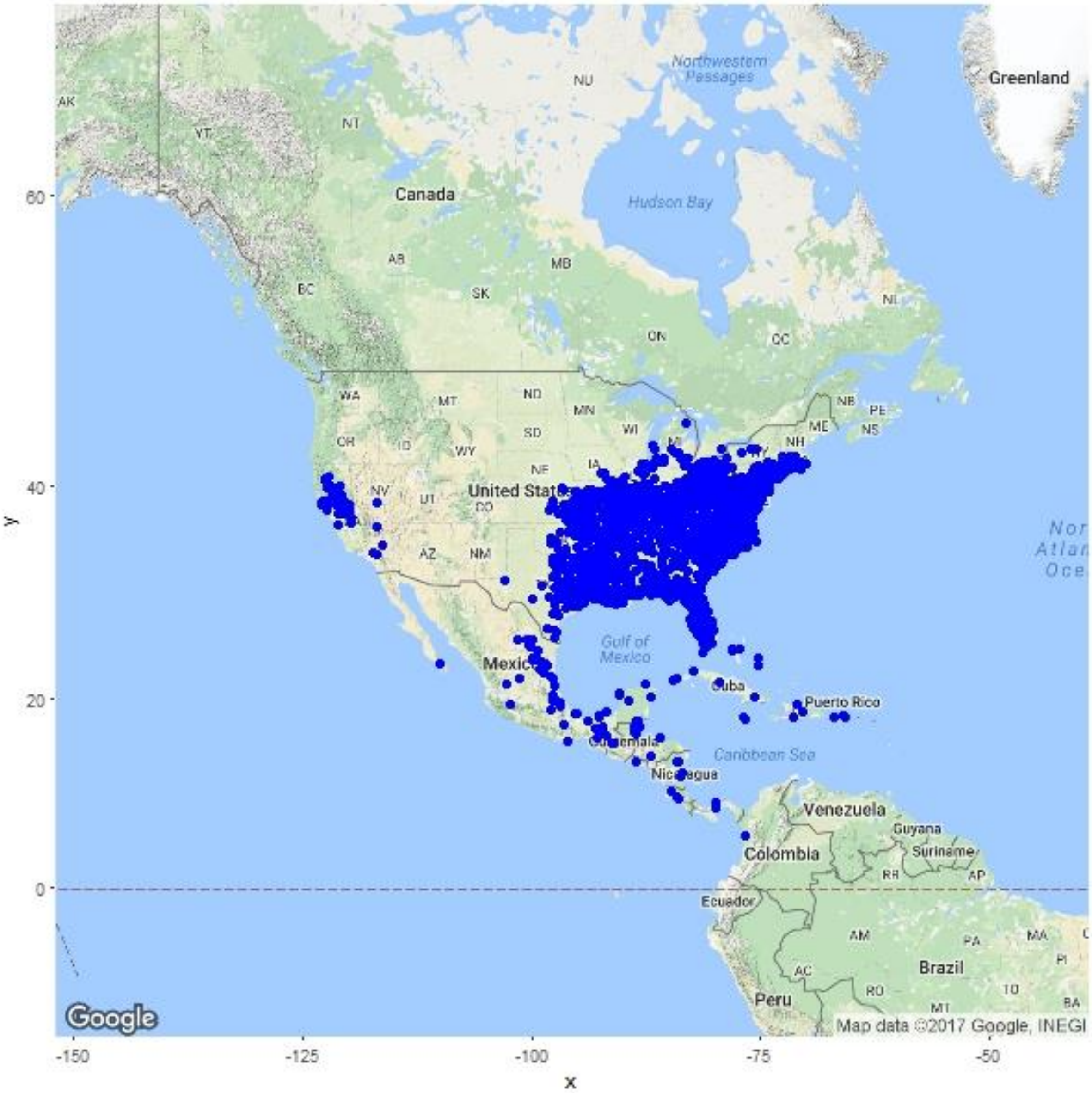


Figure 2. Occurrence of *Andropogon virginicus* in America

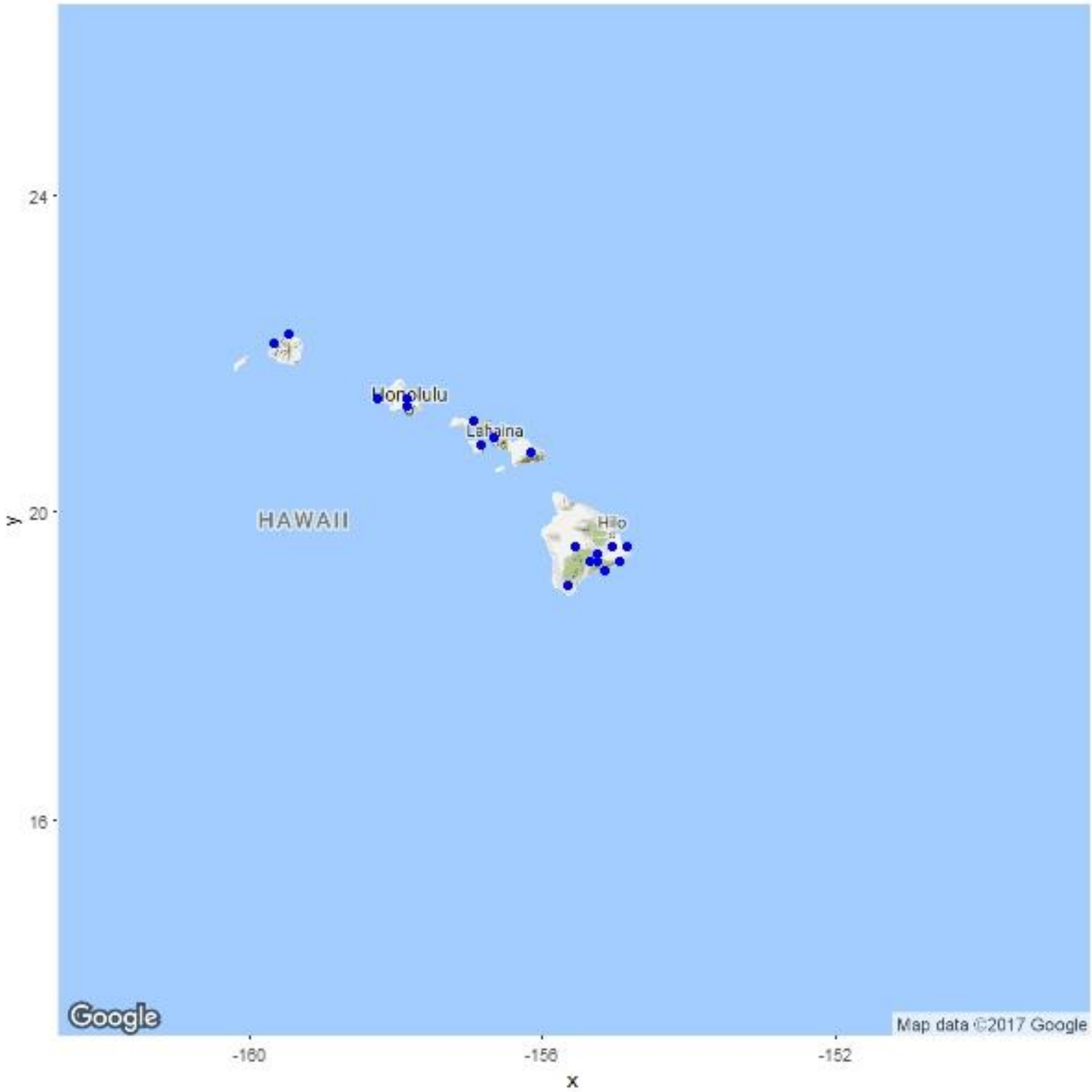


Figure 3. Occurrence of *Andropogon virginicus* in Hawaii

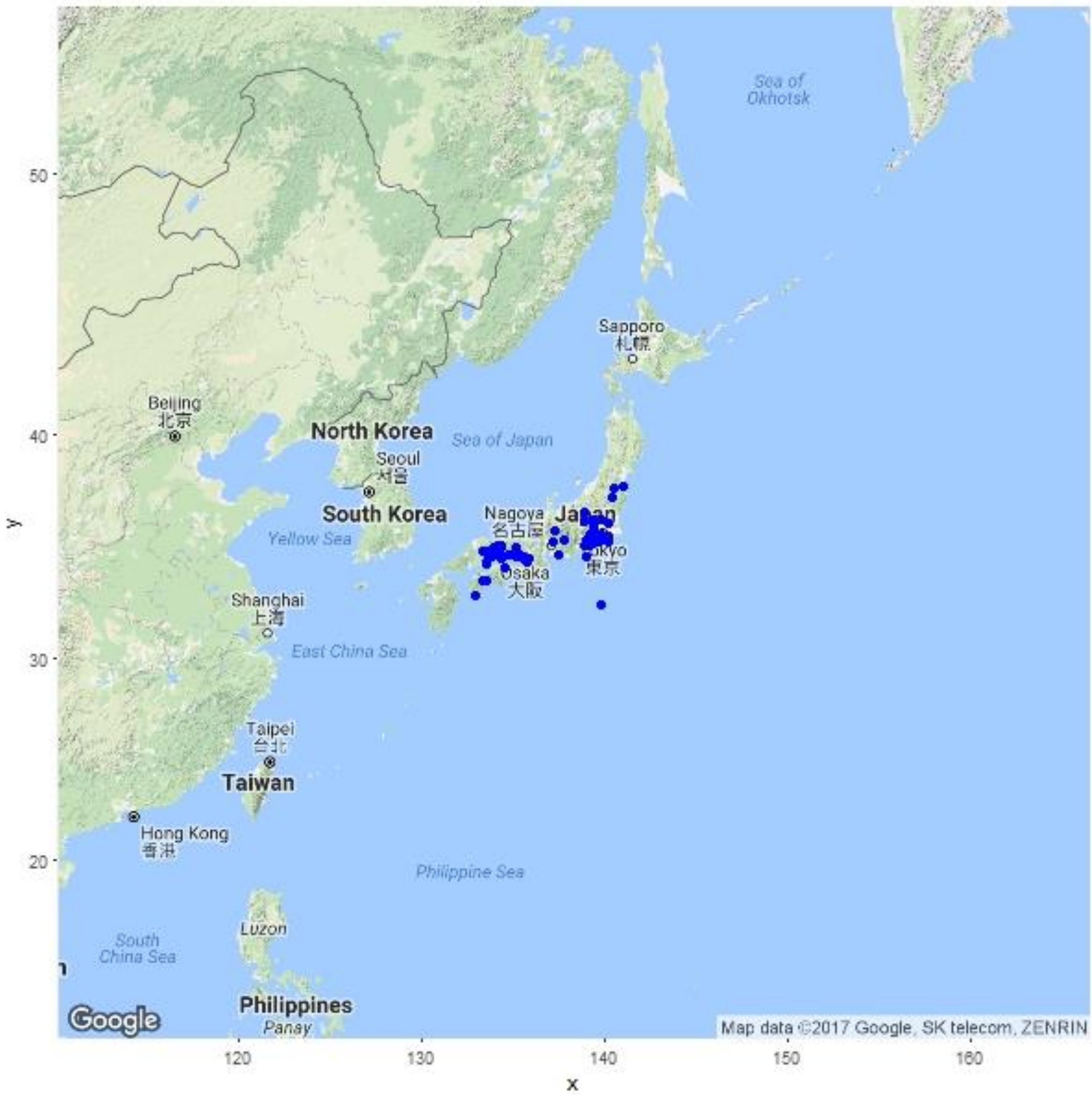


Figure 4. Occurrence of *Andropogon virginicus* in Asia

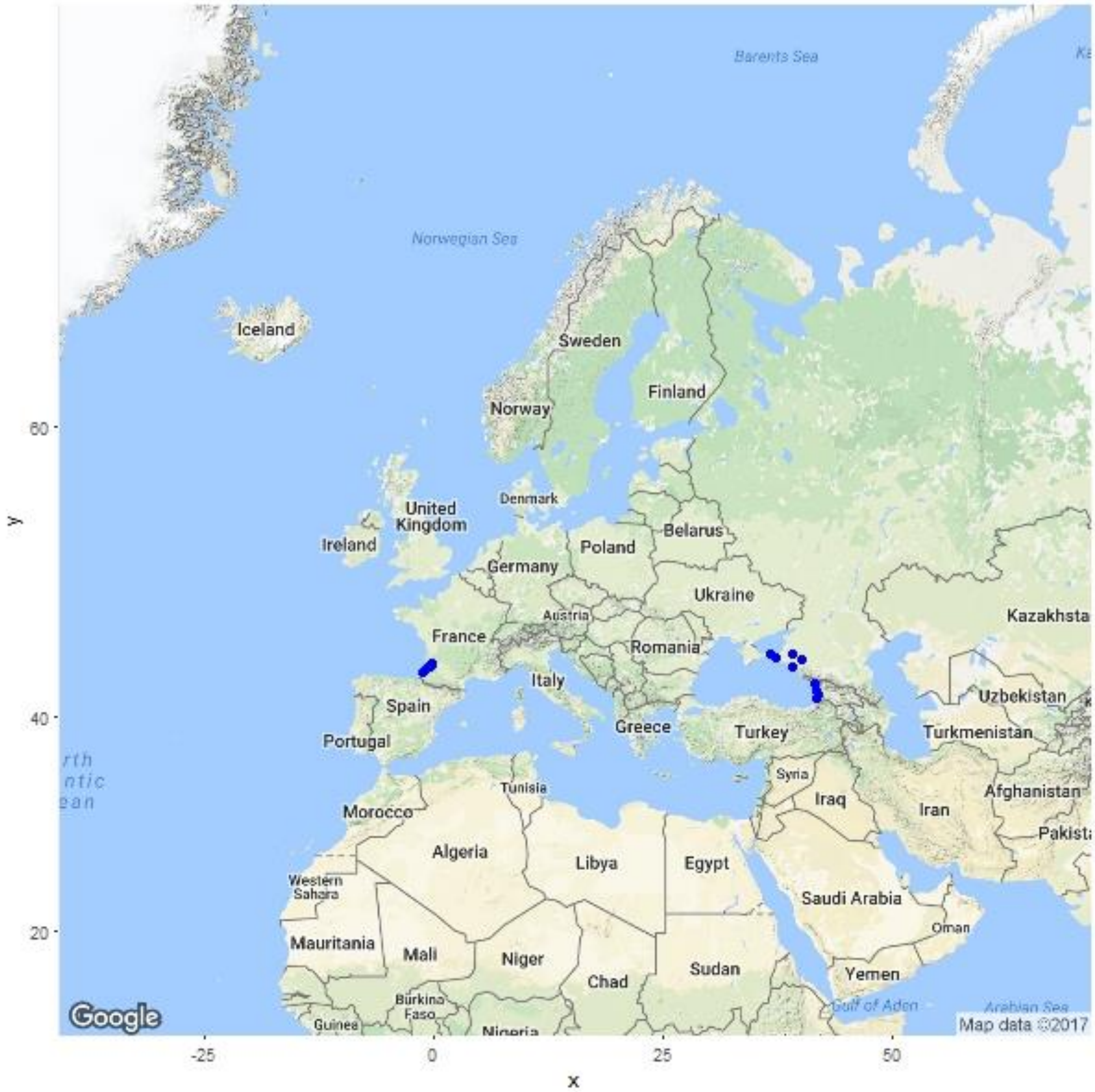


Figure 4. Occurrence of *Andropogon virginicus* in Europe

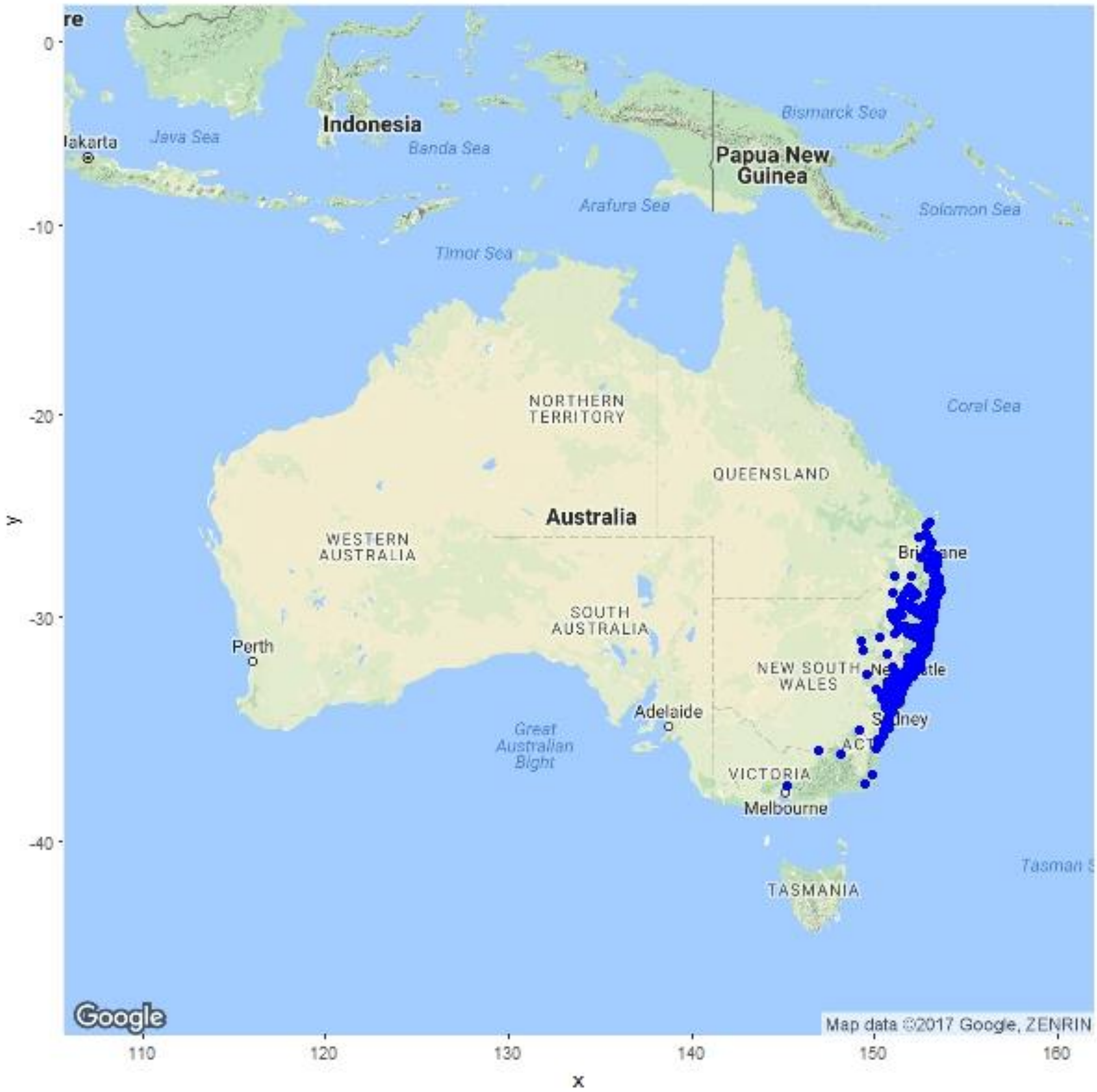


Figure 5. Occurrence of *Andropogon virginicus* in Australia

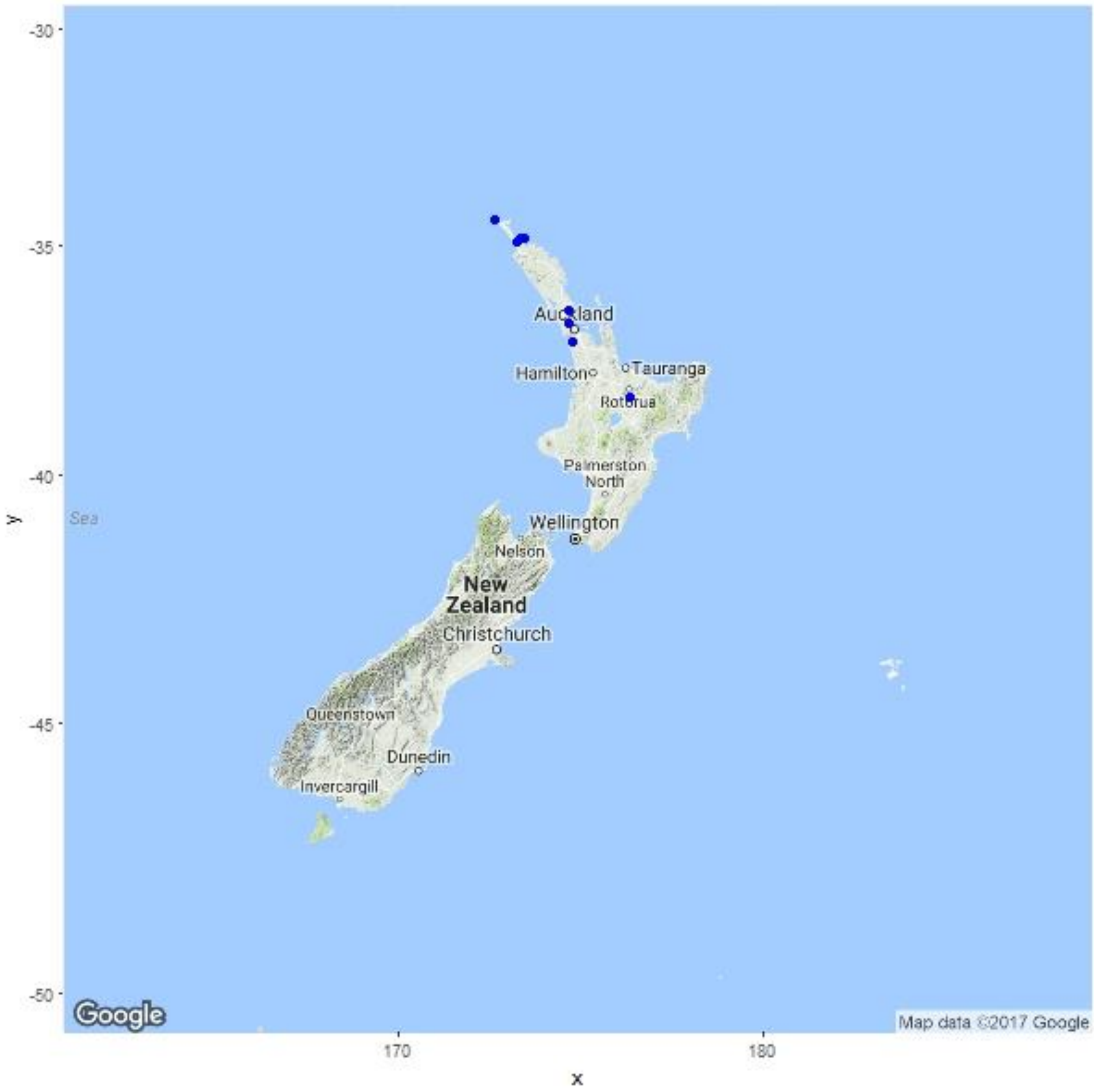


Figure 5. Occurrence of *Andropogon virginicus* in New Zealand