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Inleiding

De Nederlandse regering stimuleert de ontwikkeling van een bio-economie. Een bio-economie maakt gebruik van gewassen voor de productie van materialen, chemische stoffen, brandstof en energie in de vorm van elektriciteit en warmte. Biologische grondstoffen vervangen hierbij fossiele brandstoffen en via de petrochemische industrie verkregen stoffen. Deze verandering in het beleid wordt gedreven door de mogelijke verbetering in duurzaamheid, het economische potentieel van nieuwe producten, de gewenste vermindering van het gebruik van energie en ruwe grondstoffen en de verbetering van de landbouweconomie. Om de besluitvorming over maatregelen ter voorkoming van ongewenste ecologische, socio-economische en gezondheidseffecten te ondersteunen, heeft het Team Invasieve Exoten van de Nederlandse Voedsel- en Warenautoriteit (NVWA, Ministerie van Economische Zaken) gevraagd om een horizon scanning van recent ingevoerde of potentieel bruikbare uitheemse biomassagewassen in Nederland.

Materiaal en methoden

De horizon scanning van uitheemse biomassagewassen is uitgevoerd in twee stappen:

(1) Op basis van een literatuurstudie is een voorlopige lijst van biomassagewassen opgesteld die al aanwezig zijn of in de toekomst mogelijk in Nederland worden geteeld. Deze voorlopige lijst is vervolgens onderworpen aan vier criteria om uitheemse biomassagewassen te selecteren op grond van primair gebruik voor de productie van biobrandstof. Voor deze gewassen zijn beheersmaatregelen nodig in het geval de soort kan verwilderen en invasief is.

(2) Soorten die aan alle criteria voor opname voldoen (definitieve lijst voor horizon scanning) zijn vervolgens beoordeeld op hun (potentiële) ecologische risico's met behulp van het Belgische *Invasive Species Environmental Impact Assessment* (ISEIA) protocol. Tevens zijn kosteneffectieve beheersmaatregelen geïdentificeerd voor mogelijk invasieve biomassagewassen.

De literatuurstudie is uitgevoerd om een lijst van biomassagewassen te maken en informatie te verschaffen over de verspreiding en invasiebiologie van de uitheemse biomassagewassen die in staat zijn zich in Nederland te vestigen. Gegevens zijn verzameld over de fysiologische toleranties, kolonisatie vectoren, ecologische en socio-economische effecten en mogelijke maatregelen voor het beheer van deze soorten. De zogenoemde horizonscancriteria criteria voor opname in de definitieve lijst zijn:

1) De soort is een plant of alg.
2) De soort wordt beschouwd als een biomassagewas voor de productie van biodiesel, olie, ethanol en methaan of voor energie productie (verbranding).
3) De soort is uitheems en nog niet definitief in Nederland gevestigd. Dit wil zeggen dat de soort een beperkte verspreiding heeft en mogelijk nog kan worden uitgeroeid.
4) De soort is recent of zal mogelijk in Nederland geïntroduceerd worden als een biomassa-gewas (bijvoorbeeld, de soort wordt gekweekt in omringende landen of in landen met een vergelijkbaar klimaat als Nederland).

De beschikbare informatie over de geselecteerde soorten is vervolgens gebruikt voor een risicobeoordeling door deskundigen op het gebied van uitheemse biomassagewassen en invasiebiologie. Het ISEIA risicobeoordelingsprotocol is gebruikt als basis voor discussies die hebben geleid tot consensus met betrekking tot het mogelijke ecologische risico van elke soort voor Nederland.

Nieuwe en potentiële niet-inheemse biomassagewassen
Er is een voorlopige lijst van 52 nieuwe en mogelijk uitheemse biomassagewassen voor Nederland samengesteld. Hiervan zijn 32 soorten verwijderd na toepassing van de vier horizonscancriteria waarna een lijst van 20 soorten overblijft. Van de 32 verwijderde soorten zijn er drie verwijderd omdat het primaire gebruik anders is dan de productie van biodiesel, olie, ethanol en methaan of directe verbranding / energie productie omvatte (criterium 2); 26 soorten zijn verwijderd omdat ze inheems zijn of uitheems maar al zijn gevestigd in Nederland (criterium 3), en drie soorten zijn verwijderd omdat ze niet recent zijn geïntroduceerd of waarschijnlijk niet in de toekomst als een biomassagewas in Nederland zullen worden geïntroduceerd (criterium 4). Drie soorten, miscanthus (*Miscanthus* x *giganteus*), purgeernoot (*Jatropha curcas*) en hennepbladstokroos (*Hibiscus cannabinus*) zijn weer teruggeplaatst op de lijst vanwege interesse voor deze soorten binnen de Nederlandse Voedsel- en Warenautoriteit (NWWA). De definitieve lijst van mogelijke biomassagewassen voor Nederland omvat 23 soorten.

Risicoclassificaties van niet-inheemse biomassagewassen
Arundo donax en *Spartina pectinata* hebben hoge risicoscores (respectievelijk 12 en 11) voor het (potentiële) ecologische risico in Nederland (Tabel S1). Vijf andere soorten zijn geclassificeerd in de categorie matig risico (*Andropogon gerardii*, *Asclepias syriaca*, *Fallopia sachalinensis* var. *igniscum*, *Miscanthus sacchariflorus* and *Symphytum x uplandicum*). Vijftien soorten zijn geclassificeerd als laag risico (*Hibiscus cannabinus*, *Jatropha curcas*, *Miscanthus floridulus*, *Miscanthus sinensis*, *Miscanthus x giganteus*, *Panicum virgatum*, *Phyllostachys bissetii*, *Phyllostachys nigra*, *Phyllostachys reticulata*, *Salix schwerinii x Salix viminalis*, *Sida hermaphrodita*, *Silphium perfoliatum*, *Sorghum bicolor*, *Sorghum bicolor* var. *drummondii* en *Spartina cynosuroides*). Eén hybride is niet geclassificeerd vanwege gebrek aan gegevens (*Rumex patientia* x *Rumex thianschanicus*). Beoordeelde soorten die al aanwezig zijn

in de Nederlandse natuur zijn *A. donax*, *A. syriaca*, *Miscanthus* soorten, *P. virgatum*, *S. bicolor*, *S. pectinata*, *S. perfoliatum* en *S.* x *uplandicum*.

Tabel S1: Ecologische risicoscores en -classificatie van uitheemse biomassagewassen voor Nederland (*: Risicobeoordeling is sterk bepaald door de beste professionele kennis vanwege zeer beperkte gegevens).

Soort of hybride	Nederlandse naam	Risico-score (ISEIA)	Verspreiding in Nederland	Risico-classificatie (BFIS lijst systeem)
Fallopia sachalinensis* var. *igniscum* candy	Sachalinse duizendknoop	10	Afwezig	B0
Rumex patientia* L. x *Rumex thianschanicus*	Niet bekend	4	Afwezig	Niet geclassificeerd
Hibiscus cannabinus*	Hennepbladstokroos	4	Afwezig	C0
Sida hermaphrodita*	Virginische malva	6	Afwezig	C0
Salix schwerinii* x *Salix viminalis*	Wilg	8	Afwezig	C0
Jatropha curcas*	Purgeernoot	4	Afwezig	C0
Asclepias syriaca	Zijdeplant	10	Beperkt verspreidingsgebied	B2
Symphytum* x *uplandicum*	Bastaardsmeerwortel	10	Wijd verspreid	B3
Silphium perfoliatum*	Niet bekend	8	Geïsoleerde populaties	C1
Andropogon gerardii*	Baardgras	9	Afwezig	B0
Arundo donax	Pijlriet	12	Eén waarneming	A1
Miscanthus floridulus*	Reuzenriet	7	Afwezig	C0
Miscanthus* x *giganteus*	Miscanthus	8	Afwezig	C0
Miscanthus sacchariflorus*	Groot prachtriet	9	Eén waarneming	B1
Miscanthus sinensis*	Chinees prachtriet	6	Wijd verspreid	C3
Panicum virgatum*	Vingergras	8	Geïsoleerde populaties	C1
Phyllostachys bissetii*	Niet bekend	7	Afwezig	C0
Phyllostachys nigra*	Zwarte bamboe	7	Afwezig	C0
Phyllostachys reticulata*	Niet bekend	7	Afwezig	C0
Sorghum bicolor*	Kafferkoren	4	Geïsoleerde populaties	C1
Sorghum bicolor* var. *drummondii*	Sudangras	4	Afwezig	C0
Spartina cynosuroides*	Niet bekend	4	Afwezig	C0
Spartina pectinata	Slijkgras	11	Geïsoleerde populaties	A1

Ecologische risicocategorie: 🟥 Hoog risico; 🟧 Matig risico ; 🟨 Laag risico

Voor relatief veel soorten en hybriden zijn de risicocriteria beoordeeld met gebruikmaking van de best beschikbare professionele kennis van deskundigen (bijvoorbeeld *A. gerardii*, *F. sachalinensis* var. *igniscum*, *H. cannabinus*, *J. curcas*, *M. floridulus*, *M. sacchariflorus*, *M. sinensis*, *M.* x *giganteus*, *P. virgatum*, *P. bissetii*, *P. nigra*, *P. reticulata*, *S. schwerinii* x *S. viminalis*, *S. hermaphrodita*, *S. perfoliatum*, *S. bicolor* var. sweet, *S. bicolor* var. *drummondii*, *S. cynosuroides,* en *S.* x *uplandicum*), of niet beoordeeld vanwege gebrek aan gegevens (*R. patientia* x *R. thianschanicus*). Inherent aan deze benadering is een hoge mate van onzekerheid in de totale risicoscore van soorten en mogelijke onderschatting van hun risico(klasse) (Tabel S1; soorten en hybriden aangegeven met een *). Er is vooral een gebrek aan informatie over de variatie in (potentiële) invasiviteit van verschillende cultivars van de biomassagewassen die zijn beoordeeld. Dit geldt voor *A. gerardii*, *A. donax*, *Miscanthus* soorten, *P. virgatum*, *Phyllostachys* soorten, *S. bicolor*, *S. pectinata*, en *S.* x *uplandicum*. Karakteristieke eigenschappen die invasiviteit kunnen veroorzaken verschillen vaak tussen cultivars.

Effectieve beheeropties

Over het algemeen zijn de kosten van beheer en uitroeiing van een invasieve soort wanneer die zich eenmaal heeft gevestigd vele malen hoger dan de kosten van preventie van introductie. Wanneer een invasieve soort zich heeft gevestigd, is het vaak extreem moeilijk, zo niet onmogelijk, de soort uit te roeien. In Nederland is er relatief weinig aandacht voor de mogelijke ecologische risico's van uitheemse biomassagewassen voor biodiversiteit en ecosystemen. Dit gebrek aan belangstelling houdt mogelijk verband met het geringe oppervlak dat in gebruik is voor de teelt van biomassagewassen en de verwachting dat die teelt in Nederland in de toekomst niet sterk toeneemt. Uitheemse biomassasoorten vallen buiten de wettelijke regels voor de screening van plantensoorten voordat ze kunnen worden geteeld. Bovendien worden de mogelijke invasiviteit en invloed op biodiversiteit en ecosystemen niet beschouwd als onderdeel van het screeningsproces dat de geschiktheid van variëteiten voor de teelt in Nederland vaststelt.

In Florida (USA) moeten organisaties die van plan zijn uitheemse plantensoorten als energiegewas te telen de volgende informatie verschaffen voordat een vergunning kan worden verleend: 1) Een brief waarin wordt uitgelegd wat de bedoeling is, 2) een compleet ingevuld vergunningaanvraagformulier voor de teelt van biomassa- of biobrandstofgewassen (Appendix 1), 3) bewijs van eigendom of pacht van de akker, 4) een bewijsexemplaar van de plant, 5) een beschrijving van de uitheemse plant die moet worden geteeld inclusief de geschatte kosten van verwijdering en destructie samen met de onderbouwing van de berekening of schatting.

Het invoeren van monitoring maakt vroegtijdige identificatie van nieuwe groeiplaatsen van biomassagewassen mogelijk. Soorten met wortelstokken of een langlevende zaadvoorraad moeten strikt worden beheerd indien de teelt ervan wordt toegestaan. Eenjarige soorten zonder zaadvoorraad zouden geteeld kunnen worden onder een minder strikt beheerregiem, zoals de huidige beheerbenadering voor raapzaad (*Brassica napus*) in Nederland. Natuurorganisaties zouden de vroegtijdige identificatie van uitheemse soorten die zich in hun beheersgebieden vestigen mogelijk kunnen maken door 1) het herkennen van soorten die de prioriteit hebben bij risicoanalyse, 2) vroegtijdige signalering van verspreiding van soorten door training van de veldstaf, 3) door waarnemingen van derden te registreren, 4) door registratie van elke nieuwe waarneming in centrale databases (zoals de Nationale Databank Flora en Fauna). Bovendien kunnen open databases worden gebruikt en geraadpleegd (bijvoorbeeld www.waarnemingen.nl, met soortwaarnemingen van amateurs en deskundigen).

Opties voor de eliminatie of het beheer van kleine populaties van invasieve uitheemse biomassasoorten omvatten: de toepassing van herbiciden (zoals glyfosaat voor het beheer van *Miscanthus* soorten, de auxine-achtige groeiregulatoren en de imidazolinone en sulfonylurea herbiciden) voor het weer in cultuur brengen van verlaten productievelden en mechanische methoden (zoals snijden, schoffelen, shovelen, klepelen, maaien en grondbewerking). Biologische technieken zijn waarschijnlijk ongeschikt voor het beheer van verwilderde populaties van economisch belangrijke biomassagewassen. Cultuurtechnieken zoals branden, begrazing en hervegetatie zijn onpraktisch of niet effectief voor de uitroeiing van kleine vestigingen van invasieve plantensoorten. Niet wijd verspreide soorten met ondergrondse rhizomen zijn mogelijk nog handmatig te verwijderen. Deze soorten worden echter gemakkelijk via grondverzet verspreid naar verstoorde habitats (zoals de *Fallopia* soorten in Nederland). Indien deze soorten zich verder uitbreiden in dergelijke habitats (bijvoorbeeld op dijken of in natuurgebieden) wordt handmatige uitroeiing te arbeidsintensief en zijn gangbare beheersmaatregelen uit de landbouw niet toepasbaar. Een zoekactie via google.nl toont dat *A. donax*, *A. syriaca*, *J. curcas*, *Miscanthus* soorten, *P. virgatum, Phyllostachys* soorten, *S. hermaphrodita*, *S. perfoliatum*, *S. pectinata* en *S. x uplandicum* ook als plant of zaad worden verkocht via internethandelaren in Nederland.

Verder onderzoek

De beschikbare waarnemingen van *Miscanthus* soorten in Nederland moeten met scepsis worden behandeld vanwege moeilijkheden bij het correct determineren ervan. Daarom zijn de data over de verspreiding van *Miscanthus* soorten niet bij de risicobeoordeling betrokken. Aanbevolen wordt om Nederlandse determinatietabellen voor *Miscanthus* soorten te ontwikkelen. De determinatiesleutels, beschrijvingen, tekeningen en fotomaterialen moeten onderscheid tussen *Miscanthus* soorten mogelijk maken en kunnen worden toegevoegd aan QBank, de online bron met gegevensbestanden over plantenplagen en -ziektes. Daarnaast is ook meer onderzoek nodig om betrouwbare determinatie mogelijk te maken van bamboe soorten en gekweekte variëteiten die als sierplant in Nederland worden verkocht. Hierdoor zal de betrouwbaarheid van gegevens over de verspreiding van soorten en variëteiten uit deze groep toenemen. Tot slot wordt aanbevolen om periodiek actualisaties te maken van wetenschappelijke kennis en risicobeoordelingen van soorten waarvoor een informatiegebrek is geconstateerd en/of beste professionele kennis van deskundigen is toegepast vanwege onvoldoende gepubliceerde data.

Summary

Introduction

The government of the Netherlands is currently stimulating the development of a bio-based economy. A bio-based economy involves the use of crops for the production of materials, chemicals, fuel and energy in the form of electricity and heating. In this way biological raw materials replace fossil fuels and petro-chemical derived materials. The drivers of this change are the associated potential increases in sustainability, the economic potential of new products, energy and raw material security and improvements to the agricultural economy. To support decision making with regard to the design of measures to prevent ecological, socio-economic and public health effects, the Invasive Alien Species Team of the Netherlands Food and Consumer Product Safety Authority (Ministry of Economic Affairs) has asked for a horizon scanning of recently introduced or potential non-native biomass crops in the Netherlands.

Materials and methods

The horizonscan of non-native biomass crops was carried out in two steps:

(1) A literature study was conducted to create a preliminary list of biomass crops that are, or will potentially be cultivated in the Netherlands. The preliminary list was then subjected to inclusion criteria that identified non-native biomass crop species primarily used in the production of biofuels that would be amenable to management intervention if they escaped cultivation.

(2) Species adhering to all the inclusion criteria (definitive list species) were then assessed for (potential) ecological risk using the Belgium Invasive Species Environmental Impact Assessment (ISEIA) protocol and cost-effective management measures of potential invasive biomass crops were identified.

A literature study was carried out to create a preliminary list of biomass crops and provide information on the distribution and invasion biology of the non-native biomass crops capable of establishing in the Netherlands. Literature data were collected on the physiological tolerances, colonization vectors, ecological and socio-economic impact and potential measures for management of these species. Four inclusion criteria were agreed upon that selected a definitive list of potential biofuel species from the preliminary list produced during the literature study. The inclusion criteria, referred to as horizonscan criteria from here on in, are as follows:

1) The species is a plant or algae species.
2) The species is considered to be a biomass crop for the production of biodiesel, oil, ethanol and methane or for energy production (incineration).

3) The species is non-native and not established in the Netherlands. Species not established in the Netherlands have a limited distribution and are, therefore, amenable to eradication measures.
4) The species has been recently or will potentially be introduced as a biomass crop to the Netherlands (for example, the species is cultivated in surrounding countries or in countries with a similar climate to the Netherlands).

Information on definitive list species obtained from the literature study was used as input for a risk assessment workshop involving experts in the fields of non-native biomass crops and invasion biology. The ISEIA risk assessment protocol was chosen to provide a framework for discussions that led to consensus on the potential ecological risk of each species for the Netherlands.

New and potential non-native biomass crops

A preliminary list of 52 new and potential non-native biomass crops for the Netherlands were identified of which 32 species were removed after screening with the four horizonscan criteria leaving an initial shortlist of 20 species. Of the 32 species removed, three were excluded because their primary use is not for the production of biodiesel, oil, ethanol and methane; or for direct combustion / energy production (criteria 2); 26 were excluded because they are native to or non-native and established in the Netherlands (criteria 3); and three were excluded because they have not been recently introduced or probably will not be introduced in the future as a biomass crop to the Netherlands (criteria 4). Three species, miscanthus (*Miscanthus* x *giganteus*), jatropha (*Jatropha curcas*) and kenaf (*Hibiscus cannabinus*) were re-added to the list due to interest within the Netherlands Food and Consumer Product Authority (NVWA, Nederlandse Voedsel- en Warenautoriteit) pertaining to these species. The definitive list of potential biomass crops for the Netherlands contains 23 species.

Risk classifications of non-native biomass crops

Arundo donax and Spartina pectinata received high risk scores, scoring 12 and 11 respectively for (potential) ecological risk in the Netherlands (Table S1). Five other species were classified as medium risk (*Andropogon gerardii*, *Asclepias syriaca*, *Fallopia sachalinensis* var. *igniscum*, *Miscanthus sacchariflorus* and *Symphytum x uplandicum*). Fifteen species were classified as low risk (*Hibiscus cannabinus*, *Jatropha curcas*, *Miscanthus floridulus*, *Miscanthus sinensis*, *Miscanthus x giganteus*, *Panicum virgatum*, *Phyllostachys bissetii*, *Phyllostachys nigra*, *Phyllostachys reticulata*, *Salix schwerinii x Salix viminalis*, *Sida hermaphrodita*, *Silphium perfoliatum*, *Sorghum bicolor*, *Sorghum bicolor* var. *drummondii* and *Spartina cynosuroides*). One species remained unclassified due to complete data deficiency (*Rumex patientia* x *Rumex thianschanicus*). Species included in the risk analyses and already present in Dutch nature are *A. donax*, *A. syriaca*, *Miscanthus* spp., *P. virgatum*, *S. bicolor*, *S. pectinata*, *S. perfoliatum* and *S.* x *uplandicum*.

Many criteria were either assessed using best available professional judgement (i.e., *A. gerardii*, *F. sachalinensis* var. *igniscum*, *H. cannabinus*, *J. curcas*, *M. floridulus*, *M. sacchariflorus*, *M. sinensis*, *M.* x *giganteus*, *P. virgatum*, *P. bissetii*, *P. nigra*, *P. reticulata*, *S. schwerinii* x *S. viminalis*, *S. hermaphrodita*, *S. perfoliatum*, *S. bicolor* var. sweet, *S. bicolor* var. *drummondii*, *S. cynosuroides, S.* x *uplandicum*); or not assessed due to data limitations (i.e., *R. patientia* x *R. thianschanicus*). This approach is inherently associated with high uncertainty in the total risk score of species and may have caused an underestimation of their risk classification (Table S1; indicated with *). There was a lack of information in the literature concerning variations in the potential invasiveness of different cultivars of the crops assessed, i.e. *A. gerardii*, *A. donax*, *Miscanthus* spp., *P. virgatum*, *Phyllostachys* spp., *S. bicolor*, *S. pectinata*, *S.* x *uplandicum*. Characteristics that may influence invasiveness frequently vary between cultivars.

Table S1: Ecological risk scores and classification of non-native biomass crops for the Netherlands (*: Risk score and classification strongly determined by best professional judgement due to data limitations).

Species	Common name	Total risk score (ISEIA)	Distribution in the Netherlands	Risk classification (BFIS list system)
Fallopia sachalinensis var. _igniscum_ candy*	Giant knotweed	10	Absent	B0
Rumex patientia L. x _Rumex thianschanicus_*	Not applicable	4	Absent	Unclassified
_Hibiscus cannabinus_*	Kenaf	4	Absent	C0
_Sida hermaphrodita_*	Virginia mallow	6	Absent	C0
Salix schwerinii x _Salix viminalis_*	Willow	8	Absent	C0
_Jatropha curcas_*	Jatropha	4	Absent	C0
Asclepias syriaca	Common milkweed	10	Restricted range	B2
Symphytum x _uplandicum_*	Russian comfrey	10	Widespread	B3
_Silphium perfoliatum_*	Cup plant	8	Isolated populations	C1
_Andropogon gerardii_*	Big bluestem	9	Absent	B0
Arundo donax	Giant reed	12	Single record	A1
_Miscanthus floridulus_*	Pacific silver grass	7	Absent	C0
Miscanthus x _giganteus_*	Miscanthus	8	Absent	C0
_Miscanthus sacchariflorus_*	Japanese silver grass	9	Single record	B1
_Miscanthus sinensis_*	Chinese silver grass	6	Widespread	C3
_Panicum virgatum_*	Switchgrass	8	Isolated populations	C1
_Phyllostachys bissetii_*	Not applicable	7	Absent	C0
_Phyllostachys nigra_*	Black bamboo	7	Absent	C0
_Phyllostachys reticulata_*	Japanese timber bamboo	7	Absent	C0
_Sorghum bicolor_*	Sugar beet	4	Isolated populations	C1
Sorghum bicolor var. _drummondii_*	Sudan grass	4	Absent	C0
_Spartina cynosuroides_*	Giant cordgrass	4	Absent	C0
Spartina pectinata	Prairie cordgrass	11	Isolated populations	A1

Ecological risk categorisation: 🟥 High risk; 🟧 Medium risk; 🟨 Low risk

Effective management options

Generally, the cost of eradication or control of an invasive species once it has become established far outweighs the costs associated with prevention of introduction. Once an invasive species has become established it is extremely difficult, if not impossible, to eradicate. Currently, in the Netherlands, relatively little attention has been focussed on the potential ecological risks of non-native biomass crops to biodiversity and ecosystems. This lack of attention possibly relates to the small acreage devoted to biomass crops grown for energy production, and the expectation that the cultivation of biomass crops in the Netherlands will not hugely increase in the future. Non-native biomass crop species fall outside the scope of regulations that promote the mandatory screening of plant species prior to their cultivation. Moreover, potential invasiveness, and impacts on biodiversity and ecosystems are not considered as part of the screening process that assesses the suitability of varieties for cultivation in the Netherlands.

In Florida (USA) organisations intending to plant biofuel species must submit the following information prior to the granting of a permit: 1) A cover letter or letter of intent, 2) a completed biomass permit application form (Appendix 1), 3) evidence of site ownership/permission, 4) a voucher specimen of the plant, and 5) a description of the non-native plant to be grown including an estimated cost of removal and destruction, together with the basis for calculating or determining the estimate. In general, monitoring should be introduced that facilitates the early identification of new biomass crop stands. Rhizomatous species and species with a long-lived seed stock must be strictly managed if permitted for cultivation. Annual species without a seed stock may be cultivated under a less strict management regime, similar to the current management approach for rapeseed (*Brassica napus*) in the Netherlands. Nature organisations may facilitate the early identification of non-native species establishing in their management area by 1) identifying priority species through risk assessment, 2) encouraging early recognition by training field staff, 3) registering incoming notifications from third-parties, and 4) registering any new records in central registration databases (e.g., the 'Nationale Database Flora en Fauna'). Moreover, openly accessible databases may also be used and consulted (e.g., www.waarnemingen.nl, that feature species records made by the public and professionals).

Options for the management and control of small populations of invasive non-native biomass species include: herbicides e.g. glyphosate for the management of *Miscanthus* spp., the auxin-like growth regulators and the imidazolinone and sulfonylurea herbicides, all of which may also be used for reclaiming abandoned production fields, and mechanical methods such as weed whips, sling blades, clippers, shovels, hoes, mattocks, and weed wrenches, and mowing and tillage. Biological techniques are inappropriate for the management of escaped populations of plants that are economically important crop species. Cultural techniques such as prescribed burning, grazing and revegetation efforts are impractical or not effective for the eradication of small infestations of invasive plant species. Moreover, if these species were to become widespread at these locations (e.g., dikes and nature areas), and manual removal becomes too labour intensive, other management measures normally applied on agricultural land are not suitable. A search using google.nl revealed that *A. donax*, *A. syriaca*, *J. curcas*, *Miscanthus* spp., *P. virgatum, Phyllostachys* spp., *S. hermaphrodita*, *S. perfoliatum*, *S. pectinata* and *S. x uplandicum* are all available to the public as plant or seed from internet retailers in the Netherlands.

Further research

Due to difficulties in correctly identifying *Miscanthus* species, the current recorded distributions of *Miscanthus* spp. in the Netherlands are treated with a high degree of scepticism. Therefore, risk assessors have been unable to apply the distribution of *Miscanthus* spp. during the risk analyses. It is recommended, that Dutch identification keys for *Miscanthus* spp. are developed and that descriptions and photo material differentiating between *Miscanthus* spp. should be added to QBank, the online resource containing databases on quarantine plant pests and diseases. Similarly, more research should be undertaken that will facilitate the better identification of bamboo species and varieties cultivated and sold as ornamental plants in the Netherlands, as this will reduce the uncertainty surrounding the recorded distributions of species within this plant group. In cases where there is either data deficiency or best professional judgement is applied during risk analyses, periodical reviews of new literature and updates of risk scores are recommended.

1. Introduction

1.1 Background and problem statement

The government of the Netherlands is currently stimulating the development of a bio-based economy. A bio-based economy involves the use of crops for the production of materials, chemicals, fuel and energy in the form of electricity and heating. In this way biological raw materials replace fossil fuels and petro-chemical derived materials. The drivers of this change are the associated potential increases in sustainability, the economic potential of new products, energy and raw material security and improvements to the agricultural economy (Rijksdienst voor Ondernemend Nederland, 2015).

Biomass crops are crops with a high dry matter content, that yield high levels of starch and / or oils and are suitable for combustion, fermentation or extraction of biofuels (such as biodiesel and methanol / ethanol). Biomass crops are of increasing interest for use as a raw material for energy production in the Netherlands. Three groups of biomass crops can be defined i.e. first, second and third generation crops. Examples of first generation biofuels are fuels derived from sugars, starch, plant oils or animal fat. First generation biomass crops are primarily those that are grown in the Netherlands for food or feed usage i.e. corn, rapeseed, sugar beet and grain. Therefore, first generation biomass crops do not pose an increased risk for the introduction of invasive crops. However, there are public concerns surrounding first generation biomass crops due to potential competition between energy and food crops for agricultural land. Increasingly affluent nations, particularly those in Asia, have seen an increased consumption in meat and dairy products which puts pressure on animal feed supplies, while growing quantities of corn and other grains are being diverted for use as biofuel feedstocks, both leading to increases in food prices (Tenebaum, 2008). There is, therefore, a need to investigate the potential for alternative biomass crops to reduce this conflict, especially when they can be grown on marginal arable lands resulting in less competition with regular food / feed crops. Second generation biomass crops are not traditionally used as food crops, but primarily grown for energy production in the form of direct combustion of dry matter or the production of cellulose ethanol thereof. Third generation biofuels will be created from algae that will be cultured specifically for the production of biofuels. Both second and third generation energy crops have the potential to reduce conflicts between food and energy production.

The scale of biomass crop cultivation in the Netherlands is currently very limited. The land area devoted to biomass crop cultivation was 15,000 ha in 2007 (circa 0.08% of land area). In comparison, land area devoted to the growth of biomass crops for energy production or the growth of crops that are used for industrial goals in Germany was 19% in 2007 (AgriHolland, 2015). However, in recent years a number of new exotic crop plants have been introduced to the Netherlands, such as refined forms of miscanthus (*Miscanthus* x *giganteus* and *M. sinensis*) and the Giant knotweed (*Fallopia sachalinensis* var. *igniscum*). Moreover, a number of organisations have produced reports analysing the viability of biofuel production in the Netherlands. For example, an investigation by the Dutch research organisation Applied Plant Research (PPO) showed that co-fermentation corn, fodder and Sudan grass (*Sorghum bicolor* var. *drummondii*) offer the best prospects as biomass crops for energy production. Of the oleaginous crops, oilseed rape and linseed were reported as most financially attractive. Wheat or sugar beet is best for the production of bioethanol in the Netherlands (Van der Voort et al., 2008). In the short term, the cultivation of algal energy-crops will probably be limited in the Netherlands; however, their use is on the rise (Wikipedia, 2015).

The risk of introductions of invasive species associated with the worldwide search for suitable first, second and third generation biomass crops is relatively high, in view of their desired properties (e.g., rapid spread of roots, rhizomes and / or seeds, short generation time, high tolerance for stress, growth in a broad range of conditions and high resistance to pests and diseases). According to Chimera et al. (2010), biomass crops are three times as likely to become established and twice as likely to become invasive than other crops.

Currently, insufficient understanding exists on the probability of spread, establishment and the (potential) resulting risks posed by biomass crops to biodiversity, ecosystems, human health and / or society. Therefore, the Office for Risk Assessment & Research Programming (BuRO; Invasive Alien Species Team) of the Dutch Food and Consumer Product Authority (NVWA, Nederlandse Voedsel- en Warenautoriteit) have requested for a horizonscan of non-native biomass crops used primarily for energy production with a short risk assessment of relevant crop species for the Netherlands.

1.2 Research goals

The goals of this study are:

- To carry out a horizonscan of (potential) non-native biomass crops used primarily for energy production that have recently or will possibly be cultivated for energy production in the Netherlands.
- To carry out a ‘short’ assessment of the identified non-native biomass crops for risks to biodiversity and ecosystems in the Netherlands, including possible consequences for human health and society.
- To provide recommendations that aim to prevent or regulate the planting or sowing of invasive biomass crops used primarily for energy production.

1.3 Outline and coherence of research

The coherence between various research activities and outcomes of the study are visualised in a flow chart (Figure 1.1). The present chapter describes the problem statement, goals and research questions in order to identify potential invasive biomass crops and to perform environmental risk analyses of non-native biomass crops in the Netherlands. Chapter 2 gives the methodological framework of the project and describes the literature review and data acquisition. Chapter 3 describes the results of the literature study that resulted in the preliminary list of new and potential non-native biomass crops for the Netherlands and the results of the workshop that produced inclusion (horizonscan) criteria creating the definitive list of new and potential biomass crops for the Netherlands selected for risk analysis.

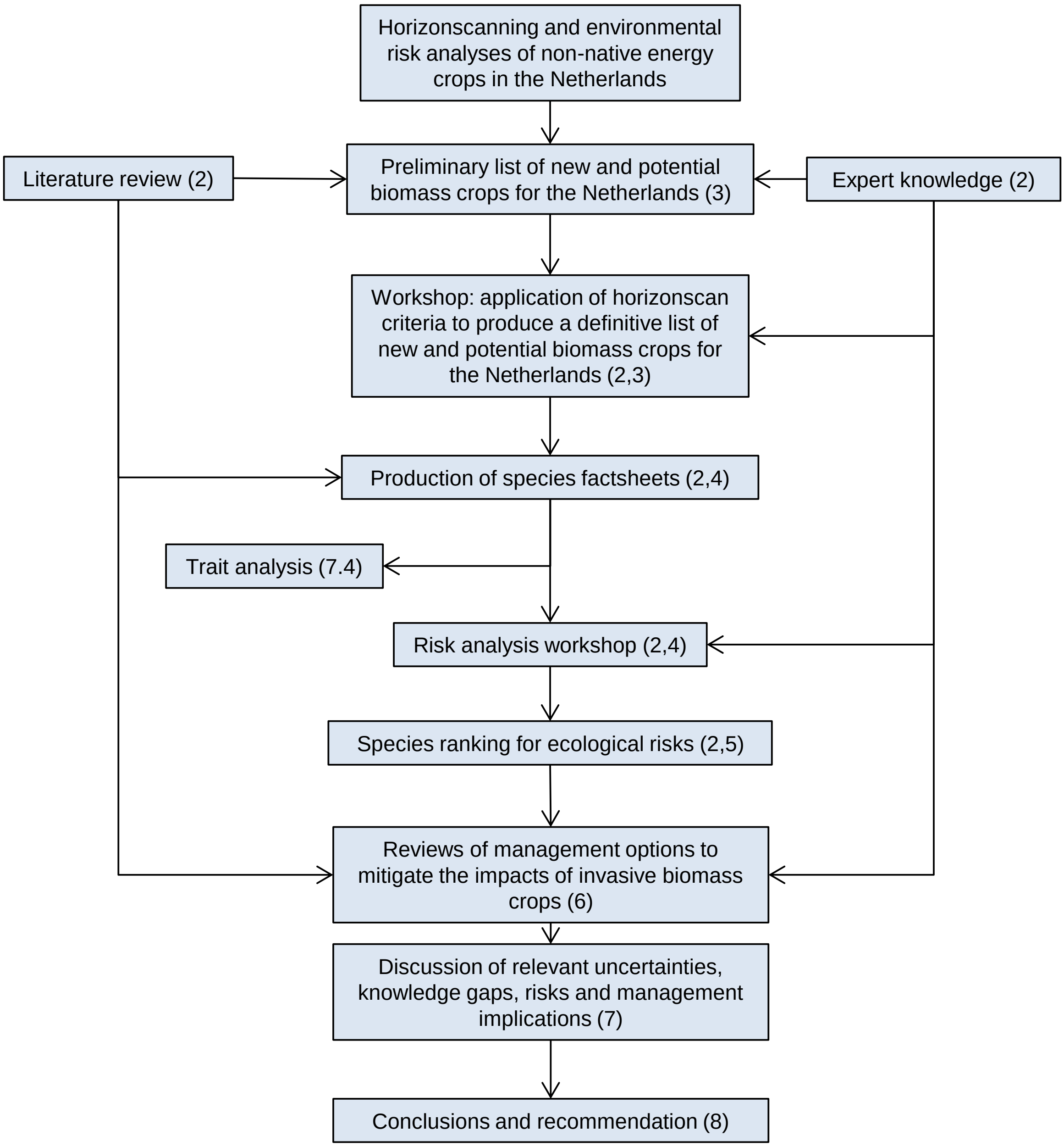

Figure 1.1: Flow chart visualising the coherence of various research activities (Chapter numbers are indicated in brackets).

Chapter 4 includes detailed descriptions of each species selected for risk analysis and describes the identity, taxonomical status, reproductive biology, habitat characteristics, geographical distribution and trends in their distribution in the Netherlands including relevant pathways and vectors for dispersal, ecological, economic and public health effects and available risk classifications from other countries. Moreover, this chapter includes the results of risk assessments of selected species that have been performed by an expert team, using available information and data. Chapter 5 ranks and evaluates risk classifications of all species involved. Chapter 6 reviews the scope of management options for these species. The relevant uncertainties, knowledge gaps, risks and management implications are discussed in chapter 7. Finally, chapter 8 draws conclusions and gives recommendations for management and further research. Appendices with raw data and background information complete this report.

2. Materials and methods

2.1 Horizon scanning

A horizonscan is a systematic examination of information to identify potential threats, risks, emerging issues and opportunities, allowing for better preparedness and the incorporation of mitigation and exploitation into the policy making process. The horizonscan was carried out by first undertaking a literature review to compile a list of potentially relevant biomass crop species that may be cultivated in the Netherlands. Secondly, information was gathered for each species on actual ecological impacts from regions climatically similar to the Netherlands. This information was then used as input for an expert meeting that first critically reviewed the initial list according to standardised inclusion criteria to create a definitive list of species most likely to be considered for cultivation or already cultivated. Species contained in the definitive listed underwent standardised risk assessments undertaken by a group of experts following consideration of the actual ecological impacts observed in climatically similar regions obtained during the literature review. The individual risk scores were then ranked to provide insight into the relative ecological risk of individual species.

2.2 Literature review

A literature review was undertaken in two steps (1) biomass crop species that may be grown in the Netherlands to produce biofuels were identified, and (2) information was gathered on ecological impacts that have occurred as a result of introduction of the identified species in climatically similar regions to the Netherlands.

The first step of the literature review was undertaken by the Netherlands Food and Consumer Product Authority. Organisations that were expected to possess information on potential biomass crops for the Netherlands were identified and information was sought using either contacts within those organisations or from available literature. The organisations identified were AgriHolland, a national agricultural knowledge bank in the Netherlands (AgriHolland, 2015); 'Innovatief Platteland' or 'Innovative Countryside' in English, an organisation that develops innovative management approaches for the Dutch agricultural sector; SenterNovem, an organisation that was tasked to advise the Dutch government on innovation, energy, climate and environment and the Dutch research organisation Applied Plant Research (PPO). Additional potential biomass crop species were obtained from experts at Wageningen UR Plant Breeding, FLORON and the Plant Protection Service. Additional literature searches were carried out using the academic search engines available at the Radboud University, Nijmegen. The lists obtained from each organisation were combined to produce a preliminary list of potential fuel crop species.

A second literature review was carried out to collect all available data and information on the distribution and invasion biology of the species identified in the preliminary list. Literature data were collected on physiological tolerances, substrate preference, colonization vectors, ecological and socio-economic impacts and potential measures for the management of this species. Our search was largely internet based, supported by the use of a university library. Academic and non-academic search engines and websites were systematically searched using the Web of Knowledge, Google Scholar and Google.nl. Specific searches of invasive species databases were made to identify ecological effects relating to the potential invasive nature of species. Databases were queried from Q-bank (http://www.q-bank.eu/Plants/), the GB non-native species secretariat (http://www.nonnativespecies.org/home/index.cfm), Invasive alien species Belgium (http://ias.biodiversity.be/), DAISIE (http://www.europe-aliens.org/), NOBANIS (http://www.nobanis.org/), EPPO (http://www.eppo.int/) and the Global non-native species database (http://www.issg.org/database/welcome/). All search results from the Web of Knowledge and the invasive species databases were examined, while the first 50 results from Google Scholar and Google.nl were examined due to the decreasing relevance of search results returned using this search engine. Search terms used to carry out the literature study were: the species scientific name, the official English common name and, if applicable, frequently used synonyms. The official preferred Dutch name of each species was taken from the Netherlands species register (www.nederlandsesoorten.nl). If no official Dutch name existed in the Dutch species register, unofficial names were taken from the Dutch plant trade websites and hobbyist forums and identified as unofficial in the text. Due to time limitations, not all the results of the literature study could be included in the making of this report. Instead, the results of the literature study were scanned to pick out information that is most relevant to an ecological risk assessment of non-native species.

2.3 Data acquisition on current distribution

Distribution data originated from the Dutch National Database of Flora & Fauna (NDFF), a web based biodiversity resource. The NDFF is the most complete and up to date biodiversity databank in the Netherlands and contains only validated information on the distribution of species (NDFF, 2015f). Distribution data and maps of the non-native biomass crops in the Netherlands were obtained by querying the online export portal. Data on international distributions was obtained from international non-native species databases and scientific literature (see citations in the text).

2.4 Risk assessment

2.4.1 Selection of risk assessment method

As one of the aims of this project is to provide insight into the relative ecological risks of non-native biomass crop species to the Netherlands, valid risk scores were required on ecological risks for all species and it was decided to apply the ISEIA protocol for this purpose. The ISEIA protocol requires less detailed information on impacts to obtain a valid risk classification than other risk assessment protocols and focuses on ecological impacts only.

2.4.2 The ISEIA ecological risk assessment protocol

The ISEIA protocol assesses risks associated with dispersion potential, invasiveness and ecological impacts only (Branquart, 2007). Definitions for risk classifications relating to the four sections contained within the ISEIA protocol are given in Table 2.1.

The ISEIA protocol contains twelve criteria that match the last steps of the invasion process (i.e., the potential for spread establishment, adverse impacts on native species and ecosystems). These criteria are divided over the following four risk sections: (1) dispersion potential or invasiveness, (2) colonisation of high conservation habitats, (3) adverse impacts on native species, and (4) alteration of ecosystem functions. Section 3 contains sub-sections referring to (i) predation / herbivory, (ii) interference and exploitation competition, (iii) transmission of diseases to native species (parasites, pest organisms or pathogens), and (iv) genetic effects such as hybridization and introgression with native species. Section 4 contains sub-sections referring to (i) modifications in nutrient cycling or resource pools, (ii) physical modifications to habitats (changes to hydrological regimes, increase in water turbidity, light interception, alteration of river banks, destruction of fish nursery areas, etc.), (iii) modifications to natural successions and (iv) disruption to food-webs, i.e. a modification to lower trophic levels through herbivory or predation (top-down regulation) leading to ecosystem imbalance.

Each criterion of the ISEIA protocol was scored. The scores range from 1 (low risk) to 2 (medium risk) and 3 (high risk). Definitions for low, medium and high risk, according to the four sections of the ISEIA protocol are given in table 2.1. If knowledge obtained from the literature review was insufficient, then the assessment was based on best professional judgement and field observation leading to a score of 1 (unlikely) or 2 (likely). If no answer could be given to a particular question (no information) then the score of 1 was given (DD - deficient data). This is the minimum score that can be applied in any risk category. In cases with data or knowledge limitations, periodical review of new literature and updates of risk scores will be recommended. Finally, the highest score within each section was used to calculate the total ISEIA risk score for the species. A maximum possible risk score per species is calculated per species. The maximum possible risk score takes into account the limitation on maximum risk score per category that is imposed by the ISEIA protocol if data deficiency occurs or the application of best professional judgement is required (a maximum possible score of one and two respectively). The maximum possible risk score will, therefore, vary between species. In cases where there is sufficient information, i.e. where there is no data deficiency and best professional judgement is not required, the maximum possible risk score is 12.

Consensus of an expert team on the risk score of each section was reached using a hierarchical method where evidence from within the Netherlands was given priority over evidence derived from impacts occurring outside the Netherlands (paragraph 2.4.3). Consideration was given to the future application or non-application of management measures that will affect the invasiveness and impacts of this invasive plant in the Netherlands.

Table 2.1: Definitions of criteria for risk classifications per section used in the ecological risk assessment protocol (Branquart, 2007).

1. Dispersion potential or invasiveness risk	
Low	The species does not spread in the environment because of poor dispersal capacities and a low reproduction potential.
Medium	Except when assisted by man, the species doesn't colonise remote places. Natural dispersal rarely exceeds more than 1 km per year. However, the species can become locally invasive because of a strong reproduction potential.
High	The species is highly fecund, can easily disperse through active or passive means over distances > 1km / year and initiate new populations. Are to be considered here plant species that take advantage of anemochory, hydrochory and zoochory, insects like *Harmonia axyridis* or *Cemeraria ohridella* and all bird species.
2. Colonisation of high conservation habitats risk	
Low	Population of the non-native species are restricted to man-made habitats (low conservation value).
Medium	Populations of the non-native species are usually confined to habitats with a low or a medium conservation value and may occasionally colonise high conservation habitats.
High	The non-native species often colonises high conservation value habitats (i.e. most of the sites of a given habitat are likely to be readily colonised by the species when source populations are present in the vicinity) and makes therefore a potential threat for red-listed species.
3. Adverse impacts on native species risk	
Low	Data from invasion histories suggest that the negative impact on native populations is negligible.
Medium	The non-native is known to cause local changes (<80%) in population abundance, growth or distribution of one or several native species, especially amongst common and ruderal species. The effect is usually considered as reversible.
High	The development of the non-native species often causes local severe (>80%) population declines and the reduction of local species richness. At a regional scale, it can be considered as a factor for precipitating (rare) species decline. Those non-native species form long standing populations and their impacts on native biodiversity are considered as hardly reversible. Examples: strong interspecific competition in plant communities mediated by allelopathic chemicals, intra-guild predation leading to local extinction of native species, transmission of new lethal diseases to native species.
4. Alteration of ecosystem functions risk	
Low	The impact on ecosystem processes and structures is considered negligible.
Medium	The impact on ecosystem processes and structures is moderate and considered as easily reversible.
High	The impact on ecosystem processes and structures is strong and difficult to reverse. Examples: alterations of physico-chemical properties of water, facilitation of river bank erosion, prevention of natural regeneration of trees, destruction of river banks, reed beds and / or fish nursery areas and food web disruption.

Subsequently, the Belgian Forum Invasive Species (BFIS) list system for preventive and management actions was used to categorise the species of concern (Branquart, 2007). This list system was designed as a two dimensional ordination (Ecological impact * Invasion stage; Figure 2.1). The BFIS list system is based on guidelines proposed by the Convention on Biological Diversity (CBD decision VI/7) and the European Union strategy on invasive non-native species.

Ecological impact of the species was classified based on the total ISEIA risk score which is converted to a letter / list: low ecological risk score 4-8 (C), moderate ecological risk score 9-10 (B - watch list) and high ecological risk score 11-12 (A - black list). This letter is then combined with a number representing invasion stage: (0) absent, (1) isolated populations, (2) restricted range, and (3) widespread. A cross is used to indicate the risk classification of the assessed species within the BFIS system. A green cross indicates a low risk species that should not appear on any list within the BFIS system. A black cross indicates a species that should appear on either the watch, alert or black list of the BFIS system.

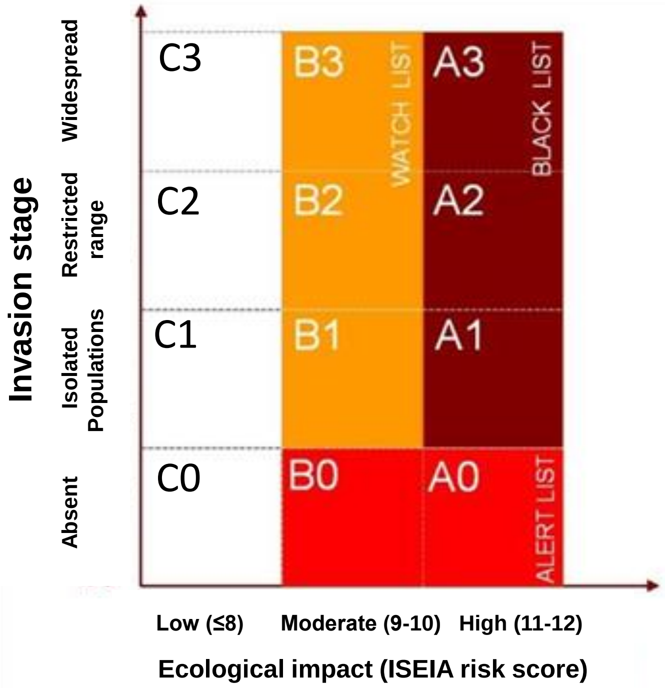

Figure 2.1: BFIS list system to identify species of most concern for preventive and mitigation action (Branquart, 2007).

2.4.3 Expert meetings on risk classification using the ISEIA protocol

Two workshops were arranged bringing together a team of nine experts. One from the Netherlands Food and Consumer Product Safety Authority; one from the Applied Plant Research centre (PPO); one from Wageningen UR Plant Breeding; one from the Plant Protection Service; two from the Dutch plant research and conservation organisation FLORON and three from the Radboud University Nijmegen.

During the first workshop, four inclusion criteria were agreed upon that species had to adhere to if they were to be selected for a definitive list of potential biomass species from the initial long list produced during the literature review. Definitive list species were then analysed using the ISEIA ecological risk assessment. The inclusion criteria, referred to as horizonscan criteria from here on, are as follows:

1) The species is a plant or algae species.
2) The species is considered as a biomass crop for the production of biodiesel, oil, ethanol and methane or for energy production (incineration).
3) The species is non-native and not established in the Netherlands.
4) The species has been recently or will potentially be introduced as a biomass crop to the Netherlands (for example, the species is cultivated in surrounding countries or in countries with a similar climate to the Netherlands).

For the purpose of this study the term ‘recently introduced’ was defined using the criteria of the Dutch species register i.e. that the species has been introduced by humans and has survived independently for less than 10 years (Naturalis, 2015). Following the application of the horizonscan criteria, an initial assessment of each species on the definitive list was carried out independently by two risk assessors based on the information presented in Chapter 5. Following the preliminary assessments, the entire project team reviewed the draft risk classifications and provided feedback which was used as input for a second workshop. During the second workshop, consensus was achieved on the risk classifications by elucidating and discussing differences in opinion and interpretation of key information.

3. Selection of relevant non-native biomass crops

A total of 28 species were identified during the literature review carried out by the NVWA. The majority of energy crops identified during the literature review and grown in the Netherlands are conventional agricultural crops that have been cultivated for a long period, such as oilseed rape, wheat, sugar beet and corn. A number of reports from different organisations have given examples of potential biomass crops for the Netherlands. AgriHolland has produced a biomass crops dossier incorporating some species which are new crops for the Netherlands (AgriHolland, 2015). The 'Innovatief Platteland' website contains a number of potential biomass crops for the Netherlands. Additionally, SenterNovem described a number of new promising bio-ethanol and biodiesel crops in a report produced in 2009 (SenterNovem, 2009). However, the report indicates that only sugar beet may be suitable for growth in the Dutch climate. Finally, PPO also published a report (Van der Mheen, 2011), that lists a number of new biomass crops for the Netherlands. Incidentally, in this report Jerusalem artichoke, sorghum, Sudan grass and miscanthus are seen as, more or less, known biomass crops. A further 20 species were identified following expert consultation and a further four were added from literature. These species were combined to form a preliminary list of potential biomass crop species for the Netherlands (Figure 3.1).

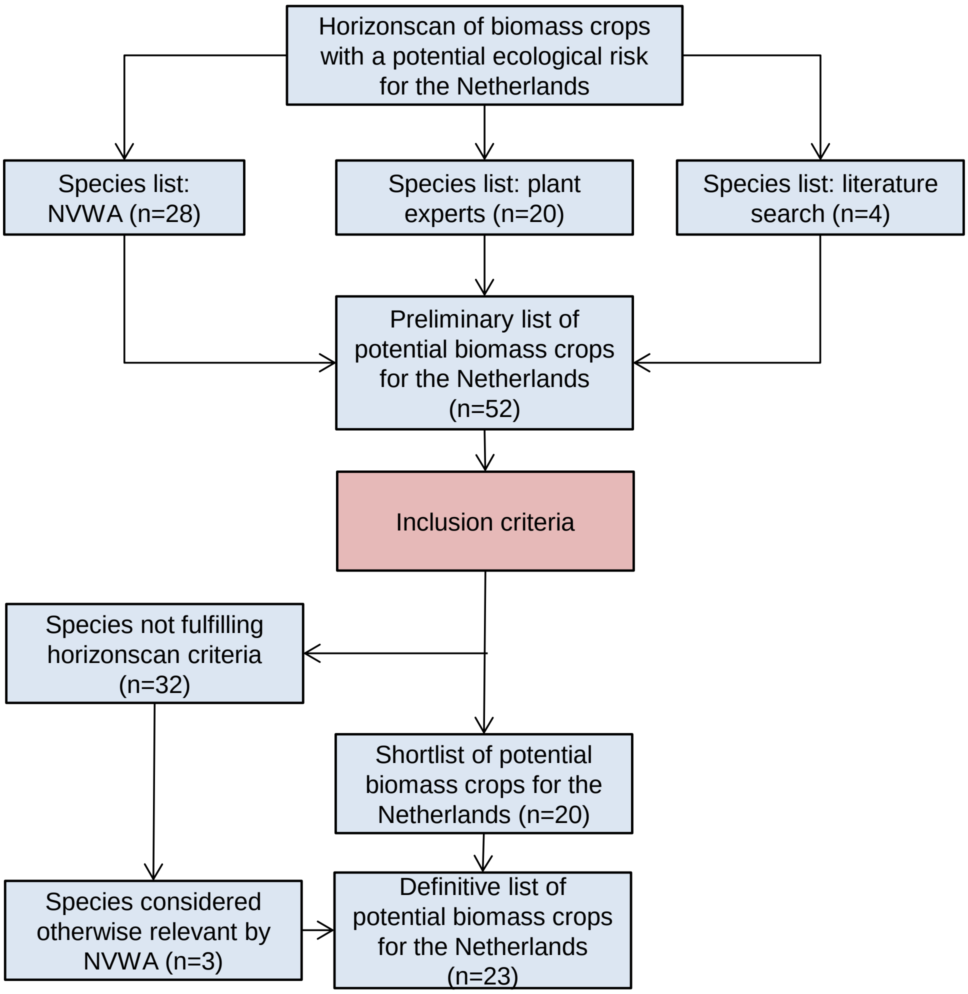

Figure 3.1: Decision process that led to the definitive list of potential biomass crops for the Netherlands.

Following application of the horizonscan criteria defined in section 2.4.3., 32 species were removed leaving an initial shortlist of 20 species. Of the 32 species removed, three were excluded because they are not primarily used as biomass crops for the production of biodiesel, oil, ethanol and methane; or for energy production (criteria 2); 26 were excluded because they are native to or non-native and established in the Netherlands (criteria 3); and three were excluded because they have not been recently introduced or probably will not be introduced in the future as a biomass crop to the Netherlands (criteria 4) (Table 3.1). The four alga species included in the preliminary list were excluded because they were found to be native in the Netherlands. *Acutodesmus obliquus* and *Scenedesmus dimorphus* have been categorised as native to the Netherlands by the National Association of Field Biology (Van Essen, 1974); *Chlamydomonas reinhardtii* was classified as native to the Netherlands by Dresscher (1976). *Phaeodactylum tricornutum* was added to the TWN list of Dutch native species in 2011 (Rijkswaterstaat, 2015).

Three species, miscanthus (*Miscanthus* x *giganteus*), jatropha (*Jatropha curcas*) and kenaf (*Hibiscus cannabinus*), were re-added to the list due to interest within the NVWA pertaining to these species. The definitive list of potential biomass crops for the Netherlands contains 23 species.

Table 3.1: Selection of potential biomass species for risk assessment. Green highlight: species adhering to the horizonscan criteria (definitive list) and re-added at the request of the NVWA, grey highlight: species not adhering to criteria and excluded from further analysis.

Latin name	Dutch / common name	Dutch distribution (FLORON Verspreidingsatlas)	Annual / perennial	1st, 2^{nd} or 3^{rd} generation energy crops	Biodiesel or bioethanol production	Methane (CH_4) production	Sugar / ethanol	Cellulose / ethanol	Solid / pellet fuel	Horizon-scan criteria
Acutodesmus obliquus		Not applicable	Annual	3rd						3
Andropogon gerardii	Baardgras, Big Bluestem	No records	Perennial	2nd				(X)	X	NA
Arundo donax	Giant reed, Pijlriet/Mammoetgras	Single record	Perennial	2nd				(X)	X	NA
Asclepias syriaca	Zijdeplant, Milkweed	Restricted range	Perennial	Classification required						NA
Beta vulgaris subsp. *vulgaris*	'Energie suikerbiet'	Widespread	Annual	1st		X	X			3
Brassica napus	Koolzaad	Widespread	Annual	1st	X					3
Camelina sativa	Huttentut / Deder	Widespread	Annual	1st	X					3
Cannabis sativa	Hennep, Hemp	Widespread	Annual	2nd				X		3
Carthamus tinctorius	Saffloer, Safflower	Widespread	Annual	1st	X					3
Chlamydomonas reinhardtii		Not applicable	Annual	3rd						3
Crambe hispanica subsp. *abyssinica*	Afrikaanse bolletjeskers	Isolated records	Annual	1st	X					2
Fallopia × bohemica	Boheemse duizendknoop	Widespread	Perennial	2nd				(X)	X	3
Fallopia sachalinensis	Sachalinse duizendknoop	Widespread	Perennial	2nd				(X)	X	3
Fallopia sachalinensis var. *igniscum* candy[b]	Igniscum Candy ®	No records	Perennial	2nd				(X)	X	NA
Glycine max	Soja	Isolated records	Annual	1st	X					2
Helianthus annuus	Zonnebloem	Widespread	Annual	1st	X					3
Helianthus tuberosus	Aardpeer	Widespread	Perennial	1st		X	X			3

[a] Species re-added to the definitive list at the request of the NVWA; [b] Distribution unclear, species, hybrids or varieties probably not always correctly distinguished due to lack of appropriate identification keys for taxa relatively new to the Dutch flora. Horizonscan criteria: [1] The species is not a plant or algae species; [2] The primary use of the species is not as a biomass crop for the production of biodiesel, oil, ethanol and methane; or for energy production (incineration); [3] The species is native to or non-native and established in the Netherlands; [4] The species has not been recently introduced or probably will not be introduced in the future as a biomass crop to the Netherlands; NA: not applicable.

Table 3.1 (cont.): Selection of potential biomass species for risk assessment. Green highlight: species adhering to the horizonscan criteria (definitive list) and re-added at the request of the NVWA, grey highlight: species not adhering to criteria and excluded from further analysis.

Latin name	Dutch / common name	Dutch distribution (FLORON Verspreidingsatlas)	Annual / perennial	1st, 2nd or 3rd generation energy crops	Biodiesel or bioethanol production	Methane (CH_4) production	Sugar / ethanol	Cellulose / ethanol	Solid / pellet fuel	Horizon-scan criteria
Hibiscus cannabinus[a]	Hennepbladstokroos, Kenaf	No records	Survives 1-2 years	1st		X				4
Jatropha curcas[a]	Jatropha	No records	Perennial	1st	X					4
Laminaria hyperborea		Not applicable	Annual	3rd						3
Linum usitatissimum	Olievlas	Widespread	Annual	1st	X					3
Miscanthus × giganteus[a,b]	Miscanthus, olifantsgras	No records	Perennial	2nd				(X)	X	4
Miscanthus floridulus[b]	Reuzenriet	No records	Perennial	2nd				(X)	X	NA
Miscanthus sacchariflorus[b]	Groot prachtriet	Single record	Perennial	2nd				(X)	X	NA
Miscanthus sinensis[b]	Klein prachtriet	Widespread	Perennial	2nd						NA
Panicum virgatum	Switchgrass (prariegras)	Isolated records	Perennial	2nd				X	X	NA
Phaeodactylum tricornutum		Not applicable	Annual	3rd						3
Phalaris arundinacea	Rietgras, Reed Canary Grass	Widespread	Perennial	2nd				X	X	3
Phyllostachys bissetii[b]	Bamboe	No records	Perennial	2nd				(X)	X	NA
Phyllostachys nigra[b]		No records		2nd				(X)	X	NA
Phyllostachys reticulata[b]		No records		2nd				(X)	X	NA
Populus tremula		Widespread	Perennial	2nd				(X)	X	3
Populus x canadensis	Populier, Poplar	Widespread	Perennial	2nd				(X)	X	3
Rumex acetosa		Widespread	Perennial	1st		X				3
Rumex patencia x *Rumex thianschanicus*		No records	Perennial	1st		X				NA

[a] Species re-added to the definitive list at the request of the NVWA; [b] Distribution unclear, species, hybrids or varieties probably not always correctly distinguished due to lack of appropriate identification keys for taxa relatively new to the Dutch flora. Horizonscan criteria: [1] The species is not a plant or algae species; [2] The primary use of the species is not as a biomass crop for the production of biodiesel, oil, ethanol and methane; or for energy production (incineration); [3] The species is native to or non-native and established in the Netherlands; [4] The species has not been recently introduced or probably will not be introduced in the future as a biomass crop to the Netherlands; NA: not applicable.

Table 3.1 (cont.): Selection of potential biomass species for risk assessment. Green highlight: species adhering to the horizonscan criteria (definitive list) and re-added at the request of the NVWA, grey highlight: species not adhering to criteria and excluded from further analysis.

Latin name	Dutch / common name	Dutch distribution (FLORON Verspreidingsatlas)	Annual / perennial	1st, 2nd or 3rd generation energy crops	Biodiesel or bioethanol production	Methane (CH$_4$) production	Sugar / ethanol	Cellulose / ethanol	Solid / pellet fuel	Horizon-scan criteria
Salix dasyclados 'Loden'		Widespread	Perennial	2nd				(X)	X	3
Salix schwerinii x *Salix viminalis*[b]		No records	Woody	2nd				(X)	X	NA
Salix viminalis 'Jorr'	(Zweedse) wilgenklonen	Widespread	Perennial	2nd				(X)	X	3
Scenedesmus dimorphus	Not applicable		Annual	3rd						3
Sida hermaphrodita	Sida	No records	Perennial	1st			X			NA
Silphium perfoliatum	Zonnekroon, Durchwachsende Silphie (Silphie; Doorgroeiende Silphie)	Isolated records	Perennial	1st		X				NA
Silybum marianum	Mariadistel	Widespread	Survives 1-2 years	1st						3
Sorghum bicolor var. *drummondii*[b]	Sudangras	No records	Annual	1st		X				NA
Sorghum bicolor[b]	Sorghumgierst (Suikergierst; suikersorghum)	Isolated records	Annual	1st		X				NA
Spartina cynosuroides		No records	Perennial	2nd				(X)	X	NA
Spartina pectinata	Slijkgras, Cordgrass	Isolated records	Perennial	2nd				(X)	X	NA
Symphytum peregrinum	Russische smeerwortel	Isolated records	Perennial	2nd				(X)	X	NA
Tagetes minuta		Isolated records		1st		X				2
Thlaspi arvense	Witte Krodde, pennycress	Widespread	Annual	1st	X					3
Ulva lactuca		Native		3rd						3
Zea mays	'Energiemais'	Widespread	Annual	1st		X				3
Zea mays	'Korrelmais'	Widespread	Annual	1st		X	X			3

[a] Species re-added to the definitive list at the request of the NVWA; [b] Distribution unclear, species, hybrids or varieties probably not always correctly distinguished due to lack of appropriate identification keys for taxa relatively new to the Dutch flora. Horizonscan criteria: [1] The species is not a plant or algae species; [2] The primary use of the species is not as a biomass crop for the production of biodiesel, oil, ethanol and methane; or for energy production (incineration); [3] The species is native to or non-native and established in the Netherlands; [4] The species has not been recently introduced or probably will not be introduced in the future as a biomass crop to the Netherlands; NA: not applicable.

4. Species descriptions and risk assessments

This chapter presents the data and information gathered during the literature review and risk assessments of the 23 species contained on the definitive list of potential biomass crops for the Netherlands that is defined in chapter three, ranked according to taxonomic family.

4.1 Polygonaceae

4.1.1 Giant knotweed (*Fallopia sachalinensis* var. *igniscum* candy)

- Species description

The giant knotweed cultivar *Fallopia sachalinensis* var. *igniscum* candy has been selected from the wild form of giant knotweed to create a new biomass crop (Veste et al., 2011; Mantovani et al., 2014). The plant can grow to a maximum of 3 to 4 m tall (Figure 4.1). The root system is deep and features rhizomes (Mantovani et al., 2014).

Figure 4.1: Giant knotweed (*Fallopia sachalinensis* var. *igniscum* candy) (Photo: Hans van der Mheen).

Species taxonomy

Table 4.1: Nomenclature and taxonomical status of giant knotweed (*Fallopia sachalinensis* var. *igniscum* candy).

Scientific name:
Fallopia sachalinensis (F.S. Petrop. ex Maxim.) R. Decr. var. *igniscum* candy

Synonyms:
Not applicable

Taxonomic tree (Catalogue of Life, 2015):
Kingdom: Plants
Phylum: Tracheophyta
Class: Spermatopsida
Order: Caryophyllales
Family: Polygonaceae
Genus: *Fallopia* Adans.
Species: *Fallopia sachalinensis* var. *igniscum* candy

Preferred Dutch name:
Sachalinse duizendknoop (Naturalis, 2015)

Preferred English name:
Giant knotweed

Other Dutch names:
Not applicable

Other English names:
Sakhalin Knotweed

Life cycle

No information on the life cycle of *F. sachalinensis* var. *igniscum* candy could be found during the literature study. However, the wild form of *F. sachalinensis* propagates both by seed and vegetatively in its European non-native range (CABI, 2015c).

Reproductive capacity

No information on the reproductive capacity of *F. sachalinensis* var. *igniscum* candy could be found during the literature study. However, it is characterized by a high biomass production (Pude & Franken, 2001; Veste et al., 2011; Koning et al., 2015).

- Habitat summary

F. sachalinensis var. *igniscum* candy is able to grow in a wide range of habitats (Adachi et al., 1996). The deep root system allows the plant to grow during drought periods in late spring and early summer that are not uncommon in eastern and northern Germany (Mantovani et al., 2014), and the climatic conditions in Central

Europe are highly suitable for the plant (Veste et al., 2011). *F. sachalinensis* var. *igniscum* candy is able to grow in soils poor in nutrients (Veste et al., 2011).

- Recorded distribution

Native range
The wild form of *F. sachalinensis* is native to the Russian island of Sakhalin, Japan and the Korean peninsula (Mantovani et al., 2014).

Cultivated range
F. sachalinensis var. *igniscum* was planted in 2014 on a one hectare field on a farm in Aalten, the Netherlands with the aim of producing biogas (De Gelderlander, 2014).

Non-native range
No information on the non-native range of *F. sachalinensis* var. *igniscum* candy could be found during the literature survey.

Distribution in the Netherlands
According to the Nationale Databank Flora en Fauna (2015), there are no current records *F. sachalinensis* var. *igniscum* candy in the Netherlands. However, the wild form of *F. sachalinensis* is a widespread non-native species in the Netherlands (NDFF, 2015b).

Colonisation of high conservation value habitats
According to the Nationale Databank Flora en Fauna (2015b), there are no current records of *F. sachalinensis* var. *igniscum* candy in the Netherlands. However, the wild form, *Fallopia sachalinensis*, has been recorded in 34 kilometre squares of Natura 2000 areas in the Netherlands.

- Invasion process

Introduction outside cultivated land
No information on the introduction of *F. sachalinensis* var. *igniscum* candy outside cultivated land could be found during a search of available literature.

Establishment
No information on the establishment of *F. sachalinensis* var. *igniscum* candy outside cultivated land could be found during a search of available literature.

Spread
No information on the spread of *F. sachalinensis* var. *igniscum* candy outside cultivated land could be found during a search of available literature.

- Environmental impacts summary

The wild form of *F. sachalinensis* has been assessed as posing a high ecological risk in Belgium (Branquart et al., 2011). However, *F. sachalinensis* var. *igniscum* candy has been bred to exhibit a lesser invasive potential than the wild type of *F. sachalinensis* (Lebzien et al., 2012). Its features include that it does not form sprouts or seeds, which makes it less invasive than its parents. However, the plant is characterized by a high annual biomass production (Lebzien et al., 2012; Vetter et al., 2009), greater than the parent species, and the plants rhizomes have been observed to spread in the Netherlands (H. van der Mheen, personal observation). The wild form, *F. sachalinensis*, is widely naturalized in most of temperate Europe, and may form very tall, dense stands that compete with native plant species for light, space, nutrients and water. Large populations can rapidly change ecosystem structure and species composition, especially in riparian habitats (GB non-native species secretariat, 2015a).

Effects on environmental targets or native species
No information on the effects of competition, parasitism, pathogens, parasites or interbreeding of *F. sachalinensis* var. *igniscum* candy on environmental targets or native species could be found during a search of available literature. However, samples of *F. sachalinensis* var. *igniscum* candy grown in the Netherlands suggest that this variety is morphologically similar to *Fallopia* x *bohemica* (*F. sachalinensis* x *F. japonica*). The samples appeared to feature stamens. Therefore, *F. sachalinensis* var. *igniscum* candy may be able to pollinate female clones of Japanese knotweed (*Fallopia japonica*) and thus contribute to the spread of *F. japonica* in the Netherlands (Duistermaat et al., 2012).

Effects on ecosystem function targets
No information on the effects of *F. sachalinensis* var. *igniscum* candy on ecosystem function targets could be found during a search of available literature. However, the plant is characterized by a high annual biomass production (Mantovani et al., 2014).

Effects on plant targets in cultivation systems
No information on the effects of *F. sachalinensis* var. *igniscum* candy on plant targets in cultivation systems could be found during a search of available literature.

Effects on animal health and production targets
No information on the effects of *F. sachalinensis* var. *igniscum* candy on animal health and production targets could be found during a search of available literature.

Human targets
No information on the effects of *F. sachalinensis* var. *igniscum* candy on human targets could be found during a search of available literature.

Effects on other targets

No information on the effects of *F. sachalinensis* var. *igniscum* candy on infrastructure could be found during a search of available literature.

- Ecological risk assessment with the ISEIA protocol

The expert team allocated *F. sachalinensis* var. *igniscum* a 'high' ecological risk classification to the categories dispersion potential and invasiveness and colonization of high value conservation habitats, and a ‘likely’ risk classification to the categories adverse impacts on native species and alteration of ecosystem functions (Table 4.2). The total ecological risk score for the species is 10 out of a maximum of 10. Therefore, *F. sachalinensis* var. *igniscum* is classified in the B list of the BFIS list system. The maximum risk score takes into account the limitation on maximum risk score per category that is imposed by the ISEIA protocol if data deficiency occurs or the application of best professional judgement is required (See section 2.4.2). The maximum risk score will, therefore, vary between species. In cases where there is sufficient information, i.e. where there is no data deficiency and best professional judgement is not required, the maximum possible risk score is 12. The rationale for the allocated scores is given in the following paragraphs.

It should be noted that the risk scores for the categories adverse impacts on native species and alteration of ecosystem functions are based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

Table 4.2: Consensus scores for potential risks of giant knotweed (*Fallopia sachalinensis* var. *igniscum*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	High	3
Colonization of high value conservation habitats	High*	3
Adverse impacts on native species	Likely	2
Alteration of ecosystem functions	Likely	2
Ecological risk score		**10**

* Quantitative analysis was focused on Natura 2000 areas may indicate a lower score; however, this species may occur in other areas with high conservation value.

Dispersion potential or invasiveness

Classification: **High risk**. Wild forms of *F. sachalinensis* propagate both by seed and vegetatively in their European non-native range and have been assessed as posing a high ecological risk in Belgium (Branquart et al., 2011). *F. sachalinensis* var. *igniscum*’s features include that it does not form sprouts or seeds, which makes it less invasive than its parents. However, we don’t expect that this will reduce vegetative propagation. *F. sachalinensis* var. *igniscum* is characterized by a high annual biomass production (Lebzien et al., 2012; Vetter et al., 2009), greater than that of the parent species, and the plants rhizomes have been observed to spread in the Netherlands (H. van der Mheen, personal observation). To conclude, *F. sachalinensis* var. *igniscum* is highly fecund, can easily disperse through active or passive means over distances > 1 km/year and initiate new populations.

Colonization of high value conservation habitats

Classification: **High risk**. At the time of writing, no records of *F. sachalinensis* var. *igniscum* exist for the Netherlands. However, *F. sachalinensis* var. *igniscum* is able to grow in a wide range of habitats (Adachi et al., 1996). Moreover, the wild form of *F. sachalinensis* has been recorded in high conservation value habitats in the Netherlands. Considering the ability of the wild form of *F. sachalinensis* to colonize high conservation value habitats, the risk of *F. sachalinensis* var. *igniscum* to colonise high conservation value habitats is judged to be high.

Adverse impacts on native species

Classification: **Likely**. Strong competition by *F. sachalinensis* var. *igniscum* for resources is likely according to recorded effects of its wild form. Samples of *F. sachalinensis* var. *igniscum* candy grown in the Netherlands suggested that this variety is morphologically similar to *Fallopia* x *bohemica* (*F. sachalinensis* x *F. japonica*). The samples appeared to feature stamens. Japanese knotweed (*Fallopia japonica*) is a non-native species that is highly invasive in the Netherlands and reproduces mainly through vegetative cloning. *F. sachalinensis* var. *igniscum* candy may be able to pollinate female clones of *F. japonica* and thus contribute to the spread of *F. japonica* in the Netherlands (Duistermaat et al., 2012).

Alteration of ecosystem functions

Classification: **Likely**. *F. sachalinensis* var. *igniscum* can grow to a maximum of three to four metres tall. The root system is deep and features rhizomes (Mantovani et al., 2014). The species develops dense stands and features a high biomass production (Pude & Franken, 2001; Veste et al., 2011; Koning et al., 2015). Strong alteration to ecosystem functions is likely according to the recorded effects of its wild form.

Risk classification according to the BFIS list system

The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.2) in combination with the current recorded distribution in the Netherlands. The species classification for *F. sachalinensis* var. *igniscum* is B0 (Figure 4.2). This characterises a non-native species that is absent from the area under assessment, poses a moderate ecological risk and is placed on the alert list of the BFIS list system.

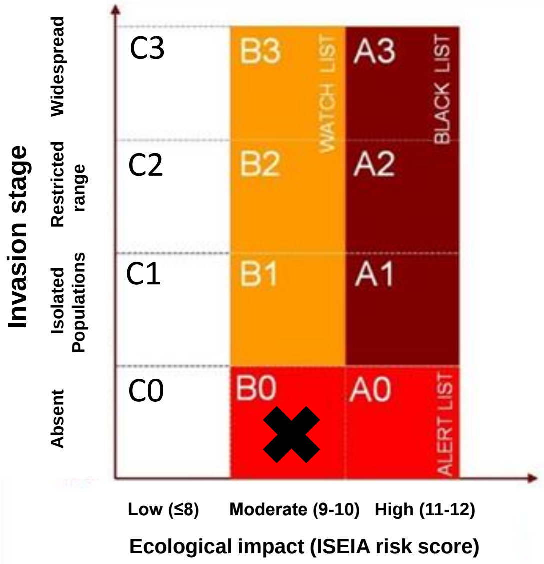

Figure 4.2: Risk classification of giant knotweed (*Fallopia sachalinensis* var. *igniscum*) according to the BFIS list system.

- Other risk assessments and classifications

No risk assessments or classifications of *F. sachalinensis* var. *igniscum* candy could be found during a search of available literature.

4.1.2 *Rumex patientia* x *thianschanicus*

- Species description

Rumex tianschanicus x *Rumex patientia* is a cross between female English spinach (*Rumex patientia* L.) and male Tien Shan sorrel (*Rumex tianschanicus* A. Los.) (Slesak et al., 2014).

Figure 4.3: *Rumex patientia* x *thianschanicus* in vivo. (Photo: Halina Ślesak).

Species taxonomy

Table 4.3: Nomenclature and taxonomical status of *Rumex patientia* x *thianschanicus*.

Scientific name:
Rumex patientia L. x *Rumex thianschanicus* Losinsk

Synonyms:
Unknown

Taxonomic tree (Naturalis, 2015):
Kingdom: Plants
Phylum: Tracheophyta
Class: Spermatopsida
Order: Caryophyllales
Family: Polygonaceae
Genus: *Rumex*
Species: *Rumex patientia* x *thianschanicus*

Preferred Dutch name:
Unknown

Preferred English name:
Unknown

Other Dutch names:
Unknown

Other English names:
Unknown

Life cycle
Both parent species, *R. thianschanicus* and *R. patientia*, feature bisexual flowers that bloom from May to June (Encyclopaedia of Life, 2015).

Reproductive capacity
No information could be found regarding the reproductive capacity of *R. patientia* x *thianschanicus* during the literature survey.

- Habitat summary

No information could be found about the habitat requirements of the hybrid *R. patientia* x *thianschanicus.* However, limited information about the parent species is available. *R. thianschanicus* establishes in moist valleys, at forest margins and on mountain slopes, ranging from 1100-1900 m. Patience doc (*R. patientia*) may be found at roadsides, in old fields, gardens and disturbed meadows, along ditches, water sides and moist valleys, from 0 to 4000 m (Encyclopaedia of Life, 2015).

- Recorded distribution

Native range
No information on the native range of *R. patientia* x *thianschanicus* could be found during the literature survey. However, at least one of the parent species, *R. patientia*, is native to Europe and temperate Asia (GB Non-native Species Secretariat, 2015b).

Cultivated range
No information on the cultivated range of *R. patientia* x *thianschanicus* could be found during the literature survey.

Non-native range
No information on the non-native range of *R. patientia* x *thianschanicus* could be found during the literature survey.

Distribution in the Netherlands
According to the Nationale Databank Flora en Fauna (2015), there are no current records *R. patientia* x *thianschanicus* in the Netherlands. The parent species *R. thianschanicus* has not been recorded, but the parent species, *R. patientia* has been recorded as an incidental import in the Netherlands (NDFF, 2015d).

Colonisation of high conservation value habitats
According to the Nationale Databank Flora en Fauna (NDFF), there are no current records of *R. patientia* x *thianschanicus* in the Netherlands.

- Invasion process

  Introduction outside cultivated land
  No information on the introduction of *R. patientia* x *thianschanicus* outside cultivated land could be found during a search of available literature.

  Establishment
  No information on the establishment of *R. patientia* x *thianschanicus* outside cultivated land could be found during a search of available literature.

  Spread
  No information on the spread of *R. patientia* x *thianschanicus* outside cultivated land could be found during a search of available literature.

- Environmental impacts summary

  Effects on environmental targets or native species
  No information on the effects of competition, parasitism, pathogens, parasites or interbreeding of *R. patientia* x *thianschanicus* on environmental targets or native species could be found during a search of available literature.

  Effects on ecosystem function targets
  No information on the effects of *R. patientia* x *thianschanicus* on ecosystem function targets could be found during a search of available literature.

  Effects on plant targets in cultivation systems
  No information on the effects of *R. patientia* x *thianschanicus* on plant targets in cultivation systems could be found during a search of available literature.

  Effects on animal health and production targets
  No information on the effects of *R. patientia* x *thianschanicus* on animal health and production targets could be found during a search of available literature.

  Human targets
  No information on the effects of *R. patientia* x *thianschanicus* on human targets could be found during a search of available literature.

  Effects on other targets
  No information on the effects of *R. patientia* x *thianschanicus* on infrastructure could be found during a search of available literature.

- Ecological risk assessment with the ISEIA protocol

The expert team allocated *R. patientia* x *thianschanicus* a 'data deficient (DD)' ecological risk classification to all categories (Table 4.4). The total ecological risk score for the species is 4 out of a maximum of 4. The maximum risk score takes into account the limitation on maximum risk score per category that is imposed by the ISEIA protocol if data deficiency occurs or the application of best professional judgement is required (See section 2.4.2). The maximum risk score will, therefore, vary between species. In cases where there is sufficient information, i.e. where there is no data deficiency and best professional judgement is not required, the maximum possible risk score is 12.

R. patientia x *thianschanicus* is not classified in the BFIS list system due to the lack of information and data that could be used to properly risk assess this hybrid. Periodical reviews of new literature and updates of the risk scores for this hybrid are recommended.

Table 4.4: Consensus scores for potential risks of *Rumex patientia* x *thianschanicus* in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	DD	1[b]
Colonization of high value conservation habitats[a]	DD	1[b]
Adverse impacts on native species	DD	1[b]
Alteration of ecosystem functions	DD	1[b]
Ecological risk score		4

[a] Quantitative analysis was focused on Natura 2000 areas may indicate a lower score; however, this species may also occur in other areas with high conservation value; [b] Deficient data (DD) scores 1 as this is the minimum that can be awarded per risk category.

Dispersion potential or invasiveness

Classification: **Deficient data**. There is insufficient information to allow an assessment of the potential dispersion or invasiveness of *R. patientia* x *thianschanicus* in the Netherlands.

Colonization of high value conservation habitats

Classification: **Deficient data**. There is insufficient information to allow an assessment of the potential colonisation by *R. patientia* x *thianschanicus* of high value conservation habitats in the Netherlands.

Adverse impacts on native species

Classification: **Deficient data**. There is insufficient information to allow an assessment of the potential impact of *R. patientia* x *thianschanicus* on native species in the Netherlands.

Alteration of ecosystem functions

Classification: **Deficient data**. There is insufficient information to allow an assessment of the potential impact of *R. patientia* x *thianschanicus* on ecosystem functions in the Netherlands.

Risk classification according to the BFIS list system

The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.58) in combination with the current recorded distribution in the Netherlands. *R. patientia* x *thianschanicus* remains unclassified in the BFIS list system due to the lack of information and data that could be used to risk assess this hybrid.

- Other risk assessments and classifications

No risk assessments or classifications of *R. patientia* x *thianschanicus* could be found during a search of available literature.

4.2 Malvaceae

4.2.1 Kenaf (*Hibiscus cannabinus*)

- Species description

Kenaf (*Hibiscus cannabinus*) is an erect, herbaceous, single stemmed plant that can reach one to five metres in height (Figure 4.4). The flowers are red or yellow with a bright red centre (Ecocrop, 2015b). *H. cannabinus* is a C3 photosynthetic plant (Khalatbari et al., 2015). It is comprised of five basic varieties and eight agricultural types (Dempsey, 1975). The varieties are named simplex, viridis, rubber, purpureus and vulgaris. The most economically attractive varieties are viridis and vulgaris because of their high-fibre-yielding and disease resistant characteristics. Crosses with the varieties simplex and purpureus produce hybrids that are late maturing, and in some cases insensitive to photoperiod with excellent hybrid vigour (Coetzee, 2004). The extended vegetative period of the late maturing types allows the plants to attain a height of 3.5 to 4.5 metres with a generally high biomass yield. Seed yields are not high when cultivars are grown over a long vegetative period, however, they produce higher seed yields when planted late (Dempsey, 1975).

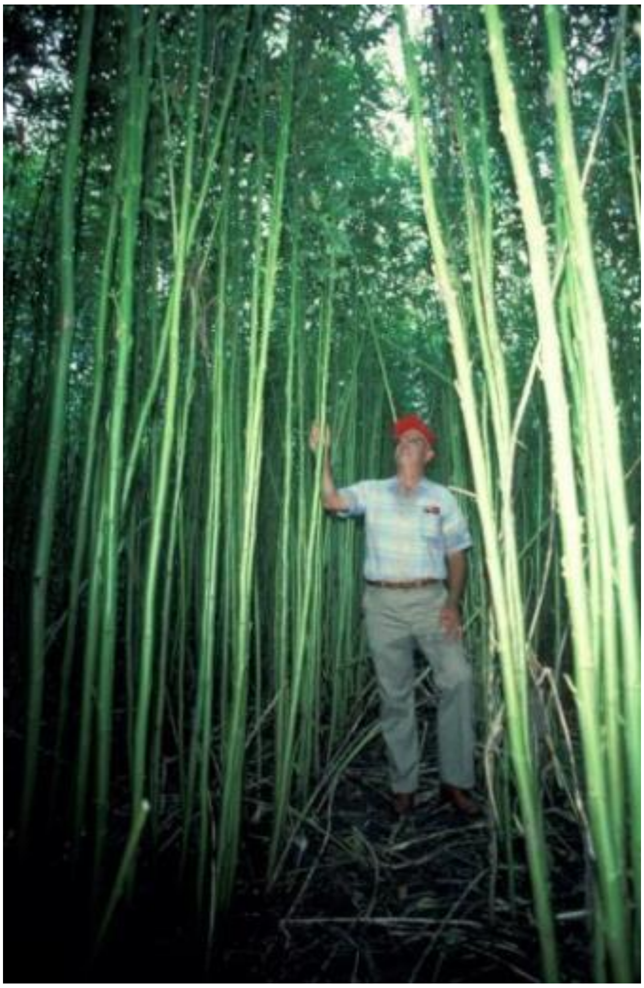

Figure 4.4: Kenaf (*Hibiscus cannabinus*) (Source: Wikimedia Commons).

Species taxonomy

Table 4.5: Nomenclature and taxonomical status of kenaf (*Hibiscus cannabinus*).

Scientific name:
Hibiscus cannabinus L. (1759)

Synonyms:
Abelmoschus verrucosus (Guill. & Perr.) Walp.
Furcaria cavanillesii Kostel
Hibiscus unidens Lindl.
Hibiscus verrucosus Guill. & Perr.
Ketmia glandulosa Moench

Taxonomic tree (Catalogue of Life, 2015):
Kingdom: Plantae
Phylum: Tracheophyta
Class: Magnoliopsida
Order: Malvales
Family: Malvaceae
Genus: *Hibiscus*
Species: *Hibiscus cannabinus*

Preferred Dutch name:
Hennepbladstokroos (unofficial)

Preferred English name:
Kenaf

Other Dutch names:
Not applicable

Other English names:
Bimli, Bimlipatum jute, Deccan hemp

Life cycle
No information on the life cycle of *H. cannabinus* could be found during a search of available literature.

Reproductive capacity
In outdoor sowing experiments in Southern Italy, *H. cannabinus* produced a maximum seed yield of 3.5 t/ha when seeds were sown in late May (Patanè & Sortino, 2010). However, a maximum seed yield of 400 kg/ha annually has also been reported (Ecocrop, 2015b).

- Habitat summary

H. cannabinus is able to grow in the following climates: tropical wet & dry, tropical wet, steppe or semiarid, subtropical humid, subtropical dry summer, subtropical dry winter, temperate oceanic, temperate continental, temperate with humid winters, temperate with dry winters (Ecocrop, 2015b).

The physiological conditions tolerated by *H. cannabinus* are listed in table 4.6. Its temperature requirement ranges from 15 to 28 ^{o}C (optimal) and 10 to 35 ^{o}C (absolute limit) (Ecocrop, 2015b). Temperatures required for germination are reported to range from 8.0 to 9.7 ^{o}C (Carberry & Abrecht, 1990; Angelini et al., 1998). Germination and seed production experiments carried out in Italy indicated that certain cultivars of *H. cannabinus* are able to germinate at a soil temperature of 8 ^{o}C. However, it was concluded that the temperate climate of central Italy appeared inadequate for seed production due to rapid seed deterioration and high susceptibility to fungal pathogens (Angelini et al., 1998). *H. cannabinus* prefers high light intensities, and is able to grow under cloudy conditions at latitudes of 35^{o} to 40^{o} and at a maximum altitude of >1250 m (Ecocrop, 2015b). Rainfall for optimal *H. cannabinus* growth is reported to be between 600 and 2000 mm annually. *H. cannabinus* can tolerate a minimum of 450 mm and maximum of 3000 mm annual rainfall (Ecocrop, 2015b). It is adapted to a relative air humidity range of 68-82% (Ecocrop, 2015b).

H. cannabinus grows best in well drained soils but tolerates dry to moderately dry soils of varying texture and moderate to high fertility (Ecocrop, 2015b). Optimal soil depth for *H. cannabinus* lies above 150 cm and the plant tolerates soil depths of between 50 and 150 cm (Ecocrop, 2015b). *H. cannabinus* is reported to be able to tolerate pHs ranging from 4.3 to 8.2 and grows optimally in soils ranging from pH 6.0 to 7.5 (Ecocrop, 2015b). *H. cannabinus* is able to tolerate soil salinities to a maximum of 4 dS/m (Ecocrop, 2015b).

Table 4.6: Physiological conditions tolerated by kenaf (*Hibiscus cannabinus*).

Parameter	Optimal	Absolute limit	References
Temperature (^{o}C)	15-28	10-35	Ecocrop (2015b)
Temperature germination (^{o}C)	-	8.0-9.7	Carberry & Abrecht (1990); Angelini et al. (1998)
Light intensity	Very bright	Very bright – cloudy skies	Ecocrop (2015b)
Altitude (m)	-	>1250	Ecocrop (2015b)
Rainfall (annual - mm)	600-2000	450-3000	Ecocrop (2015b)
Relative humidity (%)		68-82	Ecocrop (2015b)
Latitude (Degrees)	-	35-40	Ecocrop (2015b)
Soil pH	6.0-7.5	4.3-8.2	Ecocrop (2015b)
Soil depth (cm)	>150	50-150	Ecocrop (2015b)
Soil texture	Medium, organic	Heavy, medium, light	Ecocrop (2015b)
Soil fertility	High	Moderate	Ecocrop (2015b)
Soil salinity (dS/m)	<4	4	Ecocrop (2015b)
Soil drainage	well (dry spells)	well (dry spells), excessive (dry/moderately dry)	Ecocrop (2015b)

H. cannabinus responds to nitrogen enrichment during cultivation. In Greek field experiments carried out by Alexopoulou et al. (2007), both growth and yield increased when the nitrogen fertilization increased (N 0-120 kg/ha). However, this increase was statistically significant in only a few cases (Alexopoulou et al., 2007). In further experimentation, *H. cannabinus* growth was stimulated by nitrogen enrichment to a greater degree than either phosphorus or potassium enrichment (Sinha & Saha, 1980).

Atmospheric CO_2 concentration is currently 400 μmol mol^{-1} and by the end of 2050 this concentration is expected to increase to 1000 μmol mol^{-1} CO_2 (Taylor & Lloyd, 1992). In greenhouse experiments carried out in Malaysia, a doubling of ambient CO_2 concentration led to higher biomass production in *H. cannabinus* (Khalatbari et al., 2015) suggesting that future atmospheric changes will favour *H. cannabinus* growth.

- Recorded distribution

Native range

H. cannabinus is most probably native of Africa (Ecocrop, 2015b). Its native distribution extends to Senegal, Gambia, Mali, Guinea, Sierra Leone, Burkina Faso, Ivory Coast?, Ghana, Togo, Benin, Nigeria, Niger, Chad, Sudan, Cameroon, Central African Republic, Sudan, Ethiopia, Eritrea, Somalia, Congo, D.R. Congo (Zaire), Rwanda, Burundi, Kenya, Tanzania, Angola, Malawi, Mozambique, Zambia, Zimbabwe, Madagascar, South Africa (Transvaal, KwaZulu-Natal), Namibia, Swaziland and Botswana (Catalogue of Life, 2015) (Figure 4.5).

Cultivated range

No information on the *H. cannabinus* commercially cultivated range of could be found during a search of available literature. However, field trials have been carried out in Greece (Alexopoulou et al., 2007).

Non-native range

H. cannabinus is non-native to the tropics, Crete, Hungary, Russia, tropical Asia, Caucasus / Trans Caucasus, Russian Far East, Central Asia, Costa Rica, Australia (Queensland), Taiwan, Java, Jamaica, Peru, Lesser Antilles (St. Barts, St. Kitts, Guadeloupe, Martinique), Haiti, Dominican Republic, Cuba, Puerto Rico, Venezuela, New Caledonia, China (Guangdong, Hebei, Heilongjiang, Jiangsu, Liaoning, Yunnan, Zhejiang), India, Niue, Iran (North Iran: Mountains), Iraq (north-west Iraq, south-east Iraq: Mesopotamia), Sinai peninsula (Central Sinai), Yemen (Tihama, west Yemen), Afghanistan, Pakistan, Cape Verde Islands (Ilha de Maio, Ilha de Sao Tiago), Myanmar [Burma], Laos, India, Sri Lanka, Nepal, Vietnam and the USA (Florida) (Catalogue of Life, 2015) (Figure 4.5).

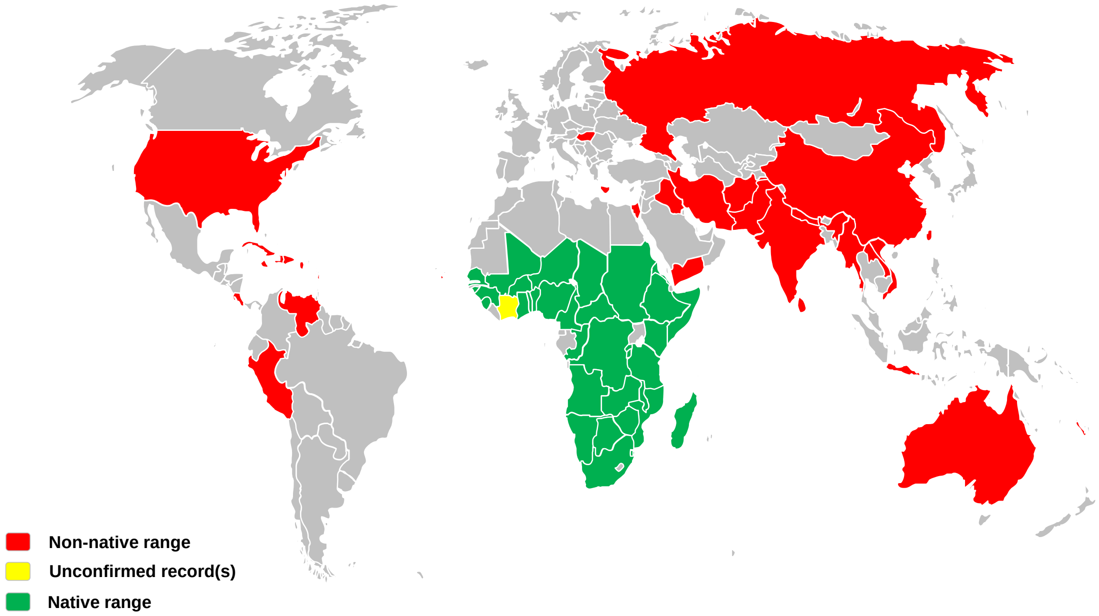

Figure 4.5: Current global recorded distribution of kenaf (*Hibiscus cannabinus*) (Source: Catalogue of Life, 2015).

Distribution in the Netherlands
According to the Nationale Databank Flora en Fauna (NDFF, 2015f), there are no current records of *H. cannabinus* in the Netherlands.

Colonisation of high conservation value habitats
According to the Nationale Databank Flora en Fauna (NDFF, 2015f), there are no current records of *H. cannabinus* in the Netherlands.

- Invasion process

Introduction outside cultivated land
No information on the introduction of *H. cannabinus* outside cultivated land could be found during a search of available literature.

Establishment
No information on the establishment of *H. cannabinus* could be found during a search of available literature.

Spread
No information on the spread of *H. cannabinus* could be found during a search of available literature.

- Environmental impacts summary

Effects on environmental targets or native species
No information on the effects of *H. cannabinus* on environmental targets or native species could be found during a search of available literature.

Effects on ecosystem function targets
No information on the effects of *H. cannabinus* on ecosystem function targets in cultivation systems could be found during a search of available literature.

Effects on plant targets in cultivation systems
No information on the effects of *H. cannabinus* on plant targets in cultivation systems could be found during a search of available literature.

Effects on animal health and production targets
No information on the effects of *H. cannabinus* on animal health and production targets could be found during a search of available literature.

Human targets
No information on the effects of *H. cannabinus* on human targets could be found during a search of available literature.

Effects on other targets
No information on the effects of *H. cannabinus* on infrastructure could be found during a search of available literature.

- Ecological risk assessment with the ISEIA protocol

The expert team allocated *H. cannabinus* a 'low' ecological risk classification to the category dispersion potential and invasiveness, and an ‘unlikely’ risk classification to the categories adverse impacts on native species, alteration of ecosystem functions and colonization of high value conservation habitats (Table 4.7). The total ecological risk score for the species is 4 out of a maximum of 9. Therefore, *H. cannabinus* is classified in the C list of the BFIS list system. The maximum risk score takes into account the limitation on maximum risk score per category that is imposed by the ISEIA protocol if data deficiency occurs or the application of best professional judgement is required (See section 2.4.2). The maximum risk score will, therefore, vary between species. In cases where there is sufficient information, i.e. where there is no data deficiency and best professional judgement is not required, the maximum possible risk score is 12. The rationale for the allocated scores is given in the following paragraphs.

It should be noted that the risk scores for adverse impacts on native species, alteration of ecosystem functions and colonization of high value conservation habitats are based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

Table 4.7: Consensus scores for potential risks of kenaf (*Hibiscus cannabinus*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	Low	1
Colonization of high value conservation habitats	Unlikely*	1
Adverse impacts on native species	Unlikely	1
Alteration of ecosystem functions	Unlikely	1
Ecological risk score		**4**

* Quantitative analysis was focused on Natura 2000 areas may indicate a lower score; however, species may occur in other areas with high conservation value.

Dispersion potential or invasiveness

Classification: **Low risk**. There is either no match between the temperature requirements of *H. cannabinus* and the climate in the Netherlands or a suboptimal match exists. *H. cannabinus* occurs in climates defined as tropical wet & dry, tropical wet, steppe or semiarid, subtropical humid, subtropical dry summer, subtropical dry winter, temperate oceanic, temperate continental, temperate with humid winters and temperate with dry winters (Ecocrop, 2015b). The species requires relatively high temperature for (optimal) growth. For example, the temperate climate of central Italy appeared inadequate for seed production due to rapid seed deterioration and high susceptibility to fungal pathogens (Angelini et al., 1998). It is therefore likely that *H. cannabinus* will display a low dispersal capacity and invasiveness potential in the Netherlands.

Colonization of high value conservation habitats

Classification: **Unlikely**. There are no current records of *H. cannabinus* in the Netherlands. It is unlikely due to a poor climate match and poor dispersion potential that establishment in areas of high value conservation habitats will occur.

Adverse impacts on native species

Classification: **Unlikely**. It is unlikely that adverse impacts on native species in the Netherlands will occur due to a poor climate match and poor dispersion potential.

Alteration of ecosystem functions

Classification: **Unlikely**. *H. cannabinus* is an erect, herbaceous, single stemmed plant that can reach 1 to 5 m in height. The cultivated annual yield for *H. cannabinus* is from 0.4 to 3.5 t/ha (Patanèa & Sortino, 2010). It is unlikely that alterations to ecosystem functions will occur in the Netherlands due to a poor climate match and poor dispersion potential.

Risk classification according to the BFIS list system

The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.7) in combination with the current recorded distribution in the Netherlands. The species classification for *H. cannabinus* is C0 (Figure 4.6). This characterises a non-native species that is absent from the area under assessment, poses a low ecological risk and is not classified in the BFIS list system.

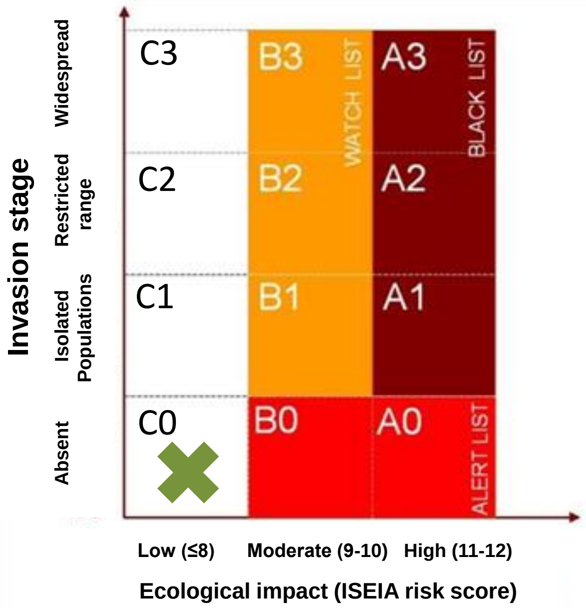

Figure 4.6: Risk classification of kenaf (*Hibiscus cannabinus*) according to the BFIS list system.

- Other risk assessments and classifications

H. cannabinus was rejected for introduction in Italy following assessment using a modified weed risk assessment method and further screening (Crosti et al., 2010) (Table 4.8). However, the criteria for rejection were not discussed by the authors.

Table 4.8: Overview of risk classifications previously performed for kenaf (*Hibiscus cannabinus*).

	Italy
Scope	Risk assessment method
Method	Modified Australian Weed Risk Assessment System (AWRAS).
Year	2009
Risk classification	**Initial score 5 (evaluate), rejected after second screening**
Source	Crosti et al. (2010)

4.2.2 Virginia mallow (*Sida hermaphrodita*)

- Species description

The Virginia mallow (*Sida hermaphrodita*) is a polycarpic perennial herb (Spooner et al., 1985; Franzaring et al., 2014). The plant is very distinctive within the genus. The branching stem of *S. hermaphrodita* is 1 to 4 m tall, and up to 3 cm in diameter (Figure 4.7). The three to five lobed leaves are irregularly serrate, deeply palmate, 10 to 20 cm long and borne on petioles. The lobes are elongated, the middle one the longest. The flowers are borne in terminal clusters and have five white petals, each circa one cm long (Encyclopaedia of Life, 2015). The schizocarp fruit splits into segments when mature (Britton & Brown, 1913; Oleszek et al., 2013; New England Wild Flower Society, 2015; Encyclopaedia of Life, 2015).

Figure 4.7: Virginia mallow (*Sida hermaphrodita*) in flower (Source: Pipi69e, 2009; Wikimedia Commons).

Species taxonomy

Table 4.9: Nomenclature and taxonomical status of Virginia mallow (*Sida hermaphrodita*).

Scientific name:
Sida hermaphrodita (L.) Rusby (1894)

Synonyms:
Napaea hermaphrodita L.

Taxonomic tree (Catalogue of Life, 2015):
Kingdom: Plantae
Phylum: Tracheophyta
Class: Magnoliopsida
Order: Malvales
Family: Malvaceae
Genus: *Sida*
Species: *Sida hermaphrodita*

Preferred Dutch name:
Virginische malva (unofficial name)

Preferred English name:
Not applicable

Other Dutch names:
Not applicable

Other English names:
Virginia fanpetals, Virginia mallow, river mallow

Life cycle

In its native range, *S. hermaphrodita* shoots appear in April and early May from the ends of multiple rhizomes and from buds that occur at the base of stems remaining from the previous year. It is possible that many large populations are clonal. Flowers emerge in early August and flowering continues until the advent of hard frosts. The seeds disperse throughout the winter and germinate in early spring (Spooner et al., 1985).

Reproductive capacity

Large examples of *S. hermaphrodita* can produce several thousand mostly viable seeds (Spooner et al., 1985). Well-watered plants grown in gardens can reproduce in the year when they germinate (Spooner et al., 1985).

- Habitat summary

S. hermaphrodita prefers habitats in moist, sunny prairies and naturally disturbed floodplains or terraces to partly shaded riverine habitats and at the edges of woods near streams and rivers (Spooner et al., 1985; Franzaring et al., 2014). It can also be seen growing in sunny, moist, disturbed situations along roadsides and railways in its native North American range or on soils (Spooner et al., 1985). According to Spooner et al. (1985), *S. hermaphrodita* occurs on silt loam, sandy clay loam, and clay loam substrates with a medium to high organic content, and tolerates soil pHs ranging from 5.4 to 7.5 (Table 4.10).

Table 4.10: Physiological conditions tolerated by Virginia mallow (*Sida hermaphrodita*).

Parameter	Data origin	Occurrence	References
pH	USA	5.4-7.5	Spooner et al. (1985)
Substrate	USA	silt loam, sandy clay loam, and clay loam	Spooner et al. (1985)
Organic content	USA	Medium - high	Spooner et al. (1985)

- Recorded distribution

Native range

S. hermaphrodita is native to the cool temperate regions of North Eastern USA where it is classified as an endangered species (Franzaring et al., 2014; Catalogue of Life, 2015; USDA, 2015b). It occurs in and is native to the District of Columbia, Indiana, Kentucky, Massachusetts, Maryland, Michigan, New Jersey, New York, Ohio, Pennsylvania, Tennessee, Virginia and West Virginia (Franzaring et al., 2014) (Figure 4.8).

Cultivated range

According to Igliński et al. (2011), *S. hermaphrodita* is cultivated on 750 ha in Poland (Franzaring et al., 2014), while in Germany it is grown solely as a trial species (Franzaring et al., 2014).

Non-native range

S. hermaphrodita is non-native to Canada (Ontario) and the Czech Republic (DAISIE, 2015b; Catalogue of Life, 2015) (Figure 4.8).

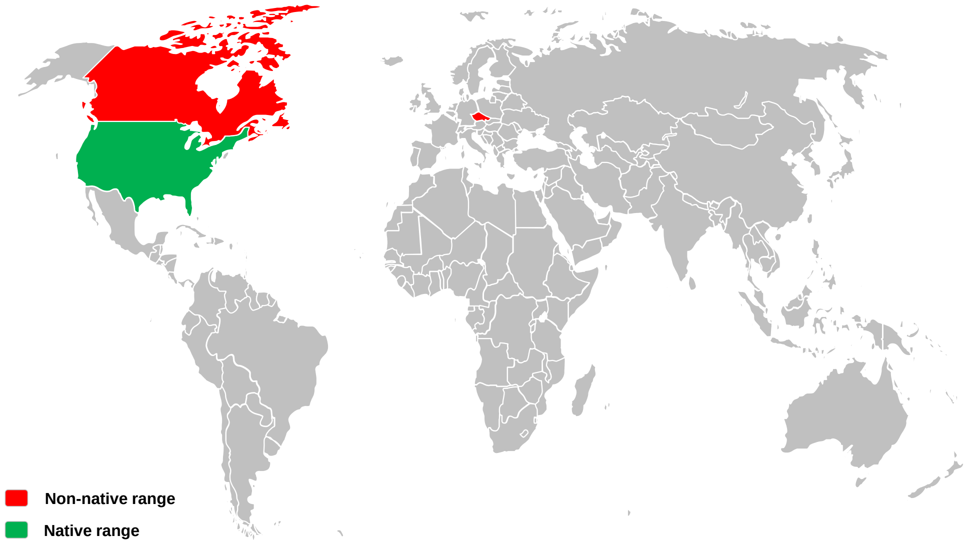

Figure 4.8: Current global recorded distribution of *Sida hermaphrodita*. Source: DAISIE, 2015b; Catalogue of Life, 2015.

Distribution in the Netherlands

According to the Nationale Databank Flora en Fauna (NDFF, 2015f), there are no current records of *S. hermaphrodita* in the Netherlands.

Colonisation of high conservation value habitats

According to the Nationale Databank Flora en Fauna (NDFF, 2015f), there are no current records of *S. hermaphrodita* in the Netherlands.

- Invasion process

Introduction outside cultivated land

No information on the introduction of *S. hermaphrodita* outside cultivated land could be found during a search of available literature. However, the species is used to provide nectar for bees.

Establishment

No information on the establishment of *S. hermaphrodita* outside cultivated land could be found during a search of available literature.

Spread

No information on the spread of *S. hermaphrodita* outside cultivated land could be found during a search of available literature.

- Environmental impacts summary

Effects on environmental targets or native species

No information on the effects of competition, parasitism, pathogens, parasites or interbreeding of *S. hermaphrodita* on environmental targets or native species could be found during a search of available literature.

Effects on plant targets in cultivation systems

No information on the effects of *S. hermaphrodita* on plant targets in cultivation systems could be found during a search of available literature.

Effects on animal health and production targets

No information on the effects of *S. hermaphrodita* on animal health and production targets could be found during a search of available literature.

Human targets

No information on the effects of *S. hermaphrodita* on human targets could be found during a search of available literature.

Effects on other targets

No information on the effects of *S. hermaphrodita* on infrastructure could be found during a search of available literature.

- Ecological risk assessment with the ISEIA protocol

The expert team allocated *S. hermaphrodita* a 'likely' ecological risk classification to the categories dispersion potential and invasiveness and colonization of high value conservation habitats, and a ‘deficient data (DD)’ risk classification to the categories adverse impacts on native species and alteration of ecosystem functions (Table 4.11). The total ecological risk score for the species is 6 out of a maximum of 6. Therefore, *S. hermaphrodita* is classified in the C list of the BFIS list system. The maximum risk score takes into account the limitation on maximum risk score per category that is imposed by the ISEIA protocol if data deficiency occurs or the application of best professional judgement is required (See section 2.4.2). The maximum risk score will, therefore, vary between species. In cases where there is sufficient information, i.e. where there is no data deficiency and best professional judgement is not required, the maximum possible risk score is 12. The rationale for the allocated scores is given in the following paragraphs.

It should be noted that the risk scores for dispersion potential and invasiveness and colonization of high value conservation habitats are based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

Table 4.11: Consensus scores for potential risks of Virginia mallow (*Sida hermaphrodita*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	**Risk**	**Consensus score**
Dispersion potential or invasiveness	Likely	2
Colonization of high value conservation habitats[a]	Likely	2
Adverse impacts on native species	DD	1[b]
Alteration of ecosystem functions	DD	1[b]
Ecological risk score		**6**

[a] Quantitative analysis was focused on Natura 2000 areas may indicate a lower score; however, species may also occur in other areas with high conservation value; [b] Deficient data (DD) scores 1 as this is the minimum that can be awarded per risk category.

Dispersion potential or invasiveness

Classification: **Likely**. Large examples of *S. hermaphrodita* can produce several thousand mostly viable seeds (Spooner et al., 1985). The species is native to the cool temperate regions of North Eastern USA, is cultivated in Poland and in Germany (Franzaring et al., 2014) and is non-native to Canada (Ontario) and the Czech Republic (DAISIE, 2015b; Catalogue of Life, 2015). According to the Nationale Databank Flora en Fauna (2015), there are no current records of *S. hermaphrodita* in the Netherlands. However, it is likely that *S. hermaphrodita* will disperse in the Netherlands if introduced due to the suitability of the temperate climate and a high seed production.

Colonization of high value conservation habitats

Classification: **Likely**. According to the Nationale Databank Flora en Fauna (2015), there are no current records of *S. hermaphrodita* in the Netherlands. However, *S. hermaphrodita* prefers habitats in moist, sunny prairies and naturally disturbed floodplains or terraces to partly shaded riverine habitats and the edges of woods near streams and rivers (Spooner et al., 1985; Franzaring et al., 2014). Therefore, it is likely that *S. hermaphrodita* will colonise high value conservation habitats in the Netherlands e.g. floodplains and other riverine habitats.

Adverse impacts on native species

Classification: **Deficient data**. There is insufficient information to allow an assessment on the potential impact of *S. hermaphrodita* on native species in the Netherlands.

Alteration of ecosystem functions

Classification: **Deficient data**. There is insufficient information to allow an assessment on the potential impact of *S. hermaphrodita* on ecosystem functions in the Netherlands.

Risk classification according to the BFIS list system

The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.11) in combination with the current recorded distribution in the Netherlands. The species classification for *S. hermaphrodita* is C0 (Figure 4.9). This characterises a non-native species that is absent from the area under assessment, poses a low ecological risk and is not classified in the BFIS list system.

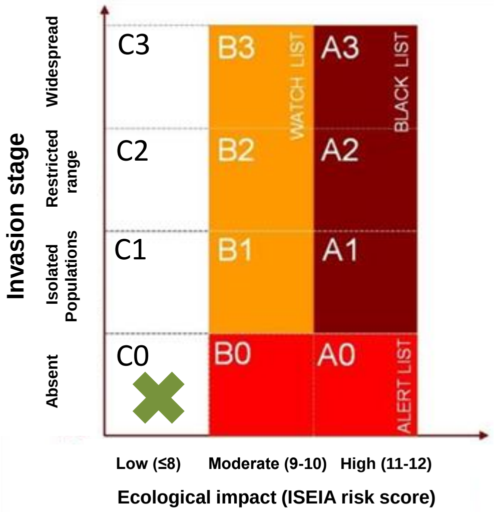

Figure 4.9: Risk classification of Virginia mallow (*Sida hermaphrodita*) according to the BFIS list system.

- Other risk assessments and classifications

  No available risk assessment or classification of *S. hermaphrodita* could be found during a search of available literature.

4.3 Salicaceae

4.3.1 *Salix schwerinii* x *viminalis*

- Species description

Salix schwerinii x *viminalis* is a tall, erect and very vigorous willow variety produced in Sweden by crossing *Salix viminalis* L. and the Russian *Salix schwerinii* E. Wolf. (crops4energy.co.uk) (Figure 4.10). At least three varieties of *S. schwerinii* x *viminalis* exist: Tora, Tordis, Björn and Gudrun.

Figure 4.10: *Salix schwerinii* x *viminalis*. (Source: www.mammothwillow.co.uk).

Species taxonomy

Table 4.12: Nomenclature and taxonomical status of *Salix schwerinii* x *viminalis*.

Scientific name:
Salix schwerinii x *viminalis*
Synonyms:
Not applicable

Taxonomic tree (Naturalis, 2015):
Kingdom: Plantae
Phylum: Tracheophyta
Class: Spermatopsida
Order: Malpighiales
Family: Salicaceae
Genus: *Salix*
Species: *Salix schwerinii* x *viminalis*

Preferred Dutch name:
Not applicable

Preferred English name:
Not applicable

Other Dutch names:
Not applicable

Other English names:
Not applicable

Life cycle

Salix spp. are perennial, deciduous (Smart & Cameron, 2008) and dioecious (occurring as male or female) and commercial strains usually reach sexual maturity within one to two years (Pei et al., 2008). Most *Salix* species are able to propagate vegetatively from detached twigs or branches (Smart & Cameron, 2008). *Salix* biomass crops are cultivated by planting dormant stem fragments of approximately one year old (Smart & Cameron, 2008; Pei et al., 2008). *Salix* individuals have a life span of usually 40 to 60 years and are relatively short lived compared to other hardwood species (Smart & Cameron, 2008).

Reproductive capacity

In general *Salix* spp. are highly productive, frequently producing 20 or 25 shoots from one coppice stool (Sennerby-Forsse et al., 1992; Robinson et al., 2004). *Salix* spp. may reach heights of 4 m in the initial 3 year coppice cycle (Bassam, 2013; Robinson et al., 2004). Under cultivation in two fields at Long Ashton Research Centre, UK, biomass production of two year old shoots of *S. schwerinii* x *viminalis* during the first rotation was 11.7 and 15.2 oven dried tonnes (odt) per ha/year respectively (Lindegaard et al., 2001; Macalpine et al., 2010; Sevel et al., 2012). In a further trial of 22 sites in Sweden, average biomass of two year old shoots during the first rotation was 7.3 odt ha/year (Larsson et al., 2001; Sevel et al., 2012).

- Habitat summary

Generally, willows are shade-intolerant pioneer species that colonise disturbed sites. They tend to grow in wetland and riparian habitats where they compete well with other species, but grow well without irrigation on upland and well-drained plantations that receive regular rainfall during the growing season (Newsholme, 1992; Smart & Cameron, 2008).

Observations of experimental *Salix* plots established in 1999 and 2000 in the province of Flevoland indicated that *S. schwerinii* x *viminalis* may be cultivated successfully in the Netherlands (Boosten, 2011). *S. schwerinii* x *viminalis* has been successfully grown in the UK for many years (crops4energy.co.uk). In general, *S. schwerinii* x *viminalis* has a greater frost tolerance than *S. viminalis* (Larsson, 1998), a willow species that is native to the Netherlands and distributed widely (Naturalis, 2015). *S. schwerinii* x *viminalis* is relatively drought sensitive compared to other *Salix* clones (Weih & Nordh, 2005; Linderson et al., 2007). In laboratory experimentation, *S. schwerinii* x *viminalis* tolerated temperatures of up to 40 ^{o}C without any significant harm or visible signs of heat stress, provided they were well irrigated (Bonosi et al., 2013) (Table 4.13). In a second laboratory experiment examining temperature tolerance on samples of *S. schwerinii* x *viminalis* grown in Sweden, the lethal temperature at which 50 % mortality occurred (LT50) varied between -2 ^{o}C in August to approximately -12.5 ^{o}C in October (Ögren, 1999). However, no measurements were taken of samples obtained during the months of December to June.

During Swedish experiments comparing growth on sandy and organic substrates of the clones Inger (*S. triandra* x *S. viminalis*, EU11635), Sven (*S. viminalis* x (*S. schwerinii* x *S. viminalis*), EU5285), Tora (*S. schwerinii* x *S. viminalis*, EU0627) and Tordis ((*S. schwerinii* x *S. viminalis*) x *S. viminalis*, EU9288), *S. schwerinii* x *S. viminalis* was observed to have the highest production of the two-year old shoots along with Inger (*S. triandra* x *S. viminalis*) on organic soil (Sevel et al., 2012). *S. schwerinii* x *S. viminalis's* preference for high nutrients is supported by other authors. According to Sevel et al. (2012) *S. schwerinii* x *viminalis* prefers more clayey soils, with high nutrients and soil water levels. Weih & Nordh (2005) found that *S. schwerinii* x *viminalis* responded well to fertilisation.

In a Swedish study *S. schwerinii* x *viminalis* was found to be relatively tolerant to chloride levels and only showed a slight reduction in production at chlorine levels of over 500 mg/l in irrigation water (Mirck et al., 2005).

Table 4.13: Physiological conditions tolerated by *Salix schwerinii* x *viminalis*.

Parameter	Data origin	Occurrence	References
LT50 (^{o}C)	Sweden	-2 to 12.5	Ögren (1999)
Temperature (^{o}C)	Laboratory	40	Bonosi et al. (2013)
Chlorine (mg/l)	Sweden	500	Mirck et al. (2005)

- Recorded distribution

Cultivated range
No information on the cultivated range of *S. schwerinii* x *viminalis* could be found during a search of available literature.

Non-native range
No information on the non-native range of *S. schwerinii* x *viminalis* could be found during a search of available literature.

Distribution in the Netherlands
According to the Nationale Databank Flora en Fauna, 2015f, there are no current records of *Salix schwerinii* x *viminalis* in the Netherlands. However, the identification of *Salix* species is difficult especially considering the number of hybrids that occur in nature.

Colonisation of high conservation value habitats
According to the Nationale Databank Flora en Fauna, 2015f, there are no current records of *Salix schwerinii* x *viminalis* in the Netherlands.

- Invasion process

Introduction outside cultivated land
No information on the introduction of *S. schwerinii* x *viminalis* could be found during a search of available literature.

Establishment
No information on the establishment of *S. schwerinii* x *viminalis* could be found during a search of available literature.

Spread
No information on the spread of *S. schwerinii* x *viminalis* could be found during a search of available literature.

- Environmental impacts summary

Effects on environmental targets or native species
No information on the effects of *S. schwerinii* x *viminalis* interbreeding on native species could be found during a search of available literature.

Predation, herbivory or parasitism

S. schwerinii x *viminalis* is grazed to a lesser degree by mammals than any other commercial *Salix* clone. Observations from German plantations show that Deer select other *Salix* clones leading to severe damage but graze *S. schwerinii* x *viminalis* sparingly. Moreover, rabbits and hares avoid the bark of *S. schwerinii* x *viminalis*, even if they have ringbarked close to 100% of the stems of surrounding *S. viminalis* clones (Larsson, 1998).

Competition

S. schwerinii x *viminalis* is a high yielding and virtually disease-free hybrid (Lindegaard & Barker, 1996), suggesting that *S. schwerinii* x *viminalis* may effectively compete with native species in suitable habitats.

Hosting pathogens or parasites

Melampsora epiphylla Dietel, a rust species, occurs on *S. schwerinii* but is confined to the Far East. The impact of *M. epiphylla* on *S. schwerinii* x *viminalis* hybrid is unknown and, therefore, the potential disease risk relating to a possible migration of *M. epiphylla* to European countries uncertain (Pei et al., 2008). However, *S. schwerinii* x *viminalis* shows good resistance to other rust species in the UK (crops4energy.co.uk).

Effects on ecosystem function targets

No information on the effects of *S. schwerinii* x *viminalis* on ecosystem function targets could be found during a search of available literature.

Effects on plant targets in cultivation systems

No information on the effects of *S. schwerinii* x *viminalis* on plant targets in cultivation systems could be found during a search of available literature.

Effects on animal health and production targets

No information on the effects of *S. schwerinii* x *viminalis* on animal health and production targets could be found during a search of available literature.

Human targets

No information on the effects of *S. schwerinii* x *viminalis* on human targets could be found during a search of available literature.

Effects on other targets

No information on the effects of *S. schwerinii* x *viminalis* on infrastructure could be found during a search of available literature.

- Ecological risk assessment with the ISEIA protocol

The expert team allocated *S. schwerinii* x *viminalis* a 'likely' ecological risk classification to all categories apart from alteration of ecosystem functions where it receives a ‘medium’ ecological risk classification (Table 4.14). The total ecological risk score for the species is 8 out of a maximum of 9. Therefore, *S. schwerinii* x *viminalis* is classified in the C list of the BFIS list system. The maximum risk score takes into account the limitation on maximum risk score per category that is imposed by the ISEIA protocol if data deficiency occurs or the application of best professional judgement is required (See section 2.4.2). The maximum risk score will, therefore, vary between species. In cases where there is sufficient information, i.e. where there is no data deficiency and best professional judgement is not required, the maximum possible risk score is 12. The rationale for the allocated scores is given in the following paragraphs.

Because scores for all categories are based on expert judgement due to lack of data, periodical reviews of new literature and updates of the risk scores for this species are recommended.

Table 4.14: Consensus scores for potential risks of *Salix schwerinii* x *viminalis* in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	Likely	2
Colonization of high value conservation habitats	Likely*	2
Adverse impacts on native species	Likely	2
Alteration of ecosystem functions	Medium	2
Ecological risk score		**8**

* Quantitative analysis was focused on Natura 2000 areas may indicate a lower score; however, species may also occur in other areas with high conservation value.

Dispersion potential or invasiveness
Classification: **Likely**. *S. schwerinii* x *viminalis* is able to survive harsh Dutch winters and reproduce vegetatively. However, the dispersal ability of this hybrid in the Netherlands and climatically similar countries is unknown. Therefore, it is considered likely that the species will establish and become locally invasive in the Netherlands.

Colonization of high value conservation habitats
Classification: **Likely**. Willows tend to grow in wetland and riparian habitats where they compete well with other species. Therefore, it is considered likely that *S. schwerinii* x *viminalis* will establish in high conservation value habitats in the Netherlands e.g. river banks and floodplains.

Adverse impacts on native species

Classification: **Likely**. *Salix* species hybridize easily and a number of *Salix* species are native to the Netherlands therefore genetic effects on native species cannot be ruled out. Moreover, rapid and dense willow growth may outcompete native species in riparian habitats. Therefore, it is likely that *S. schwerinii* x *viminalis* will impact on Dutch native species.

Alteration of ecosystem functions

Classification: **Medium**. Evidence from Germany and other countries suggests that selective herbivory of native plant species in the presence of *S. schwerinii* x *viminalis* would moderately disrupt food-webs if *S. schwerinii* x *viminalis* were to become abundant. Dense *Salix* growth would lead to competition with native species and reduce light penetration resulting in a medium risk of alteration to ecosystem functions in the Netherlands.

Risk classification according to the BFIS list system

The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.14) in combination with the current recorded distribution in the Netherlands. The species classification for *S. schwerinii x viminalis* is C0 (Figure 4.11).

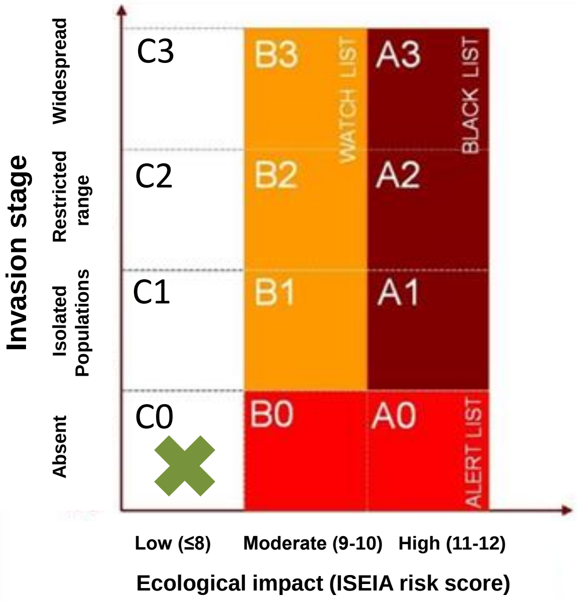

Figure 4.11: Risk classification of *Salix schwerinii* x *viminalis* according to the BFIS list system.

This characterises a non-native species that is absent from the area under assessment, poses a low ecological risk and is not classified in the BFIS list system.

- Other risk assessments and classifications

No risk assessments or classifications of *S. schwerinii* x *viminalis* could be found during a search of available literature.

4.4 Euphorbiaceae

4.4.1 Jatropha (*Jatropha curcas*)

- Species description

Jatropha (*Jatropha curcas*) is a deciduous, soft-wooded shrub or small tree that grows up to five to six metres tall (Figure 4.12). The pale brown bark is smooth, papery and peeling (Sastry & Kavathekar, 1990; Ecocrop, 2015c) and exudes copious opalescent juice that is soapy, sticky to tough in consistency but soon dries to become brittle and brownish. The stout, ascending branches are glabrous. The leaves are scattered, stalked, broad cordate, five lobed and smooth. The stipules are minute or absent, the petioles 2-20 cm long, the three to five lobed blades are 12.5-18 x 11-16 cm. Individual lobes are shortly acuminate or acute at the apex, the leaf margins entire or undulating. The seven to nine basal veins are prominent and venation reticulates. The panicles are terminal or cymose from the exterior axils and bear many small, yellow flowers. The plant is monoecious and flowers are unisexual or occasionally hermaphroditic. Male flowers appear at the end of the branches on short, articulated pedicels; female flowers in their divisions, with their pedicels not articulate. A small bract occurs below each subdivision of the panicle, and there is usually a single pressing on the calyx. The male flowers feature a calyx, are five leaved with a five petal corolla. They are campanulate, somewhat hairy, featuring a disk of five glandular bodies round the filaments bases. There are six filaments in total, the central one being very thick and columnar. The five exterior filaments are filliform, adhere to the central filament towards the base, are all erect and a little longer than the calyx. There are 10 sagittate, equal anthers, five of which are supported by the large central filament, and one by each of the others. The female flowers share the characteristics of the calyx, corolla and disk with the male flowers. The sepals are up to 1.8 cm long and persistent, featuring a 1.5-2 mm diameter, somewhat hairy, oblong, smooth, three locular ovary with three styles and a bifid stigma. The fruit is initially yellow, then black, ellipsoid, 2.5-3 cm long and 2-3 cm in diameter. The cells contain two ovoid to oblong, dull brownish-black seeds that are 1.5-2 x 1-1.1 cm (Ecocrop, 2015c; CABI, 2015d).

Figure 4.12: Jatropha (*Jatropha curcas*) (Source: Henning; Wikimedia Commons).

Species taxonomy

Table 4.15: Nomenclature and taxonomical status of Jatropha (*Jatropha curcas*).

Scientific name:
Jatropha curcas L. (1753)

Synonyms:
Castiglionia lobata Ruiz & Pav.
Curcas adansonii Endl.
Curcas curcas (L.) Britton & Millspp., nom. inval.
Curcas drastica Mart.
Curcas indica A.Rich.
Curcas lobata Splitg. ex Lanj.
Curcas purgans Medik.
Jatropha acerifolia Salisb.
Jatropha afrocurcas Pax
Jatropha condor Benth., nom. nud.
Jatropha edulis Sessé
Jatropha yucatanensis Briq.
Manihot curcas (L.) Crantz
Ricinoides americana Garsault, opus utique oppr.
Ricinus americanus Mill.
Ricinus jarak Thunb.

Taxonomic tree (Catalogue of Life, 2015):
Kingdom: Plantae
Phylum: Tracheophyta
Class: Magnoliopsida
Order: Malpighiales
Family: Euphorbiaceae
Genus: *Jatropha*
Species: *Jatropha curcas*

Preferred Dutch name:
Purgeernoot (unofficial)

Preferred English name:
Jatropha

Other Dutch names:
Schijtnoot

Other English names:
Barbados nut; Barbados nut tree; bubble bush; Mexican pine; physic nut; physic nut tree; poison nut; purging nut; purging nut tree

Life cycle

J. curcas is pollinated by insects or rarely self-pollinating. The exocarp of the fruit remains fleshy until the seeds are mature. Two flowering periods occur in November and May in its native Thailand. However, in equatorial, permanently humid regions, flowering occurs all year round (Ecocrop, 2015c).

Reproductive capacity

The female flowers of *J. curcas* are four to five times more abundant than male flowers. The plant begins to produce fruits after four to five months, reaching full productivity at about three years. Fruits require 90 days from flowering to seed maturity. Observations from the USA in the summer of 2011 revealed a high fruit setting average (75.5%). 10.1% and 64.0% of fertilisation occurred through natural pollination and asexual reproduction, respectively (Nietsche et al., 2015; Ecocrop, 2015c). Seed production ranges from about 2 tons per hectare per year to over 12.5 t/ha/year after five years of growth (jatrophaworld.org).

- Habitat summary

J. curcas is especially well adapted to arid and semi-arid conditions as it is very drought tolerant (Ecocrop, 2015c). However, it has been able to withstand occasional light frosts in the Chã das Caldeiras, Fogo, Cape Verde islands at an altitude of approximately 1700 m (Kiefer, 1986) where grapevines and apples are also grown (CABI, 2015d). Even so, its current recorded distribution indicates that *J. curcas* has been most successful in the drier regions of the tropics (Ecocrop, 2015c). *Jatropha* species occur in seasonally dry areas such as grassland-savanna (cerrado), thorn forest scrub and caatingas of South America but are completely lacking from the moist Amazon humid forest region (Dehgan & Schutzman, 1994). The plant is found in hedges, roadsides and disturbed sites in Guatemala and Florida, USA, on rocky slopes and stony dry stream courses in Cape Verde and is a common upland and wasteland weed in parts of India (PIER, 2011; CABI, 2015d). It is naturalized along roadsides, on open slopes, and sometimes in forests in Fiji and in Australia is found in disturbed areas around old settlements (PIER, 2011; CABI, 2015d). It has been reported as a potential invader of lowland forest on the Pacific Islands of Wallis and Futuna (PIER, 2011).

The physiological conditions tolerated by *J. curcas* are listed in table 4.16*. J. curcas* is very tolerant and thrives under a wide range of edapho-climatic conditions. *J. curcas'* temperature requirement ranges from 11 to 28 ^{o}C (optimal) and 7 to 36 ^{o}C (absolute limit) (Ecocrop, 2015c). Average annual temperatures at the centre of its origin lie well above 20°C and up to 28°C (CABI, 2015d). *J. curcas* is reported to tolerate minimum temperatures of -1 ^{o}C at rest and 0 ^{o}C during early growth. *J. curcas* prefers high light intensities, and is able to grow in full sunlight at latitudes of 28^{o} to 30^{o} and at a maximum altitude of 1600 m (Ecocrop, 2015c). Rainfall for optimal *J. curcas* growth is reported to be between 500 and 1500 mm annually. *J. curcas* can tolerate a minimum of 300 mm and maximum of 2000 mm annual rainfall (Ecocrop, 2015c).

Table 4.16: Physiological conditions tolerated by Jatropha (*Jatropha curcas*).

Parameter	Optimal	Absolute limit	References
Temperature requirement (°C)	11-28	7-36	Ecocrop (2015c); CABI (2015).
Killing temperature during rest (°C)	-	-1	Ecocrop (2015c)
Killing temperature early growth (°C)	-	0	Ecocrop (2015c)
Light intensity	Very bright	Very bright - clear skies	Ecocrop (2015c)
Altitude (m)	-	1600	Ecocrop (2015c)
Rainfall (annual - mm)	500-1500	300-2000	Ecocrop (2015c)
Latitude (Degrees)	-	28-30	Ecocrop (2015c)
Soil pH	5.5-7.5	5-8	Ecocrop (2015c)
Soil depth (cm)	>150	-	Ecocrop (2015c)
Soil texture	Medium	Medium, light	Ecocrop (2015c)
Soil fertility	Moderate	Low	Ecocrop (2015c)
Soil salinity (dS/m)	<4	4	Ecocrop (2015c)
Soil drainage	well (dry spells)	well (dry spells), excessive (dry/moderately dry)	Ecocrop (2015c)

J. curcas grows best in well drained soils, but tolerates dry to moderately dry soils of medium to light texture and is well-adapted to marginal soils with low nutrient content (Ecocrop, 2015c; CABI, 2015d). Optimal soil depth for *J. curcas* lies above 150 cm (Ecocrop, 2015c). *J. curcas* is reported to be able to tolerate pH values ranging from 5 to 8 and grows optimally in soils ranging from pH 5.5 to 7.5 (Ecocrop, 2015c). The plant is able to grow in sodic and alkaline conditions and is able to tolerate soil salinities to a maximum of 4 dS/m (CABI, 2015d; Ecocrop, 2015c).

- Recorded distribution

Native range

J. curcas is reported to be native to Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua and Panama, though its exact origin is uncertain (Ecocrop, 2015c; CABI, 2015d).

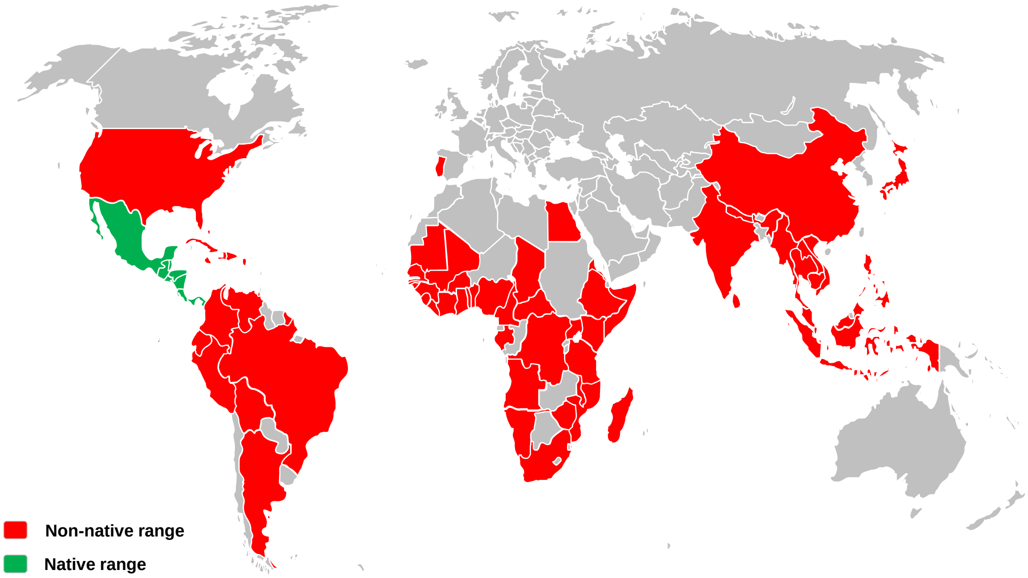

Figure 4.13: Current global recorded distribution of Jatropha (*Jatropha curcas*). Source: CABI (2015d); Ecocrop (2015c).

Kairo et al. (2003) also record *J. curcas* as native to the Caribbean, however, USDA-ARS (2015) excludes the Caribbean from *J. curcas*' native range (CABI, 2015d). Heller (1996) found many herbarium specimens of *J. curcas* from Mexico, Central America and the Caribbean, and to a lesser extent in Argentina, Bolivia, Brazil, Colombia, Ecuador, Paraguay, Peru and Venezuela. CABI (2015d) omits records for Europe citing the frost sensitivity of this species as an exclusion criterion (Figure 4.13).

Cultivated range
No information on the cultivated range of *J. curcas* could be found during a search of available literature.

Non-native range
J. curcas is non-native to Angola, Antigua and Barbuda, Argentina, Bahamas, Barbados, Benin, Bolivia, Brazil, Burkina Faso, Cambodia, Cameroon, Cape Verde, Central African Republic, Chad, China, Colombia, Cote d'Ivoire, Cuba, Democratic Republic of Congo, Dominica, Dominican Republic, Ecuador, Egypt, Eritrea, Ethiopia, French Guiana, Gabon, Gambia, Ghana, Grenada, Guadeloupe, Guinea, Guinea-Bissau, Haiti, India, Indonesia, Jamaica, Japan, Kenya, Laos, Liberia, Madagascar, Malawi, Malaysia, Mali, Martinique, Mauritania, Montserrat, Mozambique, Myanmar, Namibia, Nepal, Netherlands Antilles, Nigeria, Peru, Philippines, Portugal, Puerto Rico, Sao Tome et Principe, Senegal, Sierra Leone, Somalia, South Africa, Sri Lanka, St Kitts and Nevis, St Lucia, St Vincent and the Grenadines, Tanzania, Thailand, Togo, Trinidad and Tobago, Uganda, United States of America, Venezuela, Vietnam, Virgin Islands (US), Zanzibar and Zimbabwe (Ecocrop, 2015c) (Figure 4.13).

Distribution in the Netherlands
According to the Nationale Databank Flora en Fauna (NDFF, 2015f), there are no current records of *J. curcas* in the Netherlands.

Colonisation of high conservation value habitats
According to the Nationale Databank Flora en Fauna (NDFF, 2015f), there are no current records of *J. curcas* in the Netherlands.

- Invasion process

Introduction outside cultivated land
Following the deliberate introduction of *J. curcas* as a crop plant, local vectors, such as vehicles and machinery aid its spread through the movement of seeds and seed capsules, vegetative parts, and contaminated soil. Livestock also spread seed and selectively graze other more palatable but competitive species, aiding *J. curcas*' establishment (Pitt, 1999). Natural dispersal occurs by autochory when ripe fruits

explosively eject seeds over some distance. Seeds may also be dispersed by hydrochory and through tuberous root spread (CABI, 2015d).

Establishment
No information on the establishment of *J. curcas* could be found during the literature study or in discussion with expert contributors.

Spread
The ability of *J. curcas* to spread to new locations appears to be limited, even in suitable climates. Observations of natural seed dispersal in Zambia pointed to a limited dispersal capability as seeds were dispersed by animals to adjacent land use systems, but no natural recruitment was observed (Negussie et al., 2013). Moreover, field experiments in Burkina Faso demonstrated very low spontaneous regeneration around plantation perimeters. Individual seedling density around *J. curcas* perimeters was less than 0.01 m^{-2} and analysis indicated a low seed bank longevity and seedling survival (Negussie et al., 2015). *J. curcas* was introduced to Hawaii before 1871 but its naturalised distribution remains limited to the south slopes of Haleakala volcano, on the eastern half of the island of Maui (Wagner et al., 1999; Chimera et al., 2010). However, given the right environmental situation, such as along riparian corridors, *Jatropha* readily escapes and can become invasive, as it has along streams in Queensland, Australia (Low & Booth, 2007; Chimera et al., 2010).

The main vectors of dispersal for *J. curcas* are livestock and agricultural machinery and equipment; via the postal service as a result of the trade in plants; in soil, sand and gravel transported during erosion control or dune stabilisation and in association with forestry and industry, and during flood events (Pitt, 1999; CABI, 2015d). *J. curcas* may also be introduced to nature as a garden escape (Pitt, 1999; CABI, 2015d).

- Environmental impacts summary

Effects on environmental targets or native species
No information on the effects of parasitism, pathogens, parasites or interbreeding of *J. curcas* on environmental targets or native species could be found during a search of available literature.

Competition
J. curcas harms neighbouring plants by producing allelochemicals. The chemicals vitexin and isovitexin, stigmasterol and beta-sitosterol, isolated from *J. curcas* leaves are considered to be responsible for the plants allelopathy (Rastogi & Mehrotra, 1990; CABI, 2015d).

Effects on ecosystem function targets

No information on the effects of *J. curcas* on ecosystem function targets could be found during a search of available literature.

Effects on plant targets in cultivation systems

No information on the effects of *J. curcas* on plant targets in cultivation systems could be found during a search of available literature.

Effects on animal health and production targets

No information on the effects of pathogens or parasites of *J. curcas* on animal health and production targets could be found during a search of available literature.

Hazardous upon contact, host

The seeds of *J. curcas* are poisonous to livestock if consumed (Makkar & Becker, 1998), ingestion may cause severe diarrhoea and even death (CABI, 2015d).

Human targets

No information on the effects of pathogens or parasites of *J. curcas* on human targets could be found during a search of available literature.

Hazardous upon contact

The seeds of *J. curcas* are poisonous to humans if consumed (Makkar & Becker, 1998), ingestion may cause severe diarrhoea and even death. It is considered dangerous if this species is present in populated areas, as deaths due to ingestion have occurred frequently in India, particularly in children (CABI, 2015d).

Effects on other targets

No information on the effects of *J. curcas* on infrastructure could be found during a search of available literature.

- Ecological risk assessment with the ISEIA protocol

The expert team allocated *J. curcas* a 'low' ecological risk classification to the categories dispersion potential and invasiveness and colonization of high value conservation habitats, and an ‘unlikely’ risk classification to the categories, adverse impacts on native species and alteration of ecosystem functions (Table 4.17).

The total ecological risk score for the species is 4 out of a maximum of 10. Therefore, *J. curcas* is classified in the C list of the BFIS list system. The maximum risk score takes into account the limitation on maximum risk score per category that is imposed by the ISEIA protocol if data deficiency occurs or the application of best professional judgement is required (See section 2.4.2). The maximum risk score will, therefore, vary between species. In cases where there is sufficient information, i.e. where there is no data deficiency and best professional judgement is not required, the maximum possible risk score is 12. The rationale for the allocated scores is given in the following paragraphs.

It should be noted that the risk scores for adverse impacts on native species and alteration of ecosystem functions are based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

Table 4.17: Consensus scores for potential risks of jatropha (*Jatropha curcas*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	Low	1
Colonization of high value conservation habitats	Low	1
Adverse impacts on native species	Unlikely	1
Alteration of ecosystem functions	Unlikely	1
Ecological risk score		**4**

* Quantitative analysis was focused on Natura 2000 areas may indicate a lower score; however, species may occur in other areas with high conservation value.

Dispersion potential or invasiveness

Classification: **Low risk**. *J. curcas* can only withstand occasional light frosts. Its current recorded distribution indicates that the species has been most successful in the drier regions of the tropics (Ecocrop, 2015c). Therefore, there is no match between the temperature requirements of *J. curcas* and the Dutch climate meaning that its dispersion potential and invasiveness will be severely limited in the Netherlands.

Colonization of high value conservation habitats

Classification: **Low risk**. Establishment of *J. curcas* in habitats of high value conservation will not occur in the Netherlands due to the temperature requirements of the species. This is illustrated by *J. curcas'* adaptation to arid and semi-arid conditions (Ecocrop, 2015c) and its inability to withstand any more than light frosts.

Adverse impacts on native species

Classification: **Unlikely**. No information on the effects of parasitism, pathogens, parasites or interbreeding is available. *J. curcas* harms neighbouring plants by producing allelochemicals. However, it is unlikely that adverse impacts on native species will occur in the Netherlands due to a poor climate match. Any occurrences of *J. curcas* in the wild in the Netherlands will be temporary due to a lack of survival in winter.

Alteration of ecosystem functions

Classification: **Unlikely**. *J. curcas* is a deciduous, soft-wooded shrub or small tree that grows up to five to six metres tall. It is unlikely that alterations to ecosystem functions will occur due to a poor climate match. Any occurrences of *J. curcas* in the wild in the Netherlands will be temporary due to a lack of survival in winter.

Risk classification according to the BFIS list system

The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.17) in combination with the current recorded distribution in the Netherlands. The species classification for *J. curcas* is C0 (Figure 4.14). This characterises a non-native species that is absent from the area under assessment and poses a low ecological risk and is not classified in the BFIS list system.

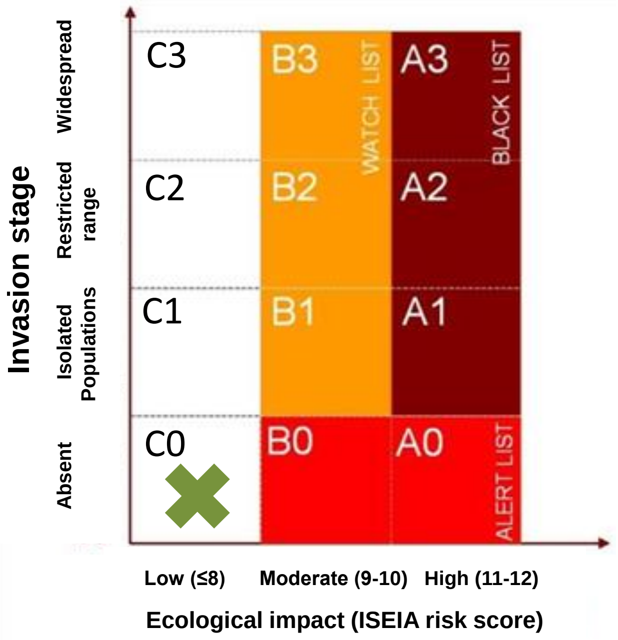

Figure 4.14: Risk classification of jatropha (*Jatropha curcas*) according to the BFIS list system.

- Other risk assessments and classifications

J. curcas has been assessed as high risk or rejected for introduction in Italy, Australia, Hawaii, the USA (Florida) and the USA in general (Table 4.18).

Table 4.18: Overview of risk classifications previously performed for Jatropha (*Jatropha curcas*).

	Italy	Australia	Pacific (Hawaii)	USA (general)	USA (Florida)
Scope	Risk assessment method	Risk assessment method	Risk assessment method	Risk assessment method	Risk assessment method
Method	Modified Australian Weed Risk Assessment System (AWRAS).	Australian Weed Risk Assessment System (AWRAS).	Modified Australian Weed Risk Assessment System (AWRAS).	Modified Australian Weed Risk Assessment System (AWRAS).	Modified Australian Weed Risk Assessment System (AWRAS).
Year	2009	Not available			
Risk classification	**Rejected (15)**	**Rejected (11)**	**High risk (17)**	**Rejected (19)**	**Rejected (19)**
Source	Crosti et al. (2010)	Hear.org (2015f)	Hear.org (2015f)	Hear.org (2015f)	Hear.org (2015f)

4.5 Apocynaceae

4.5.1 Common milkweed (*Asclepias syriaca*)

- Species description

Common milkweed (*Asclepias syriaca*) is a perennial herb with stout, erect stems that grow to a maximum of 2 m tall (Figure 4.15). Stems feature short downy hairs and milky sap. The leaves are opposite with smooth margins, oblong, 10 to 20 cm long and 5 to 11 cm wide, with prominent veins. The upper surfaces are smooth, lower surfaces are covered with short white hairs. The sweet-smelling flowers are pink to white and arranged in large, many-flowered axillary and apical bell-like clusters of 10 to more than 120 and produce copious amounts of nectar. *A. syriaca* seedpods are usually found on stems 70-100 cm in height (Morse & Schmitt, 1985). The oval seeds are brown and flat, measuring 6 mm long and 5 mm wide, each with a tuft of silky white apical hairs. The roots spread horizontally and vertically and in established stands may penetrate the soil by up to 3.8 m (Anderson, 1999; CABI, 2015b).

Figure 4.15: Common milkweed (*Asclepias syriaca*) growing in Hungary (Photo: Johan van Valkenburg).

Species taxonomy

Table 4.19: Nomenclature and taxonomical status of Common milkweed (*Asclepias syriaca*).

Scientific name:
Asclepias syriaca L. (1753)

Synonyms:
Asclepias apocinum Gaterau
Asclepias cornuti Decne.
Asclepias globosa Stokes
Asclepias grandifolia Bertol.
Asclepias illinoensis Michx. ex Steud.
Asclepias intermedia Vail
Asclepias kansana Vail
Asclepias pubescens Moench
Asclepias pubigera Dumort.
Asclepias serica Rafin
Asclepias syriaca var. *kansana* (Vail) E.J.Palmer & Steyerm.

Taxonomic tree (Catalogue of Life, 2015):
Kingdom: Plantae
Phylum: Tracheophyta
Class: Magnoliopsida
Order: Gentianales
Family: Apocynaceae
Genus: *Asclepias*
Species: *Asclepias syriaca*

Preferred Dutch name:
Zijdeplant (Naturalis, 2015)

Preferred English name:
Common milkweed

Other Dutch names:
Not applicable

Other English names:
Broadleaf milkweed, butterfly flower, cotton weed, silkweed, silky milkweed, silky swallow-wort, Virginia silkweed milkweed, wild cotton

Life cycle

A. syriaca reproduces by sexual and vegetative means. The plant flowers from June to August, depending on initial growth, climate, and location (Anderson, 1999). Flowers are self-sterile and insect-pollinated (Anderson, 1999). *A. syriaca* has a rare pollen delivery system which features the transfer of packets of pollen (pollinia) in a single unit (Pleasants, 1991). Seeds are dispersed in mid-autumn (Morse & Schmitt, 1985). Underground rootstocks develop adventitious buds which give rise to new individuals that emerge in April and May (CABI, 2015b).

Reproductive capacity

A. syriaca has a high reproductive potential (CABI, 2015b). Each plant produces an average of 4 to 6 pods containing approximately 150 to 425 seeds (CABI, 2015b). In a Hungarian study, seed numbers on neglected fields invaded by *A. syriaca* reached seven to 10 thousand per square metre. However, the species does not maintain a persistent seed bank in the soil and seeds from preceding years are non-viable (Csontos et al., 2009). Clonal colonies that develop from a single plant arising from a seed or root segment can comprise several thousand stems (Wilbur, 1976; CABI, 2015b).

- Habitat summary

A. syriaca is able to colonise a variety of habitats from woodlands to dune-lands and cleared grasslands and marshlands (Botta-Dukat, 2008; Csontos et al., 2009; CABI, 2015b). In North America, A. *syriaca* is common in areas of human disturbance such as waste places, fencerows, roadsides, meadows, railways, reduced-tillage fields, and other open habitats (Morse & Schmitt, 1985; CABI, 2015b).

A. syriaca favours temperate/mesothermal climates but tolerates a wide range of climatic conditions. The plant tolerates mean temperatures in the coldest months of 0 to 18 °C and in the warmest months of >10 °C (CABI, 2015b) (Table 4.20). Seeds planted in a non-heated greenhouse in October germinated the following spring when the mean maximum and minimum daily temperatures were 20.5 and 9.1 °C, respectively (Baskin & Baskin, 1977). *A. syriaca* is most commonly found growing on well drained soils of loamy texture but tolerates soils of any texture (CABI, 2015b). It is most commonly found on loamy, well-drained soils and grows best in full sunlight or light shade and does not tolerate excessive moisture. *A. syriaca* tolerates alkaline, neutral and acidic soils (CABI, 2015b).

Table 4.20: Physiological conditions tolerated by common milkweed (*Asclepias syriaca*).

Parameter	Data origin	Occurrence	References
Temperature of coldest month (mean °C)	unknown	0-18	CABI (2015b)
Temperature of warmest month (mean °C)	unknown	> 10	CABI (2015b)
Temperature for germination (mean °C)	unknown	9.1-20.5	Baskin & Baskin (1977)
Soil texture	unknown	Heavy, medium, light	CABI (2015b)
Soil pH	unknown	Alkaline, neutral and acidic	CABI (2015b)

- Recorded distribution

Native range

A. syriaca is native to north-eastern, north-central and south-eastern USA and adjacent areas of Canada, and grows on agricultural land in these areas (Hartzler Buhler, 2000). It’s distribution extends throughout the Great Plains ecoregion from southern Canada, south to north-eastern Oklahoma, north-western Georgia, and

Texas; and east from North Carolina to Maine (USDA-NRCS, 2010; CABI, 2015b) (Figure 4.16).

Cultivated range

No information on the cultivated range of *A. syriaca* could be found during a search of available literature.

Non-native range

A. syriaca is classified as invasive in the majority of its Canadian native range. *A. syriaca* is non-native to Japan, Austria, Croatia, France, Germany, Hungary, Moldova, the Netherlands, Poland, Romania, Serbia, Slovenia, Spain and Sweden. It is considered invasive in Hungary and Serbia (CABI, 2015b) (Figure 4.16).

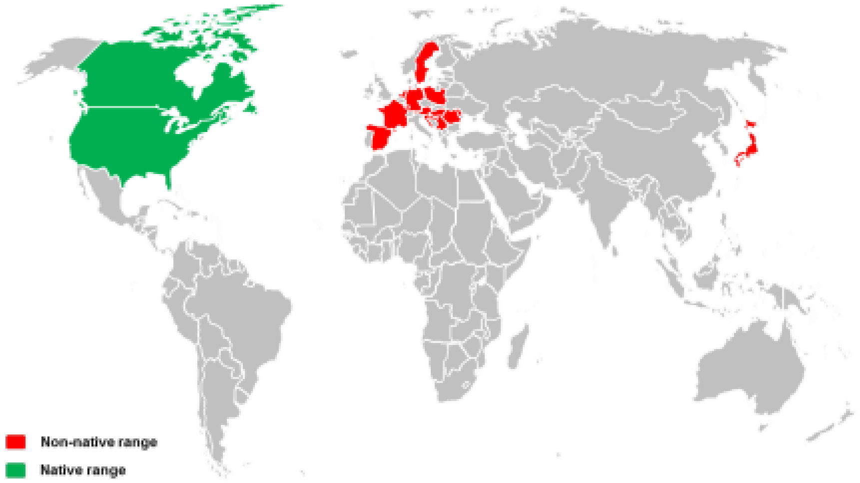

Figure 4.16: Current global recorded distribution of common milkweed (*Asclepias syriaca*) (Source: CABI, 2015b).

Distribution in the Netherlands

A. syriaca has been naturalised in the dunes of southern Kennemerland in the Netherlands since 1860. According to available records, *A. syriaca* has a limited distribution in the Netherlands with a few additional isolated populations (Figure 4.17).

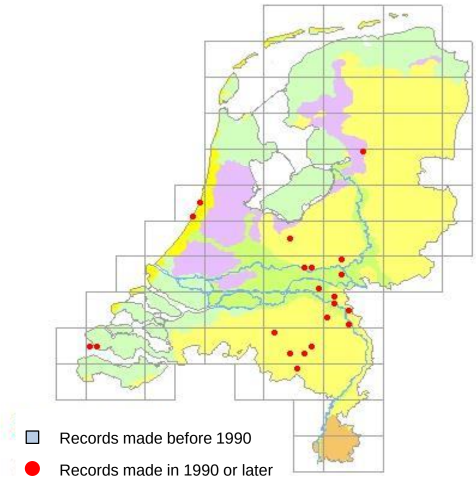

Figure 4.17: Current recorded distribution of common milkweed (*Asclepias syriaca*) in the Netherlands. Source: NDFF (2015g).

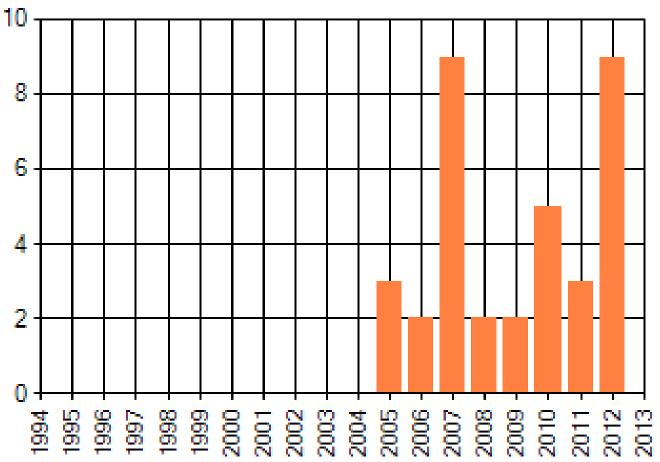

Figure 4.18: Estimated number of yearly records (5x5 km squares) of common milkweed (*Asclepias syriaca*) in the Netherlands. Source: NDFF (2015g).

A. syriaca has been grown as an ornamental plant in the Netherlands for many years. The oldest known documented records of naturalized plants date back to 1866. At that time, the plant was recorded in the dunes near Haarlem and Bloemendaal. After the year 2000, the number of recorded stands has gradually increased (Figure 4.18). Many new stands are located in or near urban areas. The plant is still present in different dune habitats including at Noordwijk, Bloemendaal and Zandvoort.

Colonisation of high conservation value habitats.

In Noordwijk *A. syriaca* grows in the South-Kennemerland Natura 2000 area in habitat types 2130 (fixed coastal dunes with herbaceous vegetation) or "grey dunes", and 2160 (dunes with *Hippophae rhamnoides*) (Table 4.21).

Table 4.21: Number of kilometre squares in Natura 2000 areas where common milkweed (*Asclepias syriaca*) has been recorded in the Netherlands.

Natura 2000 area	Definite	Possible
South-Kennemerland	2	3

- Invasion process

Introduction outside cultivated land

No information on the introduction of *A. syriaca* outside cultivated land could be found during a search of available literature.

Establishment

No information on the establishment of *A. syriaca* could be found during a search of available literature.

Spread

A. syriaca seeds are naturally dispersed by wind on tufts of floss (Bhowmik, 1982; Csontos et al., 2009). High seed production facilitates dispersal over long distances (White, 1996; CABI, 2015b). Seeds may also be spread by motor vehicles (Wyatt et al., 1993). The plant employs underground runners to steadily expand. Although the plants can produce viable seeds in the Netherlands, there are preliminary indications that *A. syriaca* is not able to spread via seeds over long distances and establish in new areas. Most new stands are located in or near urban areas, and are likely the result of the dumping of garden waste or from soil contaminated with root fragments (Beringen, 2013).

A. syriaca displays a number of characteristics which facilitate its potential for spread. It is a successful competitor (Yenish et al., 1997), is perennial and able to reproduce vegetatively (Bhowmik & Bandeen, 1976; Weber & Gut, 2004), and produces allelopathic compounds (Kazinczi et al., 2004; Csontos et al., 2009). Vegetative reproduction may be facilitated if rhizome fragments are spread by human activities like soil movement, or the use of farm machinery. *A. syriaca* occurs along water-bodies, so there is possibility that it may be spread by water (Wyatt et al., 1996).

- Environmental impacts summary

Effects on environmental targets or native species
Predation, herbivory or parasitism
No information on the effects of *A. syriaca* parasitism, interbreeding and hosting of pathogens and parasites on environmental targets or native species could be found during a search of available literature.

Competition
According to Beringen (2013), there is little evidence that native species are displaced by *A. syriaca* in the Netherlands. However, evidence from international literature is conflicting. Anderson (1999) state that *A. syriaca* can be an aggressive and persistent weed. Evetts & Burnside (1975) state that it forms large, dense, persistent populations in mostly disturbed habitats. However, the same authors state that *A. syriaca* does not compete strongly with other species, particularly with respect to light and soil resources (Evetts & Burnside, 1975; Nikolic & Popov, 2013).

Effects on ecosystem function targets
No information on the effects of *A. syriaca* on ecosystem function targets could be found during a search of available literature.

Effects on plant targets in cultivation systems
No information on the effects of *A. syriaca* parasitism, interbreeding or pathogens and parasites on plant targets in cultivation systems could be found during a search of available literature.

Competition
A. syriaca is an agricultural weed. Soybeans, corn, peanuts, grain sorghum (Anderson, 1999) and maize (Meseldžija, 2008) are most affected by this species.

Competition between *A. syriaca* and oats resulted in up to 20% yield loss of grain in Canada (Bhowmik, 1982; CABI, 2015b). Research in Minnesota, USA, revealed that wheat (*Triticum aestivum*) yield reduction occurred as a result of *A. syriaca* competition (Yenish et al., 1997). In certain regions of Serbia, the plant has negatively impacted both reclaimed and abandoned orchards and vineyards, and spring barley, sunflower and rapeseed crops (Dolmagić, 2010; Nikolic & Popov, 2013). The potential negative impact to cultivation systems in this region of Serbia was judged to be high with a low level of uncertainty (Nikolic & Popov, 2013).

Cultivation systems

The fine hairs attached to *A. syriaca* seeds can clog air intakes on combine harvesters (Anderson, 1999; CABI, 2015b).

Effects on animal health and production targets

No information on the effects of *A. syriaca* pathogens or parasites on animal health and production targets could be found during a search of available literature.

Hazardous upon contact, host

A. syriaca contains several poisonous glucosidic substances (cardenolides) that are poisonous to turkeys, chickens, sheep, goats, cattle, and occasionally horses (Salyi et al., 1987; Anderson, 1999; Nikolic & Popov, 2013; CABI, 2015b). The entire plant is considered poisonous (Nikolic & Popov, 2013).

Human targets

No information on the effects of *A. syriaca* pathogens and parasites on human targets could be found during a search of available literature.

Hazardous upon contact

A. syriaca is an allergenic species and the milky sap causes contact dermatitis to sensitive individuals. The plant is also poisonous to humans (Konstantinović et al., 2009; Anderson, 1999; Nikolic & Popov, 2013).

Effects on other targets

No information on the effects of *A. syriaca* on infrastructure, bank and dike stability etc. could be found during a search of available literature.

- Ecological risk assessment with the ISEIA protocol

The expert team allocated *A. syriaca* a 'high' ecological risk classification to the categories dispersion potential and invasiveness and colonization of high value conservation habitats, and a ‘medium’ risk classification to the categories adverse impacts on native species and alteration of ecosystem functions (Table 4.22).

The total ecological risk score for the species is 10 out of a maximum of 12. Therefore, *A. syriaca* is classified in the B list of the BFIS list system. The maximum risk score takes into account the limitation on maximum risk score per category that is imposed by the ISEIA protocol if data deficiency occurs or the application of best professional judgement is required (See section 2.4.2). The maximum risk score will, therefore, vary between species. In cases where there is sufficient information, i.e. where there is no data deficiency and best professional judgement is not required, the maximum possible risk score is 12. The rationale for the allocated scores is given in the following paragraphs.

Table 4.22: Consensus scores for potential risks of common milkweed (*Asclepias syriaca*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	High	3
Colonization of high value conservation habitats	High*	3
Adverse impacts on native species	Medium	2
Alteration of ecosystem functions	Medium	2
Ecological risk score		**10**

* Quantitative analysis was focused on Natura 2000 areas may indicate a lower score; however, this species may occur in other areas with high conservation value.

Dispersion potential or invasiveness

Classification: **High risk**. *A. syriaca* is able to grow in temperate / mesothermal climates and tolerates a wide range of climatic conditions. The species reproduces by sexual and vegetative means (underground rootstocks develop adventitious buds which give rise to new individuals). Clonal colonies that develop from a single plant arising from a seed or root segment can comprise several thousand stems (Wilbur, 1976; CABI, 2015b). *A. syriaca* seeds are naturally dispersed by wind on tufts of floss (Bhowmik, 1982; Csontos et al., 2009). High seed production facilitates dispersal over long distances (White, 1996; CABI, 2015b). Seeds may also be spread by motor vehicles (Wyatt et al., 1993). However, the species does not maintain a persistent seed bank in the soil and seeds from preceding years are non-viable (Csontos et al., 2009). Preliminary indications suggest that the species is not able to spread via seeds over long distances and establish in new areas in the Netherlands as most new stands are located in or near urban areas. However, the precautionary principle was applied due to the plant's capacity to disperse in wind and it was concluded that, the species can easily disperse through active and passive means over one kilometre per year and initiate new populations.

Colonization of high value conservation habitats

Classification: **High risk**. *A. syriaca* colonises a variety of habitats from woodlands to dune-lands and cleared grasslands and marshlands and is common in areas of human disturbance such as waste places, fencerows, roadsides, meadows, railways, reduced-tillage fields, and other open habitats (Botta-Dukat, 2008; Csontos et al., 2009; CABI, 2015b; Morse & Schmitt, 1985). *A. syriaca* stands are located in or near urban areas and in dune areas in the Netherlands. However, at least one stand is located in the South-Kennemerland Natura 2000 area showing that the species is capable of establishing in high value conservation habitats.

Adverse impacts on native species
Classification: **Medium risk**. *A. syriaca* is a perennial herb with erect stems that grow to 2 m tall. Anderson (1999) states that *A. syriaca* can be an aggressive and persistent weed. Evetts & Burnside (1975) state that it forms large, dense, persistent populations in mostly disturbed habitats. However, the same authors state that *A. syriaca* is not highly competitive, particularly with respect to light and soil resources (Nikolic & Popov, 2013). According to Beringen (2013), there is little evidence that native species are displaced by *A. syriaca* in the Netherlands.

Alteration of ecosystem functions
Classification: **Medium risk**. *A. syriaca* is not highly competitive, particularly for light and soil resources (Nikolic & Popov, 2013). Roots penetrate the soil by up to 3.8 m and the species may develop large, dense, persistent populations.

Risk classification according to the BFIS list system
The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.22) in combination with the current recorded distribution in the Netherlands. The species classification for *A. syriaca* is B2 (Figure 4.19). This characterises a non-native species that displays a restricted range in the area under assessment, poses a moderate ecological risk and is placed on the watch list of the BFIS list system.

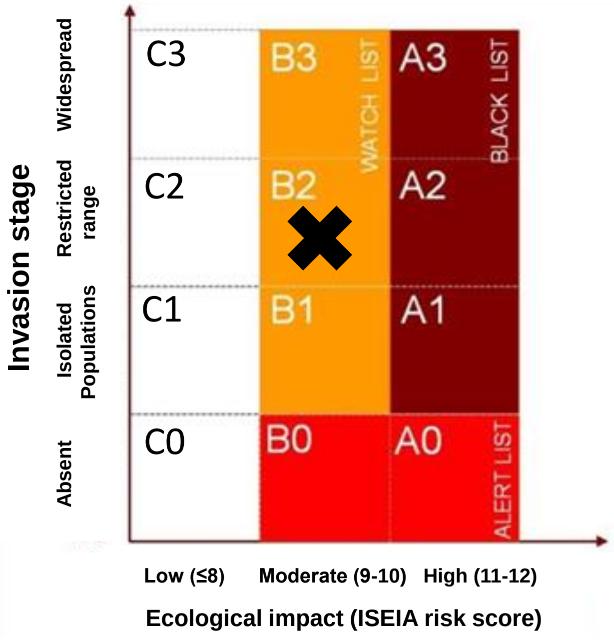

Figure 4.19: Risk classification of common milkweed (*Asclepias syriaca*) according to the BFIS list system.

- Other risk assessments and classifications

  A. syriaca is classified as a noxious species whose introduction and spread must be controlled in Spain (Maillet & Zaragoza, 2002). *A. syriaca* is classified as a prohibited noxious weed in Australia (Pheloung et al., 1999). *A. syriaca* was classified as a high risk species in Switzerland and added to the EPPO list of invasive alien plants as a result of an assessment carried out in Serbia (Table 4.23).

Table 4.23: Overview of risk classifications previously performed for common milkweed (*Asclepias syriaca*).

	Switzerland	**Serbia (Vojvodina)**
Scope	Risk assessment method	Risk prioritisation method
Method	Risk assessment scheme for assessing the invasion potential of environmental weeds in central Europe.	EPPO risk prioritisation
Year	2004	2013
Risk classification	**31 (high risk)**	**Added to the EPPO list of invasive alien plants**
Source	Weber & Gut (2004)	Nikolic & Popov (2013)

4.6 Boraginaceae

4.6.1 Russian comfrey (*Symphytum* x *uplandicum*)

- Species description

Russian comfrey (*Symphytum* x *uplandicum*) is the hybrid of native *Symphytum officinale* L. and *S. asperum* Lepech. that originates in the Caucasus. *S.* x *uplandicum* is a densely branched, tall plant featuring large, hairy leaves that are more or less rhomboid shaped, with wings that run down the stem (Figure 4.20). *S.* x *uplandicum* produces small, tube like flowers in varying colours that are treated as varieties (NNSS, 2015). A number of varieties of *S.* x *uplandicum* have been produced, for example 'variegatum', 'moorland heather', 'axminster gold' and 'bocking 14'. The variety 'bocking 14' is sterile (Cox, 2014).

Figure 4.20: Russian comfrey *(Symphytum* x *uplandicum)*. (Photo: Hans van der Mheen).

Life cycle

No information on the life cycle of *S.* x *uplandicum* could be found during the literature study.

Reproductive capacity

In the UK, most reproduction is thought to occur vegetatively, however varying degrees of fertility in naturalised populations suggest that some sexual reproduction may occur (NNSS, 2015).

Species taxonomy

Table 4.24: Nomenclature and taxonomical status of Russian comfrey (*Symphytum* x *uplandicum*).

Scientific name:
Symphytum x *uplandicum* Nyman (1855)

Synonyms:
Symphytum peregrinum Ledeb.
Symphytum officinale x *asperum*

Taxonomic tree (Catalogue of Life, 2015):
Kingdom: Plantae
Phylum: Tracheophyta
Class: Magnoliopsida
Order: Boraginales
Family: Boraginaceae
Genus: *Symphytum*
Species: *Symphytum* x *uplandicum*

Preferred Dutch name:
Bastaardsmeerwortel

Preferred English name:
Russian comfrey

Other Dutch names:
Smeerwortel hybride

Other English names:
Quaker comfrey, blue comfrey, upland comfrey

- Habitat summary

In its native range, *S.* x *uplandicum* normally grows on disturbed ground associated with wetlands. In the United Kingdom it most frequently occurs along the banks and in the floodplains of large rivers, but also occurs at roadsides and on disturbed ground (NNSS, 2015). What originally was an ornamental species in many countries of Europe has often escaped and established outside cultivation. In the European part of Russia *S.* x *uplandicum* was seen to grow individually or in small groups. Large stands were found in forest clearings. Plants were very tall at this location (up to 1.7 m) and abundantly flowered. The plants were observed to flower twice per year (Borissova, 2006). *S.* x *uplandicum* has been recorded in pine–birch–spruce forest, herbaceous spruce forest and herbaceous spruce forest in Russia (Borissova, 2006).

- Recorded distribution

Native range

S. x *uplandicum* is thought to have originated from the Caucasus (NNSS, 2015) (Figure 4.21).

Cultivated range

S. x *uplandicum* has been cultivated as a crop for hundreds of years (NNSS, 2015). Limited information is available on the cultivated range of *S.* x *uplandicum.* However, the plant is cultivated in the United Kingdom, the United States of America and Canada (New Crop Resource Online Program, 2015).

Non-native range

S. x *uplandicum* is locally invasive in the Ivanovo region of the upper Volga basin, Russia (Borissova, 2006). The plant has been recorded in the Czech Republic, Denmark, Germany, Finland, France, Great Britain, Ireland, Lithuania, the Netherlands, Norway, Portugal (The Azores), Sweden, Austria, Belgium, Luxembourg, New Zealand, Australia, Japan, Brazil (NNSS, 2015; EPPO, 2013b; USDA, 2015f; GBIF, 2015) (Figure 4.21).

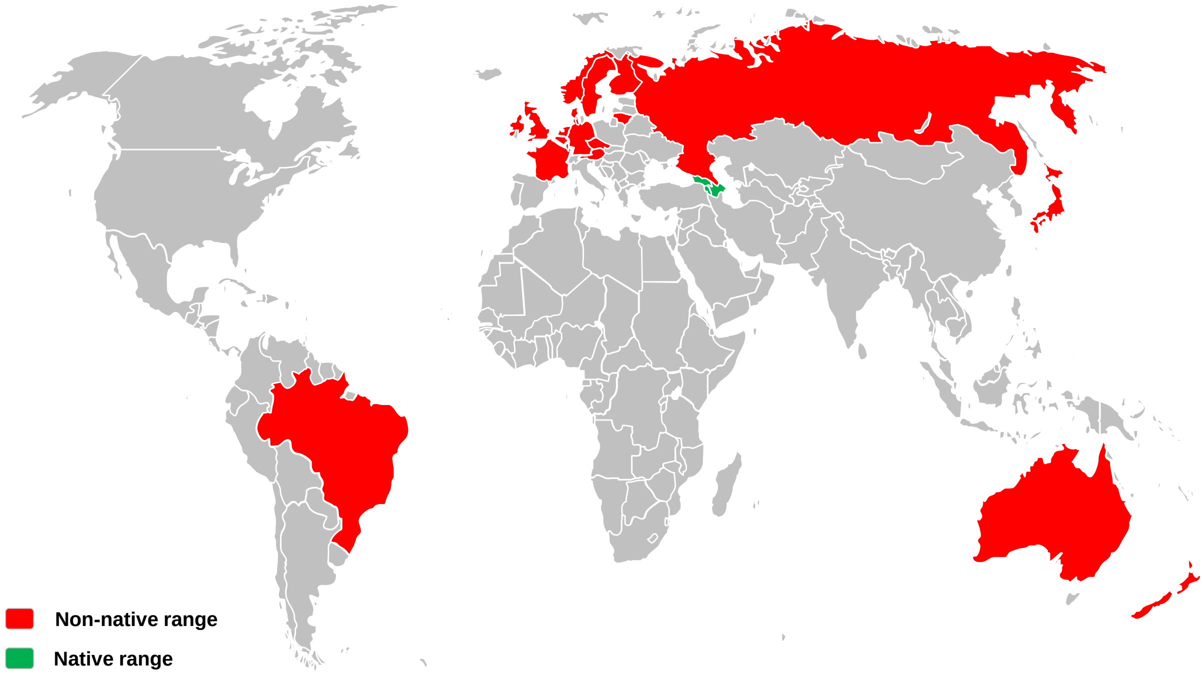

Figure 4.21: Current global recorded distribution of Russian comfrey (*Symphytum* x *uplandicum*) (Sources: NNSS, 2015; EPPO, 2015; USDA, 2015f; GBIF, 2015).

Distribution in the Netherlands

The distribution of *S.* x *uplandicum* in the Netherlands is poorly known due to issues with identification and hybridization. *S.* x *uplandicum* exhibits two chromosome numbers (2n = 36 and 2n = 40). Plants with chromosome number 2n = 40 are able to backcross with native *S. officinale*. The plants of this hybrid group are difficult to identify and may be labelled as either *S. officinale* or *S. asperum* (Gadella, 1978).

Moreover, confusion may occur with other species present in the plant trade such as *S. caucasium* and *S. grandiflorum*.

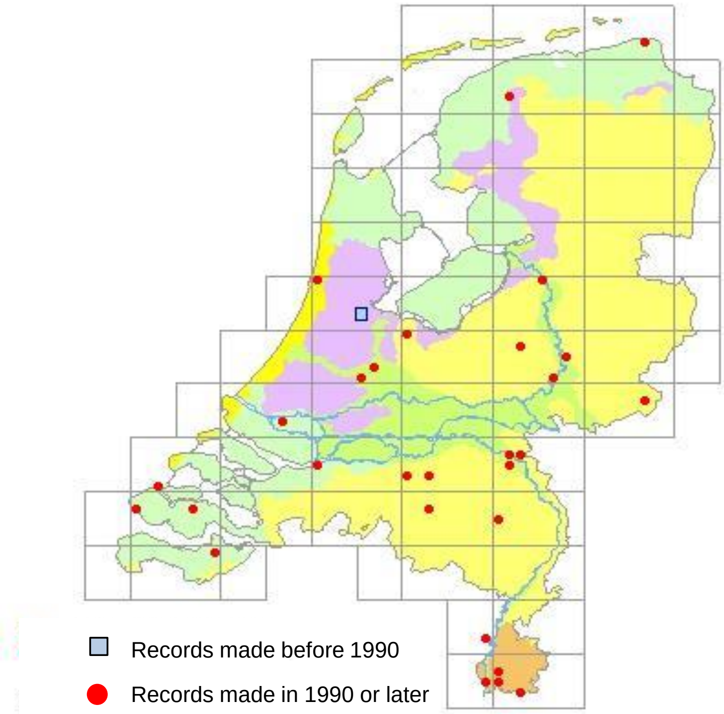

Figure 4.22: Current recorded distribution of Russian comfrey (*Symphytum* x *uplandicum*) in the Netherlands. Source: NDFF (2015h).

Most records identified as *S.* x *uplandicum* occurred in the southern half of the Netherlands. The plants have been recorded both inside and outside urban areas. Records have occurred at roadsides, forest edges and in vacant lots. In total, records exist for 28 km squares in the Netherlands (Figure 4.22).

Colonisation of high conservation value habitats
No confirmed recordings of *S.* x *uplandicum* exist for Natura 2000 areas in the Netherlands.

- Invasion process

Introduction outside cultivated land
S. x *uplandicum*, and / or *S. asperum* were grown in Europe in the past and used as a feed plant in the Netherlands. *S.* x *uplandicum* is currently marketed as an ornamental plant in the Netherlands.

Establishment
No information on the establishment of *S.* x *uplandicum* outside cultivated land could be found during a search of available literature.

Spread

S. x *uplandicum* reproduces mainly vegetatively through fragmentation and possibly also by seed which is carried in soil and silt carried by rivers. The common garden cultivar is sterile (NNSS, 2015), but may be spread by plant fragments present in garden refuse. *S.* x *uplandicum* spreads rapidly through rhizomes in the Netherlands.

- Environmental impacts summary

Effects on environmental targets or native species

No information on the effects of parasitism, pathogens or parasites of *S. x uplandicum* on environmental targets or native species could be found during a search of available literature.

Competition

In the UK, it is possible that monocultures could result from stoloniferous spread of *S.* x *uplandicum* resulting in the exclusion of native plants; however, there is no available evidence for this. In the UK, *S.* x *uplandicum* co-exists with common comfrey (*Symphytum officinale*) and out-competes other non-native species (NNSS, 2015). *S.* x *uplandicum* may be an important species for insect pollinators i.e. bees and butterflies (Cole et al., 2014).

Interbreeding

S. x *uplandicum* interbreeds with *Symphytum officinale* or ‘gewone smeerwortel’ in Dutch (Flowers in Sweden.com). *S. officinale* is a widespread and frequently occurring Dutch native species (NDFF, 2015a).

Effects on ecosystem function targets

No information on the biotic and abiotic effects of *S. x uplandicum* on ecosystem function targets could be found during a search of available literature.

Effects on plant targets in cultivation systems

No information on the effects of *S. x uplandicum* on plant targets in cultivation systems could be found during a search of available literature.

Effects on animal health and production targets

No information on the effects of *S. x uplandicum* on animal health and production targets could be found during a search of available literature.

Human targets

No information on the effects of *S. x uplandicum* on human targets could be found during a search of available literature.

Effects on other targets

No information on the effects of *S. x uplandicum* on infrastructure could be found during a search of available literature.

- Ecological risk assessment with the ISEIA protocol

The expert team allocated *S. x uplandicum* a 'high' ecological risk classification to the categories dispersion potential and invasiveness, and colonisation of high value conservation habitats, a ‘medium’ risk classification to the category adverse impacts on native species and a ‘likely’ risk classification to the category alteration of ecosystem functions (Table 4.25).

The total ecological risk score for the species is 10 out of a maximum of 11. Therefore, *S. x uplandicum* is classified in the B list of the BFIS list system. The maximum risk score takes into account the limitation on maximum risk score per category that is imposed by the ISEIA protocol if data deficiency occurs or the application of best professional judgement is required (See section 2.4.2). The maximum risk score will, therefore, vary between species. In cases where there is sufficient information, i.e. where there is no data deficiency and best professional judgement is not required, the maximum possible risk score is 12. The rationale for the allocated scores is given in the following paragraphs.

It should be noted that the risk score for the category alteration of ecosystem functions is based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

Table 4.25: Consensus scores for potential risks of Russian comfrey (*Symphytum x uplandicum*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	High	3
Colonization of high value conservation habitats	High*	3
Adverse impacts on native species	Medium	2
Alteration of ecosystem functions	Likely	2
Ecological risk score		**10**

* Quantitative analysis was focused on Natura 2000 areas may indicate a lower score; however, species may also occur in other areas with high conservation value.

Dispersion potential or invasiveness

Classification: **High risk**. *S.* x *uplandicum* is currently marketed as an ornamental plant in the Netherlands and has escaped from gardens to Dutch nature. The plants have been recorded both inside and outside urban areas. Records have occurred at roadsides, forest edges and in vacant lots. However, the distribution of *S.* x *uplandicum* in the Netherlands is poorly known due to issues with identification and hybridization. In total, records exist for 28 km squares in the Netherlands. The number of km squares within which *S.* x *uplandicum* is recorded per year appears to show an upward trend. Garden escapes of *S.* x *uplandicum* and subsequent establishment has occurred in many European countries. The plant has been recorded in the Czech Republic, Denmark, Germany, Finland, France, Great Britain, Ireland, Lithuania, the Netherlands, Norway, Portugal (The Azores), Sweden, Austria, Belgium, Luxembourg, New Zealand, Australia, Japan, Brazil (NNSS, 2015; EPPO, 2013a; USDA-NRCS, 2015; GBIF, 2015). *S.* x *uplandicum* reproduces mainly vegetatively through fragmentation, possibly also by seed which is carried in soil and silt carried by rivers (hydrochory), and exhibits extensive rhizome growth. However, the common garden cultivar is sterile (NNSS, 2015). In the UK, most reproduction is thought to occur vegetatively, however varying degrees of fertility in naturalized populations suggests that some sexual reproduction may occur (NNSS, 2015). In conclusion, the species is highly fecund, can easily disperse through active or passive means over distances > 1 km/year and initiate new populations in the Netherlands.

Colonization of high value conservation habitats
Classification: **High risk**. In the Netherlands, the plants have been recorded both inside and outside urban areas. Records have occurred at roadsides, forest edges and in vacant lots. However, there are no confirmed records of *S.* x *uplandicum* in N2000 areas. In the United Kingdom *S.* x *uplandicum* most frequently occurs along the banks and in the floodplains of large rivers (NNSS, 2015). In the European part of Russia large stands were found in forest clearings. Here the plants were very tall (up to 1.7 m) and abundantly flowered. In Russia, *S.* x *uplandicum* has been recorded in pine–birch–spruce forest, herbaceous spruce forest and herbaceous spruce forest (Borissova, 2006). Although there are no confirmed records of *S.* x *uplandicum* in N2000 areas in the Netherlands, the species preference for the banks and floodplains of large rivers in the U.K. suggests that the plant will colonize similar high value conservation habitats in the Netherlands.

Adverse impacts on native species
Classification: **Medium risk**. *S.* x *uplandicum* exhibits two chromosome numbers (2n = 36 and 2n = 40). Plants with chromosome number 2n = 40 are able to backcross with *S. officinale*, a Dutch native species. In the U.K., *S.* x *uplandicum* co-exists with common comfrey (*Symphytum officinale*) and out-competes other non-native species (NNSS, 2015). *S.* x *uplandicum* may be an important species for insect pollinators i.e. bees and butterflies (Cole et al., 2014). Therefore competition for pollinators between *S.* x *uplandicum* and Dutch native species may occur. Due to the potential for hybridization, there is a medium risk that *S.* x *uplandicum* will impact Dutch native species.

Alteration of ecosystem functions

Classification: **Likely**. *S.* x *uplandicum* may be an important species for insect pollinators i.e. bees and butterflies (Cole et al., 2014). Therefore, a disruption to natural succession may occur. In the European part of Russia, large stands of *S.* x *uplandicum* were found in forest clearings. Here the plants were very tall (up to 1.7 m) and abundantly flowered. Due to the potential for disruption to natural succession and the size of individual plants that could result in light interception, it is likely that *S.* x *uplandicum* alters ecosystem functions in the Netherlands.

Risk classification according to the BFIS list system

The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.25) in combination with the current recorded distribution in the Netherlands. The species classification for *S. x uplandicum* is B3 (Figure 4.23). This characterises a non-native species that is widespread in the area under assessment, poses a moderate ecological risk and is placed on the watch list in the BFIS list system. However, it should be noted that the actual distribution of *S. x uplandicum* in the Netherlands may be different from the distribution presented in figure 4.22 due to issues with identification and hybridization.

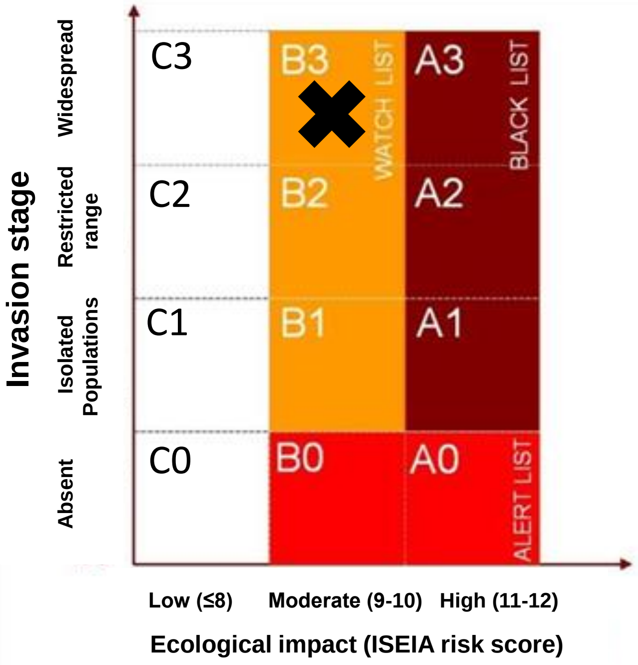

Figure 4.23: Risk classification of Russian comfrey (*Symphytum x uplandicum*) according to the BFIS list system.

- Other risk assessments and classifications

No risk assessments or classifications of *S.* x *uplandicum* could be found during a search of available literature.

4.7 Asteraceae

4.7.1 Cup plant (*Silphium perfoliatum*)

- Species description

The cup plant (*Silphium perfoliatum*) is a perennial plant that grows up to 2.5 m tall (Figure 4.24). The plants form many vertical quadrangular stalks that are covered with leaves and reach a height of up to 3 m (Neumerkel & Märtin, 1982; Wrobel et al., 2013; Gansberger et al., 2015). The number of stalks per plant (10-25 stalks) increases with age. The stalks form 8-12 internodes with a length of 20-30 cm and are filled with a spongy core (Wrobel et al., 2013; Gansberger et al., 2015). The square stems support mostly opposite leaves that are up to 40 cm long and 25 cm wide, triangular to oval with serrated edges and cuplike bases that trap water (Kindscher, 1987; USDA, 2003). The upper surface of the leaf is dark green and roughhairy (Gansberger et al., 2015). Around 8-10 flower heads develop per stem (Neumerkel & Märtin, 1982), each with a diameter of 4-8 cm, and are composed of hermaphrodite bright yellow tubular and ligulate ray flowers. The fruits are green to brown, flat achenes (Kowalski & Wiercinski, 2004; Wrobel et al., 2013), about nine to 15 mm long, 6 to 9 mm wide, and maximum 1 mm thick (Niqueux,1981; Gansberger et al., 2015). There are two recognized varieties of *S. perfoliatum*: var. *connatum*, which has variously hairy stems and var. *perfoliatum* (Minnesotawildflowers.info).

Figure 4.24: Cup plant (*Silphium perfoliatum*) in flower (Photo: Hans van der Mheen).

Species taxonomy

Table 4.26: Nomenclature and taxonomical status of cup plant (*Silphium perfoliatum*).

Scientific name:
Silphium perfoliatum L. (provisionally accepted name)

Synonyms:
Silphium perfoliatum subsp. *perfoliatum*
Silphium perfoliatum f. *perfoliatum*

Taxonomic tree (Catalogue of Life, 2015):
Kingdom: Plantae
Phylum: Tracheophyta
Class: Magnoliopsida
Order: Asterales
Family: Asteraceae
Genus: *Silphium*
Species: *Silphium perfoliatum*

Preferred Dutch name:
Zonnekroon (unofficial)

Preferred English name:
Cup plant

Other Dutch names:
Not applicable

Other English names:
Carpenter’s weed, cup rosinweed

Life cycle

S. perfoliatum grows very slowly following its initial spring germination forming around 12 to 14 leaves arranged in a rosette and a strong branching root stock (Stanford, 1990; Vacek & Repka, 1992; Gansberger et al., 2015). At the end of May in the northern hemisphere, *S. perfoliatum* reaches a height of 116 to 131 cm, as well as attaining complete ground coverage (Daniel & Rompf, 1994; Gansberger et al., 2015). In Europe, bright yellow flowers bloom from July to September (Jabłonski & Kołtowski, 2005; Wrobel et al., 2013). In the flowering period, new flower heads are constantly being formed, every head flowers for approximately 10 to 12 days (Gansberger et al., 2015). Vegetative buds are formed in late summer (Neumerkel et al.,1978; Sokolov & Gritsak, 1972), from which second year growth is initiated (Gansberger et al., 2015).

Reproductive capacity

S. perfoliatum is a facultatively self- or cross pollinator (Neumerkel et al., 1978; Vacek & Repka, 1992; Gansberger et al., 2015). *S. perfoliatum* produces approximately 18 to 30 fruits per flower head (Neumerkel & Märtin, 1982; Niqueux, 1981; Gansberger et al., 2015). The species produces prolific amounts of seed. However, seed germination potential is limited in the Netherlands.

- Habitat summary

S. perfoliatum can be found on moist sandy bottomlands and floodplains, near streambeds (Stanford, 1990), along river valleys and banks, lakesides, ravines (Sokolov & Gritsak, 1972; Vacek & Repka, 1992), and in and around open woodland (Kowalski & Kedzia, 2007; Stanford, 1990; Gansberger et al., 2015). *S. perfoliatum* grows best on fertile, humic soils, in moist, humid areas and on low-lying land (Sokolov & Gritsak, 1972; Gansberger et al., 2015). Hydromorphic soils are unsuitable for this species (Gansberger et al., 2015).

S. perfoliatum is well adapted to varied European climates (Neumerkel & Märtin, 1982). The best temperature for *S. perfoliatum* growth is about 20^{o}C and full sun promotes optimal development (Stanford, 1990) (Table 4.27). Moreover, *S. perfoliatum* is a hardy plant, surviving temperatures as low as −30^{o}C (Gansberger et al., 2015). Longer periods with alternating temperatures provide optimum conditions for the germination of *S. perfoliatum* seeds and spring regrowth begins at a temperature of approximately 5^{o}C or more (Gansberger et al., 2015).

S. perfoliatum has been reported to grow well in agricultural fields with a soil pH of between 5.2 and 5.6 in temperate regions of Chile (Pichard, 2012).

Table 4.27: Physiological conditions tolerated by the cup plant (*Silphium perfoliatum*).

Parameter	Data origin	Occurrence	References
Temperature: growth initiation (^{o}C)	Unknown	5	Gansberger et al. (2015)
Temperature: optimal growth (^{o}C)	Unknown	20	Gansberger et al. (2015)
Temperature minimum (^{o}C)	Unknown	-30	Gansberger et al. (2015)
Rainfall minimum (mm / yr)	Unknown	400-500	Gansberger et al. (2015)
pH	Chile	5.2-5.6	Pichard (2012)
Soil type	Unknown	Fertile, humic	Gansberger et al. (2015)

- Recorded distribution

Native range

S. perfoliatum is native to eastern and central North America and Canada (Ontario and Quebec) (USDA, 2003; Nichols, 2012; USDA, 2015c) (Figure 4.25).

Cultivated range

No information on the cultivated range of *S. perfoliatum* could be found during the literature search.

Non-native range

S. perfoliatum is non-native to Russia, China, Austria, Belgium, Luxembourg, Germany, Poland, Czech Republic, France, Hungary, Italy, Romania and the Ukraine (DAISIE, 2015c; CABI, 2015f; [Catalogue of Life, 2015]) (Figure 4.25).

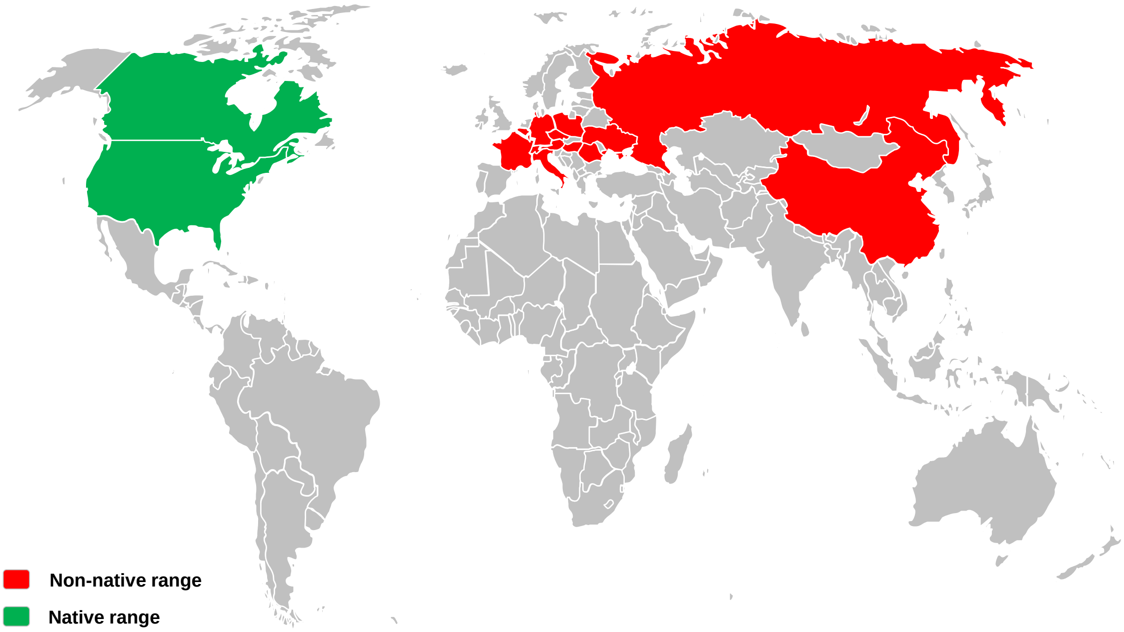

Figure 4.25: Current global cultivation range of cup plant (*Silphium perfoliatum*) (Sources: USDA, 2015h; Nichols, 2012; DAISIE, 2015c; CABI, 2015f; [Catalogue of Life, 2015)].

Distribution in the Netherlands

To date three records of *S. perfoliatum* exist for the Netherlands (Figure 4.26).

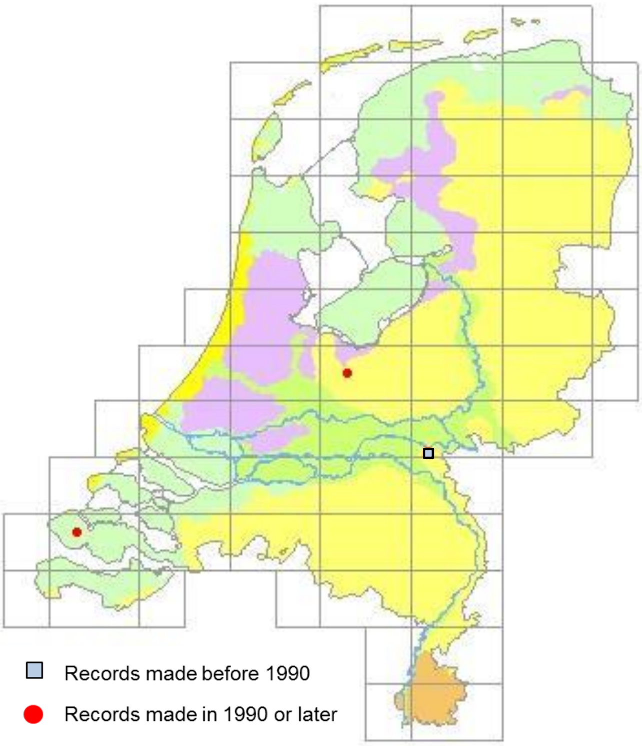

Figure 4.26: Current recorded distribution of cup plant (*Silphium perfoliatum*) in the Netherlands (Source: NDFF, 2015i).

Colonisation of high conservation value habitats
According to the Nationale Databank Flora en Fauna (NDFF, 2015f), there are no current records of *S. perfoliatum* in high conservation value habitats in the Netherlands.

- Invasion process

Introduction outside cultivated land
No information on the introduction of *S. perfoliatum* outside cultivated land could be found during a search of available literature.

Establishment
No information on the establishment of *S. perfoliatum* outside cultivated land could be found during a search of available literature.

Spread
No information on the spread of *S. perfoliatum* outside cultivated land could be found during a search of available literature.

- Environmental impacts summary

Effects on environmental targets or native species
No information on the effects of competition, parasitism, pathogens, parasites or interbreeding of *S. perfoliatum* on environmental targets or native species could be found during a search of available literature.

Effects on ecosystem function targets
No information on the biotic and abiotic effects of *S. perfoliatum* on ecosystem function targets could be found during a search of available literature.

Effects on plant targets in cultivation systems
No information on the effects of *S. perfoliatum* on plant targets in cultivation systems could be found during a search of available literature.

Effects on animal health and production targets
No information on the effects of *S. perfoliatum* on animal health and production targets could be found during a search of available literature.

Human targets
No information on the effects of *S. perfoliatum* on human targets could be found during a search of available literature.

Effects on other targets

No information on the effects of *S. perfoliatum* on infrastructure could be found during a search of available literature.

- Ecological risk assessment with the ISEIA protocol

The expert team allocated *S. perfoliatum* a 'medium' ecological risk classification to the category dispersion potential and invasiveness, and a ‘likely’ risk classification to the categories adverse impacts on native species, alteration of ecosystem functions and colonization of high value conservation habitats (Table 4.28).

The total ecological risk score for the species is 8 out of a maximum of 9. Therefore, *S. perfoliatum* is classified in the C list of the BFIS list system. The maximum risk score takes into account the limitation on maximum risk score per category that is imposed by the ISEIA protocol if data deficiency occurs or the application of best professional judgement is required (See section 2.4.2). The maximum risk score will, therefore, vary between species. In cases where there is sufficient information, i.e. where there is no data deficiency and best professional judgement is not required, the maximum possible risk score is 12. The rationale for the allocated scores is given in the following paragraphs.

It should be noted that the risk scores for adverse impacts on native species, alteration of ecosystem functions and colonization of high value conservation habitats are based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

Table 4.28: Consensus scores for potential risks of cup plant (*Silphium perfoliatum*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	Medium	2
Colonization of high value conservation habitats	Likely*	2
Adverse impacts on native species	Likely	2
Alteration of ecosystem functions	Likely	2
Ecological risk score		**8**

* Quantitative analysis was focused on Natura 2000 areas may indicate a lower score; however, species may also occur in other areas with high conservation value.

Dispersion potential or invasiveness

Classification: **Medium risk**. *S. perfoliatum* is a facultatively self- or cross pollinator (Neumerkel et al., 1978; Vacek & Repka, 1992; Gansberger et al., 2015). The species produces approximately 18 to 30 fruits per flower head (Neumerkel & Märtin, 1982; Niqueux, 1981; Gansberger et al., 2015) and produces several thousand mostly viable seeds. However, germination potential is limited in the Netherlands.

The best temperature for *S. perfoliatum* growth is about 20 ^{o}C (Stanford, 1990), and is a hardy plant, surviving temperatures as low as −30 ^{o}C (Gansberger et al., 2015). The plant seeds and spring regrowth begins at a temperature of approximately 5 ^{o}C or more (Gansberger et al., 2015). It is native to eastern and central North America and Canada (Ontario and Quebec) (USDA, 2003; Nichols, 2012; USDA, 2015c), and non-native to Belgium, Germany, Poland and France among others (DAISIE, 2015c; CABI, 2015f; Catalogue of Life, 2015). Risk classifications for *S. perfoliatum* range from high risk in New York, U.S.A (Moore, 2009) to 'invasive' for the New England (USA) region (Mehrhoff et al., 2003; Nichols, 2012). However, the species is unlikely to be able to produce seed in the Netherlands due to a suboptimal climate and, therefore, poses a medium risk for dispersion potential and invasiveness in the Netherlands.

Colonization of high value conservation habitats

Classification: **Likely**. *S. perfoliatum* can be found on moist sandy bottomlands and floodplains, near streambeds (Stanford, 1990), along river valleys and banks, lakesides, ravines (Sokolov & Gritsak, 1972; Vacek & Repka, 1992), and in and around open woodland (Kowalski & Kedzia, 2007; Stanford, 1990; Gansberger et al., 2015). *S. perfoliatum* grows best on fertile, humic soils, in moist, humid areas and on low-lying land (Sokolov & Gritsak, 1972; Gansberger et al., 2015). According to the Nationale Databank Flora en Fauna (NDFF, 2015f), there are no current records of *S. perfoliatum* in the Netherlands. However, certain high value conservation habitats, such as river banks and floodplains, are likely to be suitable habitats for *S. perfoliatum* colonisation.

Adverse impacts on native species

Classification: **Likely**. At the end of May in the northern hemisphere, *S. perfoliatum* reaches a height of 116 to 131 cm, as well as attaining complete ground coverage (Daniel & Rompf, 1994; Gansberger et al., 2015). It is also a perennial species. *S. perfoliatum* was classified as a high risk species in New York, U.S.A (Moore, 2009), and Mehrhoff et al. (2003) refer to *S. perfoliatum* as an invasive species for the New England (USA) region (Nichols, 2012). In view of its growth characteristics and risk classifications from climatically similar regions to the Netherlands, It is likely that *S. perfoliatum* will adversely impact native species in the Netherlands.

Alteration of ecosystem functions

Classification: **Likely**. At the end of May in the northern hemisphere, *S. perfoliatum* reaches a height of 116 to 131 cm, as well as attaining complete ground coverage (Daniel & Rompf, 1994; Gansberger et al., 2015). It is also a perennial species. *S. perfoliatum* was classified as a high risk species in New York, U.S.A (Moore, 2009), and Mehrhoff et al. (2003) refer to *S. perfoliatum* as an invasive species for the New England (USA) region (Nichols, 2012). In view of its growth characteristics and risk classifications from climatically similar regions to the Netherlands, It is likely that *S.*

perfoliatum will adversely alter ecosystem functions in the Netherlands, at least through the shading out of other plants in suitable habitats.

Risk classification according to the BFIS list system

The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.28) in combination with the current recorded distribution in the Netherlands. The species classification for *S. perfoliatum* is C1 (Figure 4.27). This characterises a non-native species that features isolated populations in the area under assessment, poses a low ecological risk and is not classified in the BFIS list system.

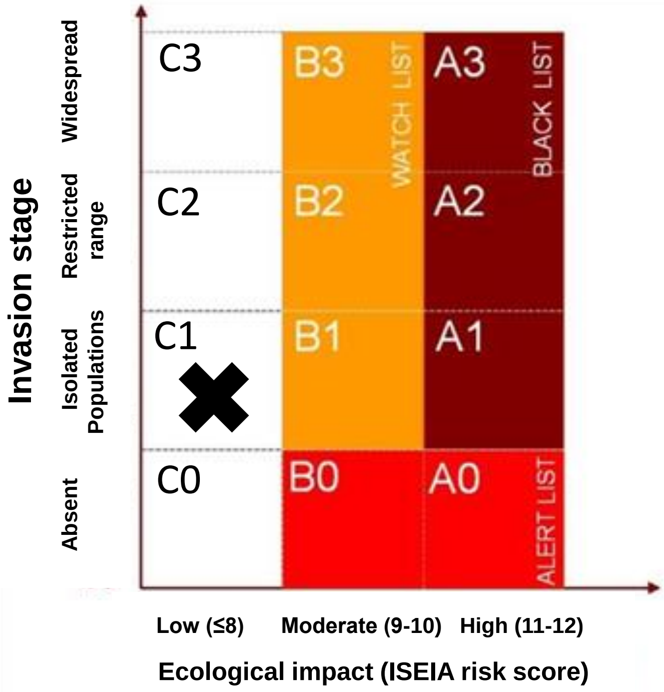

Figure 4.27: Risk classification of cup plant (*Silphium perfoliatum*) according to the BFIS list system.

- Other risk assessments and classifications

S. perfoliatum was classified as a high risk species following risk prioritisation in New York, U.S.A (Moore, 2009) (Table 4.29). Mehrhoff et al. (2003) refers to *S. perfoliatum* as an invasive species for the New England (USA) region (Nichols, 2012).

Table 4.29: Overview of risk classifications previously performed for cup plant (*Silphium perfoliatum*).

	New York (USA)
Scope	Risk prioritisation method
Method	New York non-native plant invasiveness ranking form
Year	2009
Risk classification	**High (77.78)**
Source	Moore (2009)

4.8 Poaceae

4.8.1 Big bluestem (*Andropogon gerardii*)

- Species description

Big bluestem (*Andropogon gerardii*) is a tall, perennial, C4 grass (Adam et al., 2000; Tompkins et al., 2010) (Figure 4.28). The plant features scaly rhizomes that lie 2.5 to 5 cm below the soil surface, and roots that extend to 3 metres. It can grow 180-240 cm tall, and is generally shorter in the northernmost part of its range. Leaves range from 15-60 cm in length. The seed heads are formed of 2-6 (usually 3) blooming racemes. The oblong shaped, fluffy seeds are less than 0.6 cm long (Owsley, 2011).

Figure 4.28: Big bluestem (*Andropogon gerardii*) (Source: Matt Lavin, 2009; Wikimedia Commons).

The United States Natural Resources Conservation Service (NRCS) Plants Materials Program (PMC) has released a number of cultivars of *A. gerardii*. The cultivar 'Bison' was produced for its adaptation to northern climates. Its use ranges from erosion control, upland game bird cover and nesting, nature trails to rural beautification. The ‘Eldorado’ and ‘Earl’ cultivars were released for their forage potential. Other cultivars include ‘Kaw’, ‘Niagara’ and ‘Rountree’ (USDA, 2006).

Species taxonomy

Table 4.30: Nomenclature and taxonomical status of Big bluestem (*Andropogon gerardii*).

Scientific name:
Andropogon gerardii Vitman (1792)

Synonyms:
Not applicable

Taxonomic tree (Catalogue of Life, 2015):
Kingdom: Plantae
Phylum: Tracheophyta
Class: Liliopsida
Order: Poales
Family: Poaceae
Genus: *Andropogon*
Species: *Andropogon gerardii*

Preferred Dutch name:
Baardgras (unofficial)

Preferred English name:
Big bluestem

Other Dutch names:
Not applicable

Other English names:
Bluejoint, Bluejoint beardgrass, turkeyfoot

Life cycle

Flowering occurs from July to October in North America (Owsley, 2011).

Reproductive capacity

A. gerardii is a self-incompatible and wind pollinated plant featuring no identifiable adaptation for the dispersal of seed (McKone et al., 1998).

- Habitat summary

A. gerardii grows best in full sun or partial shade, prefers moist, well-drained sandy and clay loam soils and tolerates low fertility soils. In its native North America, *A. gerardii* is a major component of the tall grass vegetation that characterised the prairies of the central and eastern USA. It is a common grass in the understory of the longleaf pine (*Pinus palustris*) communities of the south-eastern USA (Owlsey, 2011).

Limited information was available on the physiological tolerances of *A. gerardii* therefore table 4.31 gives an overview of the physiological conditions tolerated by *A. gerardii* and *A. gerardii* var. *gerardii* under cultivation. It is assumed that *A. gerardii* var. *gerardii* is representative for the tolerances of *A. gerardii. A. gerardii* requires a soil temperature above 10 °C for germination (Owlsey, 2011). While *A. gerardii* var. *gerardii* is reported to tolerate minimum temperatures of -15 ^{o}C at rest and -5 ^{o}C during early growth. *A. gerardii* var. *gerardii* prefers high light intensities at latitudes of 35^{o} and is able to grow in direct sunlight at latitudes 60^{o} (Ecocrop, 2015a). Rainfall for optimal *A. gerardii* var. *gerardii* growth is reported to be between 700 and 1200 mm annually. *A. gerardii* var. *gerardii* can tolerate a minimum of 350 mm and maximum of 2800 mm annual rainfall (Ecocrop, 2015a).

A. gerardii var. *gerardii* grows best in well drained soils of medium texture and moderate fertility (Ecocrop, 2015a). Optimal soil depth for *A. gerardii* var. *gerardii* rooting ranges from 50 to 150 cm and the plant roots at soil depths of between 20 and 50 cm (Ecocrop, 2015a). In a North American study by Tompkins et al. (2010) soil pH at eight sites of abundant *A. gerardii* growth ranged from 5.8 to 6.9. *A. gerardii* var. *gerardii* is reported to be able to tolerate pH values ranging from 4.5 to 7.6 and grows optimally in soils ranging from pH 5.5 to 6.5 (Ecocrop, 2015a). *A. gerardii* var. *gerardii* is able to tolerate soil salinities to a maximum of 4 deci Siemens per metre (dS/m) (Ecocrop, 2015a).

Table 4.31: Physiological conditions tolerated by big bluestem (*Andropogon gerardii* var. *gerardii*).

Parameter	Optimal	Absolute limit	References
Temperature (germination ^{o}C)	-	>10	Owlsey (2011)[1]
Killing temp. during rest (^{o}C)	-	-15	Ecocrop (2015a)
Killing temp. early growth (^{o}C)	-	-5	Ecocrop (2015a)
Light intensity	Very bright	Clear skies	Ecocrop (2015a)
Rainfall (annual - mm)	700-1200	350-2800	Ecocrop (2015a)
Latitude (Degrees)	35	60	Ecocrop (2015a)
Soil pH	5.5-6.5	4.5-7.6	Ecocrop (2015a)
Soil depth (cm)	50-150	20-50	Ecocrop (2015a)
Soil texture	Medium	Medium	Ecocrop (2015a
Soil fertility	Moderate	Moderate	Ecocrop (2015a)
Soil salinity (dS/m)	<4	4	Ecocrop (2015a)
Soil drainage	Well (dry spells)	Well (dry spells)	Ecocrop (2015a)

[1] Tolerances specific to *Andropogon gerardii*

A. gerardii appears to tolerate poorer soil conditions than some of its competitors. Low resource availability favours *A. gerardii* when compared to other more competitive grass species such as Indian grass (*Sorghastrum nutans*) (Silletti & Knapp, 2001; Tompkins et al., 2010). However, *A. gerardii* depends on soil mycorrhizal fungi for optimum growth in conditions of limited plant-available phosphorus (Anderson et al., 1994). *A. gerardii* is extremely drought tolerant and instead of initiating complete leaf senescence, the foliage tolerates drought stress, maintaining the capacity to recover photosynthetically under wetter conditions (Knapp, 1985). *A. gerardii* growth is strongly dependent on soil temperature, independent of air temperature. In greenhouse experiments it was found that relative growth rate of *A. gerardii* was maximum at 25 °C soil temperature, and decreased at higher and lower temperatures when air temperature remained constant (DeLucia et al., 1992). Supplementary to favourable physiological conditions, *A. gerardii's* presence may also be related to having a nearby seed source and periodic disturbance (Tompkins et al., 2010).

Future changes related to climate change may affect *A. gerardii* growth and development. Biomass production of *A. gerardii* has been observed to be higher under elevated CO_2 levels in years with substantial water stress due to a more efficient use of water (Owensby et al., 1993; Adam et al., 2000). Effects of elevated CO_2 may only be measurable during times of significant water stress (Knapp et al., 1993). This suggests that increased CO_2 concentration as a result of climate change may only increase *A. gerardii* biomass at times of water shortage. However, in experimentation where all other conditions remained optimal, temperature appears to have a stronger effect than CO_2 in regulating growth and development of *A. gerardii*. Higher CO_2 levels resulted in a lower optimum temperature for growth and developmental processes (Kakani & Reddy, 2007). In this study, plants grown at low temperature had more leaves in the high CO_2, while at optimum and above optimum temperatures more leaves were observed in the low CO_2 treatment. This suggests that temperature and CO_2 increases resulting for climate change may have opposing effects on the biomass production of *A. gerardii*. Kakani & Reddy (2007) observed a decrease in seed number per panicle with decrease/increase in temperature on either side of the optimum of 23.4 ^{o}C independent of CO_2. This suggests that the processes (pollen production, germination, tube growth) leading to fertilization and seed set are mainly sensitive to temperature which could severely hamper the species survival and spread in a given location based on current and projected temperatures (Kakani & Reddy, 2007). Mean temperature of 26 °C was found optimal for most of the vegetative and reproductive components studied suggesting that fertilization processes would be the limiting factor resulting from future temperature increase (Kakani & Reddy, 2007).

- Recorded distribution

Native range
A. gerardii grows in natural and managed ecosystems from the North American Atlantic coast to the Rocky Mountains and from Florida and New Mexico to southern Canada. *A. gerardii* is an important species of the North American tallgrass prairie (Weaver and Fitzpatrick 1934; Tompkins et al., 2010).

Cultivated range
Different varieties of *A. gerardii* are grown across North America due to a variation in photo-sensitivity that leads to variation in management and nutrient status (Kakani & Reddy, 2010).

Non-native range

No information on the non-native range of *A. gerardii* could be found during a search of available literature.

Distribution in the Netherlands

According to the Nationale Databank Flora en Fauna (NDFF, 2015f), there are no current records of *A. gerardii* in the Netherlands.

Colonisation of high conservation value habitats

According to the Nationale Databank Flora en Fauna (NDFF, 2015f), there are no current records of *A. gerardii* in the Netherlands.

- Invasion process

Introduction outside cultivated land

No information on the introduction of *A. gerardii* outside cultivated land could be found during a search of available literature.

Establishment

No information on the establishment of *A. gerardii* could be found during a search of available literature.

Spread

No information on the spread of *A. gerardii* could be found during a search of available literature.

- Environmental impacts summary

Effects on environmental targets or native species

No information on the effects of *A. gerardii* parasitism, interbreeding, pathogens and parasites on environmental targets or native species could be found during a search of available literature.

Competition

No information on the effects of *A. gerardii* competition on native species in the Netherlands or Europe could be found during a search of available literature. Evidence from its North American native range indicates that *A. gerardii* is a dominant grass species of the North American tallgrass prairie (Risser, 1981; Gustafson et al., 2004). In a study of a Kansas prairie, *A. gerardii* cover was negatively correlated with both plant species diversity and evenness, *A. gerardii* was also the most dominant plant species (Silletti & Knapp, 2002). Moreover, *A. gerardii* cultivars exhibit photosynthetic rates higher than those of local North American species (Skeel & Gibson, 1996; Gustafson et al., 2004). In North and South Carolina, data suggest that *A. gerardii* often attains a higher density than other species and dominates sites where it occurs (Tompkins et al., 2010). However, the species may require an initial period of disturbance before it establishes and attains dominance in these US states (Davis et al., 2002; Tompkins et al., 2010).

However, it should be noted that *A. gerardii* exhibits extensive phenotypic and genetic variability throughout its range (McMillan 1959; Gustafson et al., 1999; Gustafson et al., 2004). In an experiment by Gustafson et al. (2004) under glasshouse and field conditions non-local *A. gerardii* were consistently smaller than the local plants suggesting that local adaptations occur within this widespread, genetically diverse and dominant species (Knapp & Rice, 1996; Gustafson et al., 2002; Gustafson et al., 2004).

Effects on ecosystem function targets

No information on the effects of *A. gerardii* on ecosystem integrity and biotic properties could be found during a search of available literature.

Abiotic properties e.g. nutrient cycling, structural modification

A. gerardii has been shown to demonstrate species-specific effects on nutrient cycling and soil community interactions (Wedin & Tilman, 1990; Hobbie, 1992). For example, in an experimental study comparing five perennial grasses, *A. gerardii* had a significantly lower level of N mineralization compared to all but one species, *Schizachyrium scoparium*, and is a superior competitor in Low-N sites (Wedin & Tilman, 1990). The positive feedback created influences nutrient availability in the habitats where the plant naturally occurs (Hobbie, 1992).

Effects on plant targets in cultivation systems

No information on the effects of *A. gerardii* on plant targets in cultivation systems could be found during a search of available literature.

Effects on animal health and production targets

No information on the effects of *A. gerardii* on animal health and production targets could be found during a search of available literature.

Human targets

No information on the effects of *A. gerardii* on human targets could be found during a search of available literature.

Effects on other targets

No information on the effects of *A. gerardii* on infrastructure could be found during a search of available literature.

- Ecological risk assessment with the ISEIA protocol

The expert team allocated *A. gerardii* a 'likely' ecological risk classification to the categories dispersion potential and invasiveness, colonization of high value conservation habitats and alteration of ecosystem functions, and a ‘high’ risk classification to the category adverse impacts on native species (Table 4.32).

The total ecological risk score for the species is 9 out of a maximum possible risk score of 9. Therefore, *A. gerardii* is classified in the B list of the BFIS list system. The maximum risk score takes into account the limitation on maximum risk score per category that is imposed by the ISEIA protocol if data deficiency occurs or the application of best professional judgement is required (See section 2.4.2). The maximum risk score will, therefore, vary between species. In cases where there is sufficient information, i.e. where there is no data deficiency and best professional judgement is not required, the maximum possible risk score is 12. The rationale for the allocated scores is given in the following paragraphs.

It should be noted that the risk scores for the categories dispersion potential and invasiveness, colonization of high value conservation habitats and alteration of ecosystem functions are based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

Table 4.32: Consensus scores for potential risks of big bluestem (*Andropogon gerardii*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	Likely	2
Colonization of high value conservation habitats	Likely*	2
Adverse impacts on native species	High	3
Alteration of ecosystem functions	Likely	2
Ecological risk score		**9**

* Quantitative analysis was focused on Natura 2000 areas may indicate a lower score; however, this species may also occur in other areas with high conservation value.

Dispersion potential or invasiveness

Classification: **Likely**. *A. gerardii* is a self-incompatible and wind pollinated plant featuring no identifiable adaptation for the dispersal of seed (McKone et al., 1998). Invasiveness may increase in future as the plant tolerates drought stress and higher production at higher CO_2 levels. However, there is limited information on the risk of dispersion and invasiveness of *A. gerardii* in the Netherlands and in climatically similar countries.

Colonization of high value conservation habitats

Classification: **Likely**. According to expert judgement, a climate match between the Netherlands and other regions where *A. gerardii* is established, and its natural geographical range, indicates that colonisation of high conservation value habitats may be possible (e.g., in areas with sandy soils). The species occurs in full sun or partial shade, prefers moist, well-drained sandy and clay loam soils and tolerates low fertility soils. It is a major component of the tall grass vegetation and a common grass in the understory of the longleaf pine communities of the south-eastern USA (Owlsey, 2011).

Adverse impacts on native species

Classification: **High risk**. *A. gerardii* is a very dominant grass species of the North American tallgrass prairie (Gustafson et al., 2004; Risser, 1981; Silletti & Knapp, 2002; Tompkins et al., 2010). In a study of a Kansas prairie, *A. gerardii* cover was negatively correlated with both plant species diversity and evenness, *A. gerardii* was also the most dominant plant species (Silletti & Knapp, 2002). Moreover, *A. gerardii* cultivars exhibit photosynthetic rates higher than those of local North American species (Skeel & Gibson, 1996; Gustafson et al., 2004) and the species often attains a higher density than other species and dominates sites where it occurs (Tompkins et al., 2010). It should be noted that *A. gerardii* exhibits extensive phenotypic and genetic variability throughout its range (McMillan 1959; Gustafson et al., 1999; Gustafson et al., 2004).

Alteration of ecosystem functions

Classification: **Likely risk**. According to expert judgement, alteration of ecosystem functions by *A. gerardii* may be expected because it is a tall (180-240 cm), perennial grass with scaly rhizomes, roots that extend to 3 metres. *A. gerardii* is a dominant species and reaches high densities.

Risk classification according to the BFIS list system

The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.32) in combination with the current recorded distribution in the Netherlands.

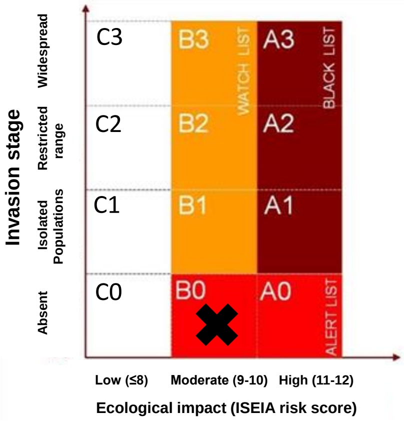

Figure 4.29: Risk classification of big bluestem (*Andropogon gerardii*) according to the BFIS list system.

The species classification for *A. gerardii* is B0 (Figure 4.29). This characterises a non-native species that is absent from the area under assessment and poses a moderate ecological risk that should be placed on the alert list of the BFIS list system.

- Other risk assessments and classifications

  No information on available risk assessments and classifications of *A. gerardii* could be found during a search of available literature.

4.8.2 Giant reed (*Arundo donax*)

- Species description

Giant reed (*Arundo donax*) is a tall, erect, perennial cane- or reed-like grass. It is the largest of six species in the genus *Arundo* and is one of the tallest grasses (up to 10 m) (Lambert et al., 2010) (Figure 4.30).

Figure 4.30: Giant reed (*Arundo donax*). (Source: Shizhao; Wikimedia Commons).

The root structure is very strong. The fleshy, almost bulbous, creeping horizontal rhizomes form compact bundles from which the fibrous roots grow. The rhizomes usually lie close to the soil surface (usually 5 to 15 cm deep, up to a maximum of 50 cm), while roots can reach more than 100 cm long (Sharma et al., 1998; Lewandowski et al., 2003). The rhizomes give rise to tough, multiple stemmed, hollow, cane-like clumps. Like bamboo, the individual stems or culms are divided by partitions at the nodes. The nodes are 12 to 30 cm in length and reach 1 to 4 cm in diameter, with 2-7 mm thick walls. Single lateral branches develop from the nodes in the second year of growth. The outer surface of the stem is silicaceous, hard and brittle, with a smooth glossy surface that turns pale yellow on maturity. The stems may remain green throughout the year but often fade with semi-dormancy during the winter or in droughts. The pale, blue to green leaves attach to the stem with a broad, heart-shaped, hairy-tufted base. The leaves are 2-6 cm wide at the base, are up to 70 cm or more in length, tapering to a fine tip. The leaves are arranged alternately over the entire stem and are very distinctly two-ranked in a single plane. The closely packed cream to brown-coloured flowers bloom between March and September and display in large, plume-like panicles, 30-65 cm long, at the upper tips of stems. The spikelets and flowering units are comprised of one or more florets enclosed by two bracts or glumes, are several flowered, approximately 1.2 cm long with florets that become successively smaller. The rachilla (the segmented central axis of the spikelet), is glabrous. The more or less unequal glumes are slender, narrow and pointed, and as long as the spikelets. The larger, outer, bract which, along with the palea, contains the florets, are thin and covered with fine hairs. They are upwardly narrowed and the nerves terminate in slender teeth (CABI, 2015f).

A. donax is characterised by a number of cultivars. Cultivars of *A. donax*, which are usually variegated and smaller than the naturally occurring species, include striped giant reed (*A. donax* var. versicolor, also known as cv. 'variegata', 'macrophylla', 'peppermint stick', 'golden chain', ‘versicolor’ and ‘nile fiber’ (Floridata, 2015; Washington State, 2013; United States Plant Patent Application, 2014). Cultivars are being produced that increase the biomass production of *A. donax* to make it more attractive for cultivation. For example the variety ‘nile fiber’, produced in the USA has almost twice as much growth as other ecotypes of *A. donax*, its growth rate can be over 3.5 metres of vertical growth in 25 days, reaching about eight to 10 metres high with a spread of three to five metres, two to three years after planting. Moreover, it displays at least 95 % germination rates of nodal sections and ramets. Typical germination rates for ecotypes of *A. donax* range from 25 to 35 % (United States Plant Patent Application, 2014).

Species taxonomy

Table 4.33: Nomenclature and taxonomical status of Giant reed (*Arundo donax*).

Scientific name:
Arundo donax L. (1753)

Synonyms:
Donax arundinaceus Beauv.
Aira bengalensis (Retz.) J.F.Gmel.
Amphidonax bengalensis Roxb. ex Nees
Amphidonax bengalensis (Retz.) Steud.
Arundo bambusifolia Hook.f.
Arundo bengalensis Retz.
Arundo bifaria Retz.
Arundo coleotricha (Hack.) Honda
Arundo sativa Lam.
Arundo triflora Roxb.
Arundo versicolor P. Mill
Cynodon donax (L.) Raspail
Donax arundinaceus P. Beauv. (Bed)
Donax bengalensis (Retz.) P. Beauv.
Donax bifarius (Retz.) Spreng.
Donax donax (L.) Asch. & Graebn.
Donax sativa (Lam.) J. Presl
Donax sativus C. Presl
Donax versicolor (Mill.) P.Beauv.
Scolochloa donax (L.) Gaudin

Taxonomic tree (Catalogue of Life, 2015):
Kingdom: Plantae
Phylum: Tracheophyta
Class: Liliopsida
Order: Poales
Family: Poaceae
Genus: *Arundo*
Species: *Arundo donax*

Preferred Dutch name:
Pijlriet (unofficial)

Preferred English name:
Giant reed

Other Dutch names:
Mammoetgras

Other English names:
Wild cane, bamboo reed, giant cane, Spanish reed

Life cycle

A. donax has been reported as an asexual reproductive species that produces usually sterile seeds (Lewandowski et al., 2003). Reproduction occurs almost exclusively by vegetative means in most reported cases, either from underground rhizomes or from plant fragments carried downstream that subsequently become rooted resulting in the formation of dense stands (Else, 1996; Herrera & Dudley, 2003; Quinn & Holt, 2008; PIER, 2015). As a result, reed population abundance tends to increase with distance from headwaters (Else, 1996; Lambert et al., 2010). Reproduction occurring when attached stems come into contact with substrate and sprout roots occurs more often in *A. donax's* non-native North American range than other reproductive means (Boland, 2006; CABI, 2015a). It has been reported that plants have been grown in scattered locations from seed collected in Asia (CABI, 2015a). However, the importance of sexual reproduction to the species, as well as seed viability, dormancy, germination and seedling establishment have not been well studied. During vegetative reproduction new shoots sprout from rhizomes most commonly in the spring but can develop in any season. Later emerging shoots do not grow well and often die, probably due to shading (Lewandowski et al., 2003). Growth also occurs in any season, but is highly sensitive to temperature and moisture. *A. donax* exhibits growth rates of 0.3 to 0.7 m per week over a period of several months during the vegetative stage when conditions are favourable (warm and wet months) (Perdue, 1958; Lewandowski et al., 2003). This puts it among the fastest growing terrestrial plants. Young stems are soft, very high in moisture and develop at the full diameter of older canes and further growth involves thickening of the walls (Perdue, 1958; CABI, 2015a).

Reproductive capacity

In its introduced range, vegetative propagation is the key to *A. donax*'s establishment in new locations. The species rarely blooms in the Netherlands and is propagated vegetatively through plant fragments (B. Hendrikx pers. comm.). Rhizome fragments travel between river basins and downstream, dispersing along watercourses, particularly post flooding (CABI, 2015a). In the USA, wild stands of *A. donax* have been reported to yield over 20 tonnes of oven-dry biomass per hectare (Perdue, 1958; CABI, 2015a).

- Habitat summary

A. donax is extremely tolerant to different climates and can survive and grow at almost any time under a wide variety of climatic conditions (Table 4.34). According to CABI (2015a), *A. donax* prefers tropical savannah climates with dry summer; tropical wet and dry savannah climates; temperate/mesothermal climates; warm temperate climates, wet all year; warm temperate climates with dry summers, and warm temperate climates with dry winters. *A. donax* tolerates dry (arid and semi-arid), steppe and desert climates (CABI, 2015a).

On a landscape scale, *A. donax* grows in moist areas, such as along ditches and riverbanks (PIER, 2015). It often occurs on sand dunes near seashores, estuarine environments, even colonizing marine islands after rhizomes are transported from rivers across ocean waters during flooding (Lambert et al., 2010; CABI, 2015a).

Table 4.34: Climates tolerated by giant reed (*Arundo donax*). (Adapted from CABI, 2015a).

Climate	Status	Description
Tropical savannah climate with dry summer	Preferred	< 60mm precipitation driest month (in summer) and < (100 - [total annual precipitation{mm}/25])
Tropical wet and dry savannah climate	Preferred	< 60mm precipitation driest month (in winter) and < (100 - [total annual precipitation{mm}/25])
Dry (arid and semi-arid)	Tolerated	< 860mm precipitation annually
Steppe climate	Tolerated	> 430mm and < 860mm annual precipitation
Desert climate	Tolerated	< 430mm annual precipitation
Temperate/Mesothermal climate	Preferred	Average temp. of coldest month > 0°C and < 18°C, mean warmest month > 10°C
Warm temperate climate, wet all year	Preferred	Warm average temp. > 10°C, Cold average temp. > 0°C, wet all year
Warm temperate climate with dry summer	Preferred	Warm average temp. > 10°C, Cold average temp. > 0°C, dry summers
Warm temperate climate with dry winter	Preferred	Warm temperate climate with dry winter (Warm average temp. > 10°C, Cold average temp. > 0°C, dry winters

The physiological conditions tolerated by *A. donax* are listed in table 4.35. *A. donax* is able to survive harsh Dutch winters. Aboveground portions of the plant die off in the winter and regrowth begins in spring (B. Hendrikx pers. comm.). In general, *A. donax* is able to survive frost, however, if frosts occur after the initiation of spring growth serious damage occurs (Perdue, 1958). Even though *A. donax* is a hydrophyte it can grow in a wide range of moisture conditions, and is commonly referred as a drought resistant species because it is able to tolerate extended periods of severe drought and low atmospheric humidity (Lewandowski et al., 2003). According to CABI (2015a), *A. donax* habitats occur in areas where the mean annual temperature ranges from seven to 29 ^{o}C and at latitudes of seven to 45 degrees (Table 2). It has been recorded at altitudes approaching 4000 m in Ecuador (Solomon, 2011; CABI, 2015a). It tends to favour low gradient slopes (<2% grade) (Duke, 1975).

Table 4.35: Physiological conditions tolerated by giant reed (*Arundo donax*).

Parameter	Range	References
Mean annual temperature (^{o}C)	7-29	CABI (2015a)
Latitude (Degrees)	7-45	CABI (2015a)
Altitude (m)	0-4000	CABI (2015a)
Gradient (%)	<2	Duke (1975)
Rainfall (annual - mm)	300-4000	CABI (2015a)
Soil pH	5.0-8.7	Duke (1975)
Soil texture	Light-medium	CABI (2015a)
Soil fertility	Tolerates low fertility	CABI (2015a
Soil drainage	Moist and well drained to Impeded / seasonally waterlogged	CABI (2015a)

A. donax occurs at locations where annual rainfall ranges from 300 to 4000 mm and prefers soils ranging from moist and well-drained, to those with a water table at or near the surface. *A. donax* is able to grow on heavy clays, river sediments, coarse sands and gravelly soils with a pH between 5.0 and 8.7 (Perdue, 1958; Duke, 1975; CABI, 2015a). It tolerates low quality soils such as saline soils (Lewandowski et al., 2003), however, appears to prefer high nutrient conditions with maximum sunlight. In a greenhouse study, nitrogen addition and soils high in organics had the strongest positive effect on total biomass production. In this experiment, allocation to below-ground structures was significantly increased by nitrogen addition and full sunlight (Lambert et al., 2014).

- Recorded distribution

Native range

A. donax is native to tropical, subtropical and temperate regions of the Old World. Although it is often considered indigenous to the Mediterranean region (Jepson & Hickman, 1993) or to warmer regions of the Old World (Munz, 1959), it may be an ancient introduction to Europe from South Asia (CABI, 2015a) (Figure 4.31).

Cultivated range

A. donax has been cultivated across Asia, southern Europe, North Africa, and the Middle East for thousands of years (Perdue, 1958; Lambert et al., 2010).

Non-native range

The species extends to every continent of the world (Figure 4.31). Table 4.36 gives an overview of the countries where *A. donax* is non-native.

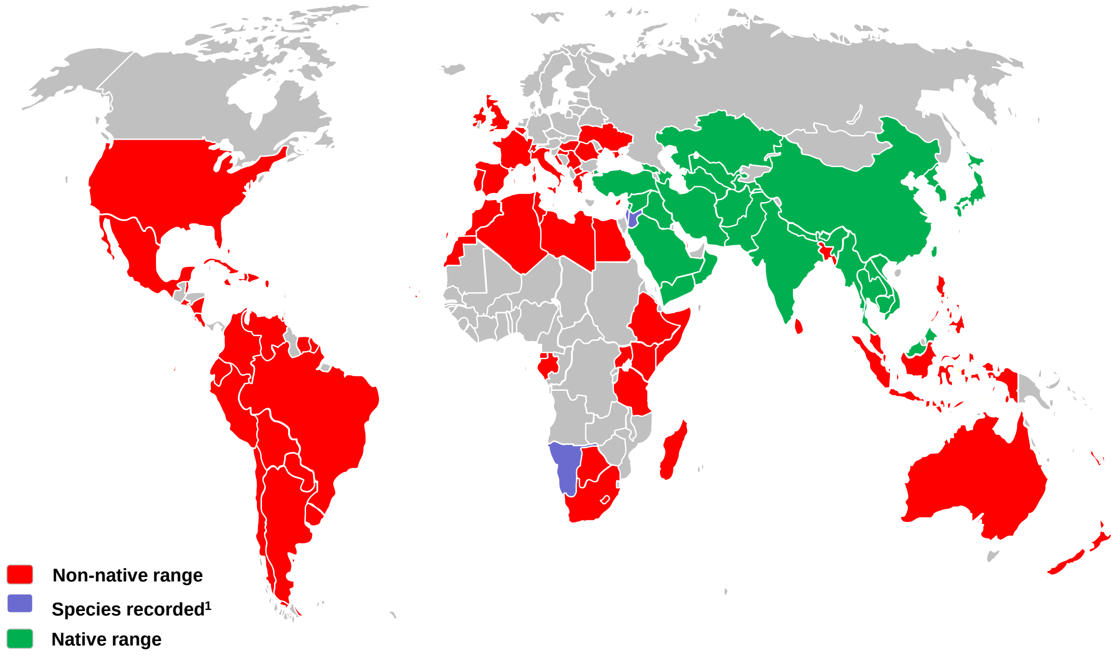

Figure 4.31: Current global recorded distribution of Giant reed (*Arundo donax*) (Sources: CABI, 2015a; DAISIE, 2015a). [1]Range not defined as native or non-native in literature.

Distribution in the Netherlands

According to the Nationale Databank Flora en Fauna (NDFF, 2015f), there are no current records of *A. donax* in the Netherlands. However, a single record of the species has recently been reported growing in more or less dry reed vegetation on the verge between a canal and main road that crosses the border to Belgium (Figure 4.32). The stand extends to approximately 1.5 m^2, is estimated to have been present for a few years and consists of individuals of the natural form i.e. not cultivars (B. Hendrikx, pers. comm.).

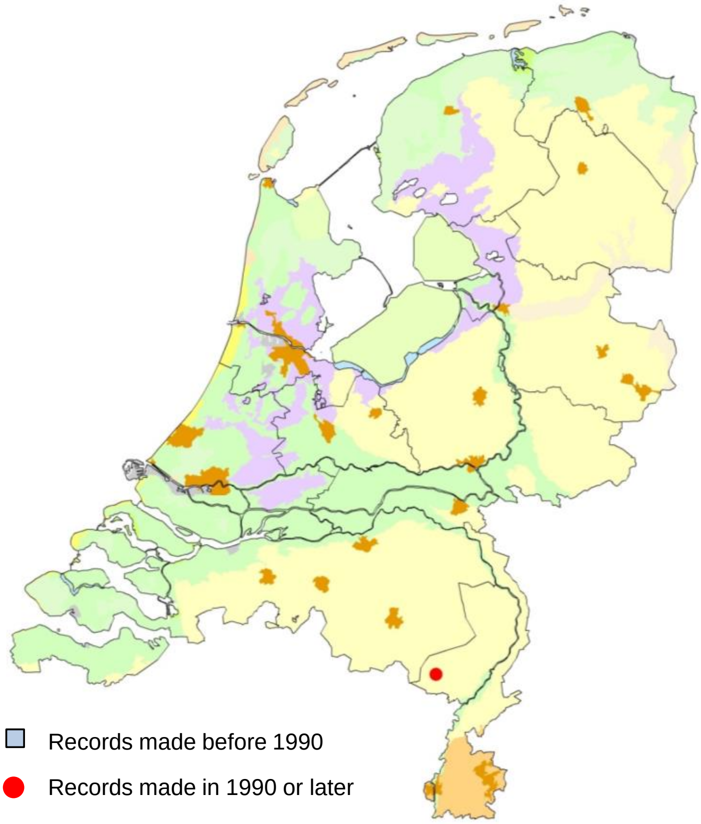

Figure 4.32: Current recorded distribution of Giant reed (*Arundo donax*) in the Netherlands. Source: B. Hendrikx, pers. comm.

Colonisation of high conservation value habitats

There is one record of *A. donax* in the Netherlands (Figure 4.32). However, this location lies outside any Natura 2000 areas.

Table 4.36: Current global non-native distribution of giant reed (*Arundo donax*). Sources: CABI, 2015a; DAISIE, 2015a.

Continent /country	Invasive status
Asia	
Bangladesh	Invasive
Christmas Island (Indian Ocean)	Invasive
Philippines	
Singapore	Invasive
Sri Lanka	
Africa	
Aldabra	
Algeria	
Botswana	
Cape Verde	
Egypt	
Ethiopia	
Kenya	
Lesotho	
Libya	
Madagascar	
Morocco	
Saint Helena	
Seychelles	
Somalia	
South Africa	Invasive
Tanzania	Invasive
Tunisia	
Uganda	Invasive
Western Sahara	
North America	
Bermuda	
Mexico	Invasive
USA	Invasive
Central America and the Caribbean	
Antigua and Barbuda	
Bahamas	
Barbados	
Belize	
Cayman Islands	
Costa Rica	
Cuba	Invasive
Dominica	
Dominican Republic	
El Salvador	
Grenada	
Guadeloupe	
Guatemala	
Haiti	Invasive
Jamaica	
Martinique	
Montserrat	
Nicaragua	
Puerto Rico	Invasive
Saint Kitts and Nevis	
Saint Lucia	Invasive
Saint Vincent and the Grenadines	
Sint Maarten	
Trinidad and Tobago	
United States Virgin Islands	Invasive
South America	
Argentina	Invasive
Bolivia	
Brazil	
Chile	Invasive
Colombia	Invasive
Ecuador	Invasive
French Guiana	
Paraguay	
Peru	
Suriname	
Uruguay	
Venezuela	Not invasive
Europe	
Albania	
Belgium	
Croatia	
Cyprus	
France	
Greece	
Hungary	
Italy	Invasive
Macedonia	
Malta	
Portugal	
Romania	
Serbia	
Spain	
Switzerland	Invasive
UK	
Ukraine	
Yugoslavia (former)	
Yugoslavia (Serbia and Montenegro)	
Oceania	
Australia	Invasive
Cook Islands	
Fiji	Invasive
French Polynesia	Invasive
Guam	
Marshall Islands	
Micronesia, Federated states of	
Nauru	Invasive
New Caledonia	Invasive
New Zealand	Invasive
Niue	
Norfolk Island	Invasive
Northern Mariana Islands	
Palau	Invasive
Samoa	Invasive
Tonga	Invasive
Vanuatu	
Wallis and Futuna Islands	Invasive

- Invasion process

Introduction outside cultivated land
A number of pathways and vectors have been suggested that potentially facilitated the introduction of *A. donax* to its single recorded location in the Netherlands. The planting or spilling of *A. donax* seed is an unlikely pathway as seeds rarely establish in the Netherlands. Moreover, the planting of fragments also seems unlikely due to the difficulty in accessing the location from the road and its visibility to passers by (B. Hendrikx, pers. comm.). The most likely pathway is the deposition of a plant fragment on the canal bank after being transported from Southern Europe attached to the hull of an inland ship (R. Beringen, pers. comm.). Abundant naturalized populations in California, along the Rio Grande River, Texas, USA, and in Mexico almost certainly have resulted from escapes from commercial plantations and horticultural propagation (CABI, 2015a). *A. donax* agricultural machinery may be a vector for introduction and the plant is a contaminant in soil and crop seeds (Haddadchi et al., 2013; CABI, 2015a).

Establishment
No information on the establishment of *A. donax* outside cultivated land in the Netherlands or climatically similar regions could be found during a search of available literature. A field study demonstrated that *A. donax* height and survival were correlated with soil moisture and percentage of bare ground (Quinn & Holt, 2008). This suggests that environmental factors, especially those modified by humans, are major determining factors in the establishment of *A. donax* (Lambert et al., 2010).

Spread
No information on the spread of *A. donax* outside cultivated land in the Netherlands or climatically similar regions could be found during a search of available literature. Dispersal of heptaploid *A. donax* in south-eastern Australia occurs despite the sterility of the *A. donax* seeds. In Australia, reproduction through vegetative fragments is the major mechanism (Haddadchi et al., 2013). In the south-western United States fragment spread is facilitated by the dynamic hydrologic regimes of local river systems (Bell, 1997; Lambert et al., 2010). Heavy rains in the rainy season lead to flooding that causes rhizome fragments to fragment and be carried downstream. Reed populations therefore tend to increase with distance from upstream locations (Else, 1996; Lambert et al., 2010). In the coastal river basins of southern California, *A. donax* sometimes colonises entire river channels from bank to bank. Invasion is thought to have followed heavy storms that occurred in the late 1960s (CABI, 2015a).

- Environmental impacts summary

Effects on environmental targets or native species
No information on the effects of *A. donax* parasitism, interbreeding and hosting pathogens or parasites on environmental targets or native species could be found during a search of available literature.

Competition
Field observations of the only recorded stand of *A. donax* in the Netherlands indicate that there is no evidence that *A. donax* outcompetes associated reed species. Generally, the location has poor species diversity. However, the species has been able to survive among the native reed species for a number of years (B. Hendrikx pers. comm.). No other information on the effects of *A. donax* competition with environmental targets or native species in the Netherlands or climatically similar regions could be found during a search of available literature. However, it is listed as one of the 100 world's worst invasive alien species (ISSG, 2015a). *A. donax* is an aggressive species with an ability to reproduce quickly and to develop huge monocultures which can cover hundreds of hectares, allowing it to out-compete native plant species and is one of the major threats to riparian habitats in its introduced range (CABI, 2015a). For example, in the Santa Ana River of Southern California (USA) *A. donax* comprises approximately 68% of the riparian vegetation (Dudley, 2000; CABI, 2015a). This dominance has a major impact on native species. A study of *A. donax* stands in a low gradient stream in central California demonstrated that total biomass, and species and taxonomic richness of aerial invertebrates in *A. donax* stands was approximately half that of native vegetation (Herrera & Dudley, 2003). Shannon-Weaver (Wiener) diversity associated in native vegetation stands was also higher than that of *A. donax* vegetation. *A. donax* monocultures reduce arthropod diversity and abundance (Herrera & Dudley, 2003; Lambert et al., 2010) and also result in a decline in avian abundance and diversity (Kisner, 2004; Lambert et al., 2010). *A. donax* has displaced native vegetation which provides habitats for a number of endangered and threatened species in the US e.g. the Least Bell's Vireo (*Vireo bellipusillas*) and the Willow Flycatcher (*Empidonax traillieximos*) (Bell, 1997). *A. donax* is also known to be a habitat for the brown rat (*Rattus norvegicus*), a species non-native to but common in the Netherlands (www.nederlandsesoorten.nl), which has caused/contributed to the extinction/range reduction of many native species (CABI, 2015a).

Effects on ecosystem function targets
Abiotic properties e.g. nutrient cycling, structural modification
No information on the effects of *A. donax* on the abiotic properties of ecosystems in the Netherlands or climatically similar regions could be found during a search of available literature. Compared to native riparian plants, *A. donax* provides far less shading to the in-stream habitat. This can lead to increased water temperatures, lower oxygen and reduced aquatic habitat quality (Hoshovsky, 1986; CABI, 2015a).

A. donax consumes three times more water than native plants and is thought to alter hydrological regimes and reduce groundwater availability in semi-arid regions outcompeting native vegetation (Iverson, 1993). *A. donax* burns easily and can alter fire regimes in invaded areas (CABI, 2015a). Substantial alterations to water flow resulting from *A. donax* colonisation may lead to increased erosion during storm events (CABI, 2015a).

Effecting ecosystem integrity by biotic properties
No information on the effects of *A. donax* on the abiotic properties of ecosystems in the Netherlands or climatically similar regions could be found during a search of available literature. In general, once complex food webs become simplified following *A. donax* invasion, leaving fewer species that can survive in its presence. *A. donax* dramatically alters ecological and successional processes (CABI, 2015a).

Effects on plant targets in cultivation systems
No information on the effects of *A. donax* parasitism, interbreeding or pathogens or parasites on plant targets in cultivation systems could be found during a search of available literature.

Competition
No information on the effects of *A. donax* on competition with plant targets in cultivation systems in the Netherlands or climatically similar regions could be found during a search of available literature. In general, *A. donax* is not a crop weed, however, it has been reported as invasive in pasture and cropland in South Africa, Tanzania, Egypt, Argentina, Uruguay, Chile, Puerto Rico, and the Dominican Republic (ISSG, 2015a; Randall, 2002; CABI, 2015a).

Effects on animal health and production targets
No information on the effects of *A. donax* on animal health and production targets could be found during a search of available literature.

Human targets
No information on the effects of *A. donax* on human targets could be found during a search of available literature.

Effects on other targets
A. donax is known to interfere with flood defences (CABI, 2015a).

- Ecological risk assessment with the ISEIA protocol

The expert team allocated *A. donax* a 'high' ecological risk classification to all risk categories (Table 4.37). The total ecological risk score for the species is 12 out of a maximum of 12. Therefore, *A. donax* is classified in the A list of the BFIS list system. The maximum risk score takes into account the limitation on maximum risk score per category that is imposed by the ISEIA protocol if data deficiency occurs or the application of best professional judgement is required (See section 2.4.2). The maximum risk score will, therefore, vary between species. In cases where there is sufficient information, i.e. where there is no data deficiency and best professional judgement is not required, the maximum possible risk score is 12. The rationale for the allocated scores is given in the following paragraphs.

Table 4.37: Consensus scores for potential risks of giant reed (*Arundo donax*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	High	3
Colonization of high value conservation habitats	High*	3
Adverse impacts on native species	High	3
Alteration of ecosystem functions	High	3
Ecological risk score		**12**

* Quantitative analysis was focused on Natura 2000 areas may indicate a lower score; however, this species may occur in other areas with high conservation value.

Dispersion potential or invasiveness

Classification: **High risk**. *A. donax* is able to reproduce quickly and develops huge monocultures (CABI, 2015a). The plant reproduces through vegetative fragments, from underground rhizomes and plant fragments (Bell, 1997; Haddadchi et al., 2013; Lambert et al., 2010). *A. donax* is highly fecund, dispersing through rhizomes and plant fragments and can easily disperse passively more than 1 km/y and therefore poses a high risk of dispersion and invasiveness in the Netherlands. It should be noted that *A. donax* is listed as one of the 100 world’s worst invasive alien species (ISSG, 2015a). Moreover, the species tolerates temperate/mesothermal climates. However, its noxious weed status appears to be related to Mediterranean-type climates and sub-tropical riparian ecosystems throughout the world (Lambert et al., 2014).

Colonization of high value conservation habitats

Classification: **High risk**. *A. donax* grows in moist areas, such as along ditches and riverbanks. *A. donax* will potentially establish in riverine habitats due to the dispersal of rhizome and plant fragments by water flow and anthropogenic vectors. It often occurs on sand dunes near seashores, estuarine environments, even colonizing marine islands after rhizomes are transported from rivers across ocean waters during flooding.

Adverse impacts on native species

Classification: **High risk**. Information on the effects of *A. donax* on native species in the Netherlands or climatically similar regions is not available. However, *A. donax* develops huge monocultures, allowing it to out-compete native plant species and is one of the major threats to riparian habitats in its introduced range (CABI, 2015a). *A. donax* growth occurs in any season, but the plant is highly sensitive to temperature and moisture. *A. donax* exhibits growth rates of 0.3 to 0.7 m per week over a period of several months during the vegetative stage when conditions are favorable (warm and wet months) (Perdue, 1958; Lewandowski et al., 2003). This puts it among the fastest growing terrestrial plants. It should also be noted that *A. donax* is listed as one of the 100 world's worst invasive alien species (ISSG, 2015a). Therefore, *A. donax* poses a high risk to native species in the Netherlands.

Alteration of ecosystem functions

Classification: **High risk**. Information on the effects of *A. donax* on the abiotic properties of ecosystems in the Netherlands or climatically similar regions is not available. *A. donax* develops huge monocultures which can cover hundreds of hectares and can dramatically alter ecological and successional processes (CABI, 2015a). *A. donax* provides habitat for the brown rat (*Rattus norvegicus*), a species non-native to but common in the Netherlands (www.nederlandsesoorten.nl), which has caused/contributed to the extinction/range reduction of many native species (CABI, 2015a).

Risk classification according to the BFIS list system

The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.37) in combination with the current recorded distribution in the Netherlands. The species classification for *A. donax* is A1 (Figure 4.33). This characterises a non-native species with isolated populations in the area under assessment and poses a high ecological risk that should be placed on the black list of the BFIS list system.

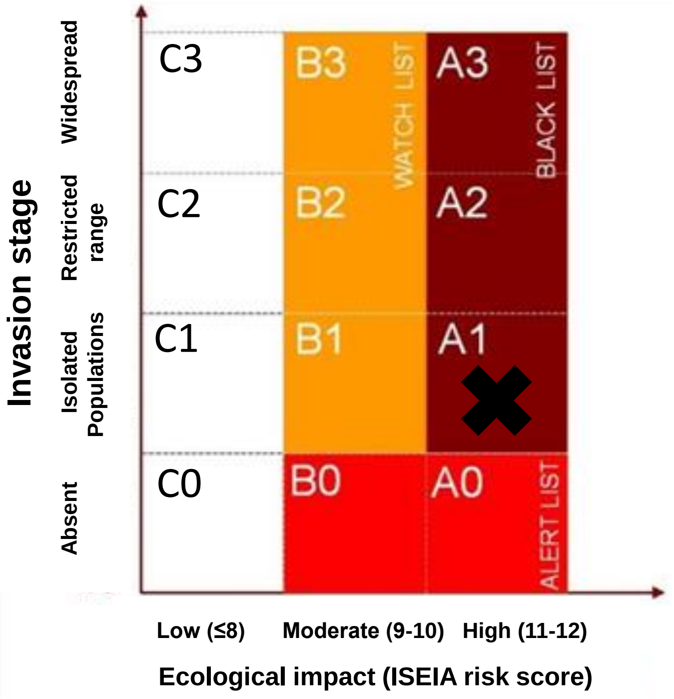

Figure 4.33: Risk classification of giant reed (*Arundo donax*) according to the BFIS list system.

- Other risk assessments and classifications

The U.S. California Invasive Plant Council has classified *A. donax* among the top five invasive species negatively impacting natural ecosystems in the state (Cal-IPC, 2006; Lambert et al., 2010). *A. donax* is classified as a noxious weed in Texas, USA (USDA, 2009; Lambert et al., 2010). Any cultivar of *A. donax* is included in the Washington State, USA noxious weed listing (Washington State, 2013). Weed risk assessments on *A. donax* for Florida, Hawaii, the USA in general, Canada and the Bonin islands (Japan) all resulted in an outcome of “reject” or high risk (Daehler et al., 2004; Gordon et al., 2011; Hear.org, 2015b) (Table 4.38). Generally, *A. donax*’s noxious weed status appears to be related with Mediterranean-type climates and sub-tropical riparian ecosystems throughout the world (Lambert et al., 2014). However, the high risk category given to the species in Canada suggests that the species could become invasive at more Northerly latitudes.

Table 4.38: Overview of risk classifications previously performed for giant reed (*Arundo donax*).

	Canada	**USA (general)**	**USA (Florida)**	**USA (Hawaii)**	**Japan (Bonin islands)**
Scope	Risk assessment method	Risk assessment method	Risk assessment method	Risk assessment method	Risk assessment method
Method	Modified Weed Risk Assessment (WRA).	Modified Weed Risk Assessment (WRA).	Modified Weed Risk Assessment (WRA).	Modified Weed Risk Assessment (WRA).	Modified Weed Risk Assessment (WRA).
Year	2011				
Risk classification	**High risk with low uncertainty**	**Reject (11)**	**Reject (11)**	**Reject (12)**	**Reject (19)**
Source	Canada Food Inspection Agency (2015)	Hear.org (2015b)	Hear.org (2015b)	Daehler et al. (2004)	Kato et al. (2006)

4.8.3 *Miscanthus* species

- Genus description

Miscanthus is a woody, perennial, tufted or creeping rhizomatous C4 grass that belongs to the Andropogoneae tribe within the Poaceae (Barling et al., 2013). The genus is characterised by vertically tall species of up to four to five metres, with long (0.5 to 1.2 m) and broad (0.8 to 3 cm) leaves (Watson & Dallwitz, 1992). Chinese silver grass (*Miscanthus sinensis*) is the shortest species (Figure 4.34d), ranging in height between two and 3.5 metres, but its stem production (50 to 150 per plant) and compact crown diameter (0.4 to 0.6 m) exceeds that of Miscanthus (*Miscanthus* x *giganteus*). Japanese silver grass (*Miscanthus sacchariflorus*) is taller than *M.* x *giganteus* but produces fewer stems (one to two per plant) (Figure 4.34b). *M.* x *giganteus* ranges in height from 3.5 to four metres and sits between *M. sacchariflorus* and *M. sinensis* in terms of morphological structure (Anzoua & Yamada, 2013) (Figure 4.34c). In contrast to *M. sinensis*, Pacific island silver grass (*Miscanthus floridulus*) is an evergreen plant with culms ranging from two to four metres tall (Figure 4.34a). The central axis length is two thirds that of the entire panicle length in *M. floridulus* whereas it is shorter in *M. sinensis*. Moreover, the leaf blade is more hairy and waxy at the base in *M. floridulus* than in *M. sinensis* (Xi & Jezowski, 2004).

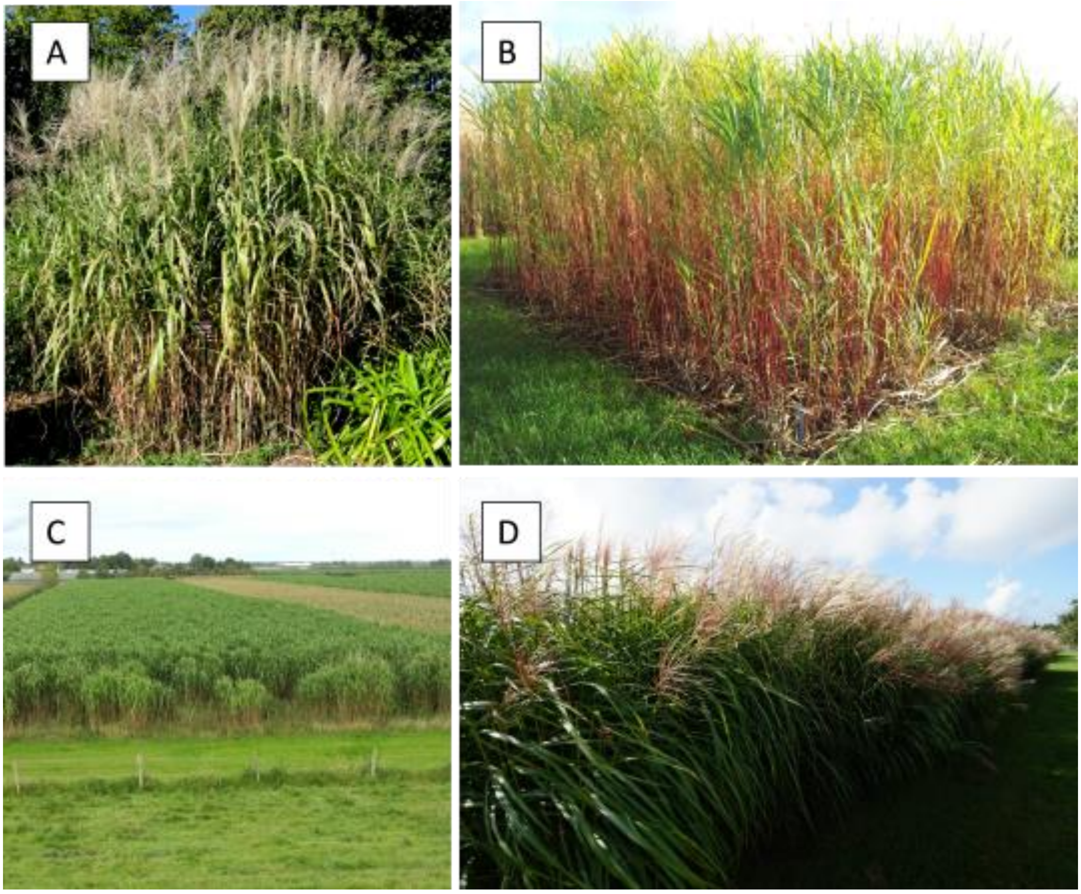

Figure 4.34: *Miscanthus* species A) Pacific island silver grass (*Miscanthus floridulus*), source: Tonatsu; Wikimedia Commons; B) Japanese silver grass (*Miscanthus sacchariflorus*), photo: Tim van der Weijde; C) Miscanthus (*Miscanthus x giganteus*) growing in a field at Slijk Ewijk, the Netherlands (Photo: Rob Leuven); D) Chinese silver grass (*Miscanthus sinensis*), photo: Tim van der Weijde.

Species taxonomy

Table 4.39: Nomenclature and taxonomical status of *Miscanthus* species.

Scientific name:			
Miscanthus floridulus (Labill.) Warb.ex K. Schumann & Lauterbach (1900)	*Miscanthus sacchariflorus* (Maxim.) Hack. (1887)	*Miscanthus sinensis* Andersson (1855)	*Miscanthus* × *giganteus* J.M.Greef, Deuter ex Hodk., Renvoize (2001)
Synonyms:			
Saccharum floridulum Labill. *Miscanthus japonicus* Anderss. *Miscanthus formosanus* A. Camus *Eulalia japonica* Trin.	*Imperata saccharifera* Andersson ex Benth. *Imperata eulalioides* Mi *Imperata sacchariflora* Maxim. *Miscanthus sacchariflorus* f. *latifolius* *Miscanthus saccharifer* Benth. *Miscanthus hackelii* var. *breviberbis* *Miscanthus sacchariflorus* var. *gracilis* *Miscanthus sacchariflorus* f. *purpurascens* *Miscanthus hackelii* Nakai *Miscanthus ogiformis* Honda *Triarrhena hackelii* (Nakai) Nakai *Triarrhena sacchariflora* (Maxim.) Nakai	*Eulalia japonica* Trin. *Miscanthus condensatus* Hack. *Miscanthus purpurascens* Anderss. *Miscanthus sinensis* f. *glaber* Honda *Miscanthus sinensis* var. *condensatus* (Hack) Makino *Miscanthus sinensis* var. *formosanus* Hack. *Miscanthus sinensis* var. *gracillimus* Hitchc. *Miscanthus sinensis* var. *purpurascens* (Anderson) Matsum. *Miscanthus sinensis* var. *variegatus* Beal *Miscanthus sinensis* var. *zebrinus* Beal *Saccharum japonicum* Thunb. *Xiphagrostis condensatus* (Hack) W. Wight	*Miscanthus ogiformis* Honda *Miscanthus sinensis* var. *sunanensis* Y.N. Lee
Taxonomic tree (Catalogue of Life, 2015):			
Kingdom: Plantae Phylum: Tracheophyta Class: Liliopsida Order: Poales Family: Poaceae Genus: *Miscanthus* Species: *Miscanthus floridulus*	Kingdom: Plantae Phylum: Tracheophyta Class: Liliopsida Order: Poales Family: Poaceae Genus: *Miscanthus* Species: *Miscanthus sacchariflorus*	Kingdom: Plantae Phylum: Tracheophyta Class: Liliopsida Order: Poales Family: Poaceae Genus: *Miscanthus* Species: *Miscanthus sinensis*	Kingdom: Plantae Phylum: Tracheophyta Class: Liliopsida Order: Poales Family: Poaceae Genus: *Miscanthus* Species: *Miscanthus* x *giganteus*
Preferred Dutch name:			
Reuzenriet (unofficial)	Groot prachtriet (Naturalis, 2015)	Chinees prachtriet (unofficial)	Miscanthus
Preferred English name:			
Pacific island silver grass	Japanese silver grass	Chinese silver grass	Miscanthus
Other Dutch names:			
Chinees Reuzenriet, Chinees prachtriet, Japans reuzenriet, Japans sierriet	Reuzenriet	Prachtriet, Japans riet, sierriet	Olifantsgras
Other English names:		Chinese fairy grass; Eulalia grass; Japanese pampas grass; Japanese silver grass; maiden grass; pampas grass; plume grass; wild sugar cane; zebra grass	Giant Chinese silver grass
Japanese silver grass, Pacific Island silver grass, sawgrass, swordgrass, giant miscanthus	Amur silver grass, silver banner grass		

Life cycle

All *Miscanthus* are perennial and rhizomatous. No information on the life cycle of *M. floridulus* could be found during the literature survey. The primary mode of reproduction *M. sacchariflorus* in Europe is vegetative (Clifton-Brown et al., 2001; Bonin et al., 2014). *M. sinensis*, flowering takes place in August to October in the Northern hemisphere (EPPO, 2015). It is a wind pollinated plant (Hayashi, 1979; Hayashi et al., 1981; Nakagoshi, 1984) that appears to be self-incompatible (Nechiporenko et al., 1997; Matumura, 1998; Stewart et al., 2009). *M. sinensis* produces seeds which are mainly dispersed by wind and reproduces vegetatively through rhizomes (US Forest Service, 2006). Rhizomes allow a moderate horizontal expansion. No information on the life cycle of *M.* x *giganteus* in Europe could be found during the literature study. In its native Japan, *M.* x *giganteus* starts growing in April or early May, continuing throughout August (Yamane et al., 1958), and into November in some areas (Kobayashi & Yokoi, 2003a). Shoots appear between June and November in the warmer regions of Japan (Kobayashi & Yokoi, 2003b). *M. x giganteus* flowers from September to October; however, altitude has an effect on the time of flowering (Adati 1958 cited in Stewart et al., 2009). Shoot senescence occurs at the end of the season (Kobayashi & Yokoi, 2003a), and culms may become yellow and begin to wither in September (Yamane et al., 1958). Late developing shoots may be able to survive the winter (Kobayashi & Yokoi, 2003a).

Reproductive capacity

The flowers of *M. floridulus* are hermaphrodite, wind pollinated and the plant is very effective at self-seeding (Plants for a Future.org; NRCS, 2011). *M. floridulus* does not form a persistent seed bank and seed fertility may be lost six months following wind dispersal (FuHsing, 2000). The species is also able to spread and enlarge slowly with short underground rhizomes (Floridata.com). *M. floridulus* is highly productive, yields during cultivation range from 1500 to 2500 bunch/ha, 7425 to 12209 tillers/ha and 8890 to 9000 seed/tiller (approximately 100 million seeds/ha) (Chou, 2009).

M. sacchariflorus may not produce viable seed in cooler climates in parts of Europe (Sacks et al., 2012; Bonin et al., 2014). The plant flowers infrequently in European countries and, generally, flowering occurs later in the growing season than other *Miscanthus* species (Clifton-Brown et al., 2001; Bonin et al., 2014). Observations of *M. sacchariflorus* flowering in the U.K. revealed that 6% or less of the plants surveyed completed flowering (Jensen et al., 2011), while a second study concluded that no flowering occurs in the U.K. (Clifton-Brown et al., 2001; Bonin et al., 2014). Moreover, in Ontario, Canada, spread of *M. sacchariflorus* is hampered by limited seed production or viability (Hager et al., 2015). However, Hager et al. (2015) suggested that its occurrence along disturbance-prone roadways and drainages facilitates its local vegetative spread. The lack of unrelated individuals with which to cross and/or a growing season that is too short for seeds to mature fully may explain the lack of sexual production (Hager et al., 2015). *M. sacchariflorus* has significantly lower seed set than *M. sinensis* in its native Japan (Nishiwaki et al., 2011). However, *M. sacchariflorus* is a strongly rhizomatous species. Rhizomes are extensive, creeping and may spread several metres in a few years (Anzoua et al., 2011; Jørgensen, 2011; Bonin et al., 2014). Under cultivation, *M. sacchariflorus* is capable of producing high yields (10.7t DM ha/yr) (Bonin et al., 2014).

M. sinensis produces seeds which are mainly dispersed by wind and is propagated vegetatively through rhizomes (US Forest Service, 2006). *M. sinensis* produces prolific numbers of seeds (EPPO, 2015). Certain varieties of *M. sinensis* are capable of growing 100 panicles which together produce 6500 to 140,000 seeds per m^2 in its native range (Stewart et al., 2009). Thus, certain varieties of *M. sinensis* are able to produce 6.5 x 10^{-7} to 1.4 x 10^{-9} seeds per ha (Quinn et al., 2011). However, seed production varies widely between *M. sinensis* varieties and depends on the location of growth. *M. sinensis* also establishes seed banks that can lead to further establishment (ISSG, 2015b). Hayashi and Numata (1971) found that about half of the seeds produced in one year were still viable the following summer but concluded that the *Miscanthus* community was more dependent on vegetative reproduction rather than seed production. Germination rates of up to 72% for ornamental *M. sinensis* individuals setting large quantities of seed (>3,000 3+ panicles^{-1}) have been reported (Meyer & Tchida, 1999). However, seed viability depends on variety (EPPO, 2015). While Meyer & Tchida (1999) found viable seed set by many ornamental cultivars of *M. sinensis,* most variegated forms set less than 18% viable seed. Moreover, Matumura et al. (1975) found a wide variation in seed set over a number of years (CABI, 2015e). Moreover, Clifton-Brown et al. (2001) predicted that establishment of *Miscanthus* spp. from seed in spring is unlikely in Northern Europe without crop management practices aimed at raising soil temperature under present climatic conditions. *M. floridulus* and *M. sinensis* are morphologically similar and have overlapping native ranges. Phenotypic evaluation shows that these two species morphologically intergrade and that hybrids are potentially common (Scally et al., 2001).

M. x *giganteus* is an allopolyploid hybrid that does not produce viable seed (Raghu et al., 2006). However, allopolyploidy is not a total guarantee of continued sterility (Raghu et al., 2006). After the second year of growth, a single *M.* x *giganteus* individual can grow up to 100 inflorescences that produce an average of 1,270 spikelets each (L. Smith, unpublished data in Smith & Barney, 2014), totalling over 2.5 billion spikelets ha^{-1} yr^{-1} (Smith & Barney, 2014). Therefore, even low rates of seed viability and survival, seedling survival and seed germination will support rapidly expanding populations in a fertile genotype (Matlaga & Davis, 2013). *M.* x *giganteus* is also able to reproduce vegetatively and, generally, vegetative propagation is often associated with invasiveness or directly contributes to it (Raghu et al., 2006). Matlaga & Davis (2013) predicted that adult *M.* x *giganteus* plants must produce several rhizome fragments per individual to establish a growing population. Field observations from the same study suggested that a population would expand if one rhizome fragment was produced per two individual plants. However, *M.* x *giganteus* produces extremely tough rhizomes and sufficient fragmentation may only occur under cases of severe and frequent disturbance (Matlaga & Davis, 2013).

- Habitat summary

Pacific island silver grass (Miscanthus floridulus)

In its native range, *M. floridulus* can be found on slopes and in valleys and grassy places (eFloras.org), it may also be found at disturbed sites, degraded or deforested lands or steep, eroded areas (NRCS, 2011; QBank, 2015). The species is naturalized in tropical regions, but tolerates a broad range of climates (Hear.org, 2015a), reflecting its successful introductions as an ornamental plant in more northerly locations (NRCS, 2011). For example, when *M. floridulus* was grown in Northern France, it yielded a higher biomass than *M.* x *giganteus* (Zub et al., 2011). However, seedlings do not survive the relatively cold climate of Northern France (L. Trindade, pers. comm.), suggesting that crops were cultivated from rhizomes. *M. floridulus* is tolerant of wind and salt spray (NRCS, 2011).

Table 4.40: Physiological conditions tolerated by *Miscanthus* species.

Species	**Parameter**	**Values**	**References**
Japanese silver grass (*Miscanthus sacchariflorus*)	Temperature (LT50 rhizomes °C)	-3.4	Clifton-Brown & Lewandowski (2000b)
	Temperature (LT50 shoots °C)	-7	Clifton-Brown & Lewandowski (2000b)
	Base temperature (shoot emergence °C)	8.6	Farrell et al. (2006)
	Temperature (rhizome damage °C)	-5	Bonin et al. (2014)
Pacific island silver grass (*Miscanthus floridulus*)	Temperature (optimum for biomass accumulation °C)	30/25 (day/night temperature)	Kao et al. (1998)
Chinese silver grass (*Miscanthus sinensis*)	Mean annual temperature (ºC)	12-18	CABI (2015e)
	Mean maximum temperature of hottest month (ºC)	22-32	CABI (2015e)
	Mean minimum temperature of coldest month (ºC)	-2-12	CABI (2015e)
	50% germination within 15 days of sowing (T_{15d} ºC)	12-17	Clifton-Brown et al. (2001)
	Mean annual rainfall (mm)	1003-2093	CABI (2015e)
	Soil characteristics	Free draining, acidic, shallow and infertile soils with a light to medium texture	CABI (2015e)
Miscanthus (*Miscanthus* x *giganteus*)	LT_{50} (°C)	-6 to -9	Farrell et al. (2006)
	Thermal tolerance of rhizomes (°C)	-4	Clifton-Brown & Lewandowski (2000b)

In its native Taiwan, *M. floridulus* is the dominant grass at locations below 2000 m where the mean July temperature is above 15 °C (Chou & Chang, 1988; Kao et al., 1998) and may grow down to sea level (NRCS, 2011). Field experiments in Taiwan revealed that the optimum temperatures for biomass accumulation for *M. floridulus* were 30/25 °C (day/night temperature) (Table 4.40) (Kao et al., 1998).

M. floridulus tolerates a wide range of soil conditions and is potentially able to exploit many different habitat types (Hear.org, 2015a). The species displays a preference for a deep, loamy, fertile soil that does not dry out. However, it does not tolerate heavy clay soils (NRCS, 2011).

Japanese silver grass (Miscanthus sacchariflorus)

M. sacchariflorus is typically found in mesic environments, i.e. areas near wetlands and water. However, the species is intolerant of flooding and it is generally limited to the upper shoreline (Yamasaki, 1990; Bonin et al., 2014).

A climate match for present conditions and for future climate change using the CLIMEX model suggests that the climate in the Netherlands will not pose a barrier for *M. sacchariflorus* colonisation now and in the future (Hager et al., 2014). Moreover, a *M. sacchariflorus* genotype has been cultivated in west Wales but has never been reported to flower under field conditions (daily maximum temperature reached 28 ^{o}C) (Purdy et al., 2013). However, cold tolerance appears to vary according to genotype and plant origin. For example genotypes originating from northern China (latitude of about 44° N) display a greater overwintering survival rate compared to *M. sinensis* (Yan et al., 2012; Bonin et al., 2014). Moreover, northern *M. sacchariflorus* genotypes have the highest establishment rates at colder sites owing to their strong cold tolerance (Yan et al., 2012). During growth experiments in Europe where genotypes originating from subtropical Asia (Sac-5) were used, 50 to 67% mortality occurred in the first year in northern field sites (e.g. Sweden and Denmark), where soil temperatures dropped below -4.5 °C (Clifton-Brown et al., 2001). The base temperature (Tb) for shoot emergence is 8.6 °C for this genotype (Farrell et al., 2006) (Table 4.40). The LT50 (i.e. temperature when 50% of plants die) of *M. sacchariflorus* (Sac-5) was -3.4 °C for rhizomes and -7 °C for shoots (Clifton-Brown & Lewandowski, 2000b). Finally, at an early stage of development, rhizomes may become damaged or die when temperatures drop below -5 °C. However, once established, the overall damage that winter temperatures have on rhizomes is reduced (Bonin et al., 2014). It is expected that other genotypes native to more northerly locations will tolerate lower overwintering temperatures (Bonin et al., 2014).

Chinese silver grass (Miscanthus sinensis)

In its native Japan, *M. sinensis* is a dominant grass species representing approximately 25% of all natural and semi-natural grasslands (USDA Forest Service, 2015). In its non-native range, *M. sinensis* often colonises ruderal, disturbed and urban areas (ISSG, 2015b). It is often found on roadsides, along railways, power-lines, shores of reservoirs forest edges, sides of reservoirs, and in old fields following fires (CABI, 2015e; EPPO, 2015).

The mean maximum temperature and mean minimum temperature tolerated by *M. sinensis* are 22-32 ºC and -2-12 ºC, respectively (CABI, 2015e) (Table 4.40). The plant grows well in cool temperate climates (Farrell et al., 2006), and is able to survive cold climates with temperatures as low as -26°C (US Forest Service, 2006). Moreover, a climate match for present conditions and for future climate change using the CLIMEX model suggests that the climate in the Netherlands will not pose a barrier for *M. sinensis* colonisation now and in the future (Hager et al., 2014). However, it does not grow well in humid, hot southern climates such as Spain or Portugal (EPPO, 2015). Cold tolerance together with an ability to be grown from seed affords *M. sinensis* practical advantages over current cultivars of the higher-yielding hybrid species, *M.* x *giganteus* (Jørgensen, 1997; Clifton-Brown et al., 2001; Farrell et al., 2006; Quinn et al., 2010). However, in Japan, *M. sinensis* started producing visible biomass at a mean air daily temperature of 7 ^{o}C (Stewart et al., 2009). Moreover, there was significant variation between the *M. sinensis* half-sib families with 50% germination within 15 days of sowing (T_{15d}) ranging from 12 to 17 ^{o}C (Clifton-Brown et al., 2001). Clifton-Brown et al. (2001) predicted that soil temperatures in spring in Northern Europe would inhibit germination under present climatic conditions.

M. sinensis is shade intolerant but can be found in sparsely wooded areas and in small clearings (ISSG, 2015b). It has been shown to tolerate shade in the United States (Horton et al., 2010; Quinn et al., 2010). However, EPPO (2015) states that *M. sinensis* needs full light to establish and reproduce. *M. sinensis* is a C4 photosynthetic plant and so has high radiation efficiency compared with most C3 plants (Farrell et al., 2006).

M. sinensis requires a mean annual rainfall of 1003 to 2093 mm (CABI, 2015e). The plant is said to be the most drought tolerant member of *Miscanthus* and may be better adapted to drought stress than current varieties of *M*. x *giganteus* (Clifton-Brown & Lewandowski, 2000a; Clifton-Brown et al., 2002; Quinn et al., 2010). At very low soil moisture *M. sinensis* is able to effectively reduce leaf conductance and maintain leaf area (Clifton-Brown & Lewandowski, 2000a; Smith & Barney, 2014). It is a C4 photosynthetic plant and so has high water use efficiency compared with most C3 plants (Farrell et al., 2006).

Once established, genotypes of *M. sinensis* can tolerate a wide range of poor soil conditions, but prefers rich, moist, well-drained substrate for maximum growth (CABI, 2015e; EPPO, 2015). It is able to tolerate soils of various (low) pH, compacted soils and nutrient poor soils (ISSG, 2015b; EPPO, 2015; Stewart et al., 2009; Quinn et al., 2010). In its native Japan, *M. sinensis* has been found to be the sole plant species growing in highly acidic soils (Stewart et al., 2009). Moreover, it is tolerant of heavy metals (Hsu & Chou, 1992) and aluminium in the soil (Ezaki et al., 2008; CABI, 2015e). It is a C4 photosynthetic plant and so has high nitrogen efficiency compared with most C3 plants (Farrell et al., 2006). *M. sinensis* doesn't survive in soil with a high salt content (CABI, 2015e).

Miscanthus (Miscanthus x *giganteus)*

M. x *giganteus* has received much attention as a potential biomass crop due to its C4 photosynthesis (Naidu et al., 2003), highly efficiency water usage (Clifton-Brown et al., 2002), low nutrient requirements (Lewandowski et al., 2003), capability of C mitigation (Clifton-Brown et al., 2007), and high yields (Clifton-Brown et al., 2001; Stewart et al., 2009). *M.* x *giganteus* tolerates a variety of climatic conditions (Barney & DiTomaso, 2008), and grows well in cool temperate climates (Farrell et al., 2006). However, *M.* x *giganteus* individuals grown during field trials in Germany, Denmark, and southern Ontario, Canada, have often suffered high mortality in the first winter after planting (Clifton-Brown et al., 2001; Jørgensen et al., 2003; Deen et al., 2011; Friesen et al., 2015). However, frost tolerance appears to depend on genotype with LT_{50} values (temperatures at which 50% mortality occurs) ranging from -6 to -9 ^{o}C for different genotypes (Farrell et al., 2006) (Table 4.40). Other authors also refer to the poor frost tolerance of *M.* x *giganteus.* For example, Clifton-Brown & Lewandowski (2000b) cite a modest thermal tolerance threshold of near −4°C for *M.* x *giganteus* rhizomes. Moreover, in Sweden and Denmark, *M.* x *giganteus* appears to perform better at warmer sites (Hodkinson et al., 2002; Farrell et al., 2006). *M.* x *giganteus* appears to be a reasonably drought tolerant species, but the availability of soil water has been reported as the most important limiting factor determining production of biomass (Richter et al., 2008; Smith & Barney, 2014). A low soil water level also reduces the probability of establishment (Barney et al., 2012; Smith & Barney, 2014).

- Recorded distribution

Native range

M. floridulus is native to Japan, Taiwan and the Pacific Islands (EPPO Reporting Service, 2007) (Figure 4.35a).

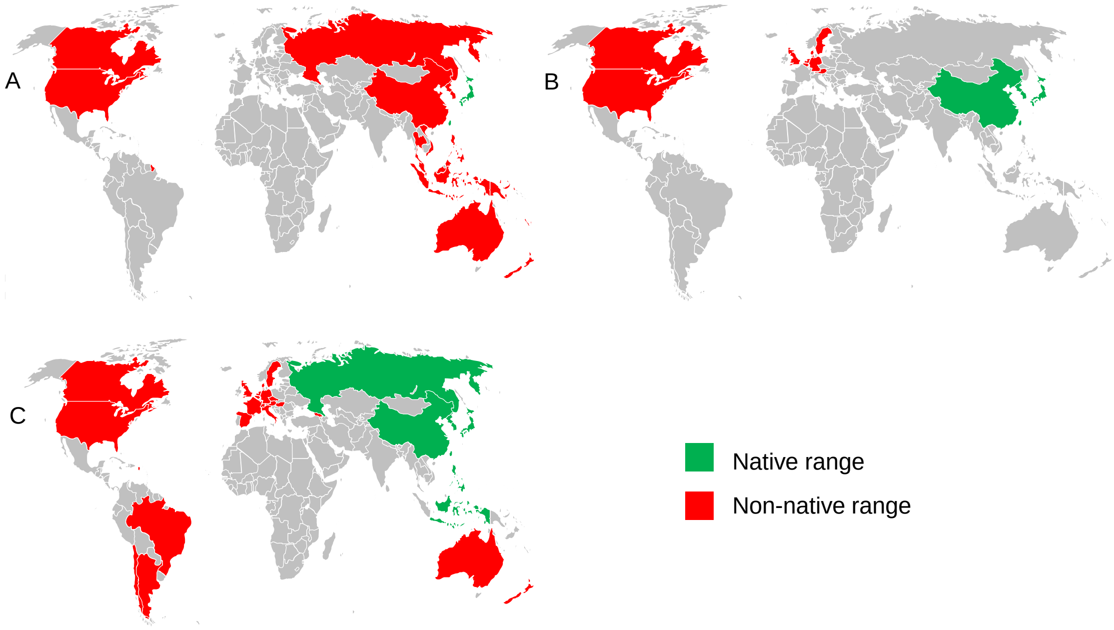

Figure 4.35: Current global recorded distribution of A) Pacific island silver grass (*Miscanthus floridulus*). Sources: EPPO Reporting Service (2007); QBank (2015). B) Japanese silver grass (*Miscanthus sacchariflorus*). Sources: Quinn et al. (2010); Bonin et al. (2014); Hager et al. (2014); NDFF (2015e); Schnitzler & Essl (2015); DAISIE (2015f). C) Chinese silver grass (*Miscanthus sinensis*). Source: ISSG, 2015b; EPPO, 2015.

M. sacchariflorus is native to the subarctic Kuril Islands (Russia) and Taiwan (Quinn et al., 2010; Bonin et al., 2014), Japan, Korea, south-central and eastern China, and in parts of northern and north-eastern China (Hager et al., 2014) (Figure 4.35b). *M. sinensis* is native to the Russian Federation, China, Japan, Taiwan, Republic of Korea, Philippines, and Indonesia (ISSG, 2015b) (Figure 4.35c). *M.* x *giganteus* is a naturally existing sterile hybrid of *M. sinensis* and *M. sacchariflorus* and is native to Southeast Asia (Lewandowski et al., 2000; Vanloocke et al., 2010).

Cultivated range

M. floridulus is cultivated in Northern France (Zub et al., 2011). *M. sacchariflorus* was introduced to Europe in the late 1800s and is cultivated in west Wales (Lewandowski et al., 2000; Purdy et al., 2013; Bonin et al., 2014). No information on the cultivated range of *M. sinensis* could be found during a search of available literature.

No information on the commercial cultivated range of *M.* x *giganteus* could be found during a search of available literature. However, a number of field trials of *M.* x *giganteus* have been undertaken in the Netherlands, for example a trial carried out by Wageningen University and Research Center (WUR) near Schiphol airport, Amsterdam. Moreover, additional trials have been carried out in Germany, Denmark, and southern Ontario, Canada (Clifton-Brown et al., 2001; Jørgensen et al., 2003; Deen et al., 2011; Friesen et al., 2015).

The following information is taken from the Miscanthus dossier published on the Wageningen University Research Center (WUR) website (original text written in Dutch). The dossier describes current progress in the cultivation of *M.* x *giganteus* in the Netherlands:

In 2010, three farmers and a contractor in the Haarlemmermeer area began the small scale cultivation of *M.* x *giganteus*. WUR provided these farmers (the miscanthus group) with advice, and examined the effect of the crop on the landscape and the presence of geese. In 2011, a so called ‘green deal’ was made with the Dutch government, meaning that the government supports this sustainable initiative. Wageningen UR also established contact with partners in the processing industry who are able to use *M.* x *giganteus* as a raw material.

From April 2013, the cultivation of *M.* x *giganteus* around Schiphol airport expanded to 60 hectares. The crop is planted on an industrial estate in development, Schiphol Trade Park (formerly known as A4 Zone West). Innovative companies that aim to use *M.* x *giganteus* as a raw material are being encouraged to establish between the miscanthus fields. In this way Schiphol Airport and the city of Amsterdam, hope to promote this undeveloped area as a location for new business, in order to create a hub of ‘innovative logistics’. To tempt the Schiphol Trade Park companies, an old farmhouse in the area has been redeveloped into an information centre. Knowledge institutions have united around this project, namely Wageningen University, Van Hall Institute Larenstein and a major US university.

The *Miscanthus* hybrid (*M.* x *giganteus*) that is being cultivated in the Haarlemmermeer is sterile. Therefore no pollen is produced; good news for people with hay fever symptoms. Plants are therefore not sown, but planted. Rhizome segments, provided by a company in Germany, are put into a converted potato planter and subsequently planted into the ground. This plant material is a substantial investment, however, more than ten years of crop may be harvested. The plants require a year to establish, after which about 20 tons per hectare of harvested miscanthus is produced per year. Weeding will be required in the first establishment year only, after which weeds are unable to establish due to the height of the crop plant. Moreover, insecticides, fertilizer, and irrigation are not required. The crop requires 600 to 700 millimetres of rain per year, an amount that is nearly always exceeded in the Netherlands.

Mowing and baling of *M.* x *giganteus* is carried out using a converted corn harvester. Harvesting occurs in the spring, just before the crop sprouts again. Subsequently, *M.* x *giganteus* regrows, achieving its full height within six months. In the summer the plant is green, however, in the winter months the plants withers which allows it to be harvested virtually dry. Because of the expensive initial investment, *M.* x *giganteus* must be cultivated for at least ten years. This contrasts with other agricultural crops, which are often grown in four-year cycles: the so called one-to-four rotation. The initial investment in *M.* x *giganteus* rhizomes is recouped after about five or six years, after which profit is more likely.

The climate, soil and water characteristics in many places in the Netherlands are suitable for *M.* x *giganteus*. Moreover, crop yields are about the same as cereal crops, but, for the time being; significantly lower than either beet or potatoes. If the sale price of harvested *M.* x *giganteus* increases, farmers will undoubtedly grow more. However, the fear that cultivated land in the Netherlands will become dominated by *M.* x *giganteus* is unfounded. In places where food is grown, it is unlikely that farmers will switch cultivation from non-edible biomass. Additionally, farmers almost never invest all their resources in one product. Therefore, diversity will be preserved.

A tall crop such as *M.* x *giganteus* does not fit anywhere in the landscape, but there are many places that will be suitable for its cultivation. Cultivation near Schiphol, for example, discourages geese and offers an attractive environment for hares and partridges. *M.* x *giganteus* will likely provide a good barrier to noise and particulate matter when sited along highways. Additional research should be undertaken to provide concrete evidence of these positive effects. Incidentally, this tall crop plant should not be planted directly on road margins or at intersections, due to the resulting restriction of road user’s view.

Non-native range

The non-native range of *M. floridulus* extends to Asia: China, Indonesia, Korea, Malaysia, Papua New Guinea, Philippines, Russian Federation, Thailand, Vietnam; North America: Canada, USA; South America: French Guiana; Oceania: Australia, Fiji, French Polynesia, New Caledonia and New Zealand (QBank, 2015) (Figure 4.35a).

Most escaped populations of *M. sacchariflorus* occur on grassland sites, along rivers and in ruderal habitats such as open cast mining sites, roadsides and near urban gardens (Schnitzler & Essl, 2015; EPPO reporting service, 2015). *M. sacchariflorus* occurs mainly as a non-native plant in north-western Europe, Denmark, Sweden, the north-eastern United States, and south-eastern Canada (Hager et al., 2014) (Figure 4.35b). The species is present in the Netherlands (NDFF, 2015e). Multiple casual observations have been recorded in Germany and Austria and one casual observation has been recorded on the Isle of Man, in the U.K. (Schnitzler & Essl, 2015). *M. sacchariflorus* has been recorded as established at three locations at Salzwedel, Saxony-Anhalt, Germany (Schnitzler & Essl, 2015). The species is classified as alien but not established in Belgium (DAISIE, 2015f). *M. sacchariflorus* is present in eastern Canada and 11 states of the USA. The species is thought to have escaped cultivation in the 1940s and 1950s from the Midwest where it spread along the Mississippi River in Iowa, Wisconsin, and Illinois. Since then, *M. sacchariflorus* has spread to many North Eastern States of the USA (Bonin et al., 2014).

M. sinensis is non-native to Europe: occurring in The Netherlands, Austria, Belgium, Czech Republic, France, Georgia, Germany, Hungary, Italy, Russia (native), Switzerland, Spain, the United Kingdom, Denmark (EPPO, 2015) and Sweden (CABI, 2015e); North America: It is considered invasive in certain parts of the USA (ISSG, 2015b), however, no information on how this invasive status was determined could be found during the literature search. *M. sinensis* is present in the States of Alabama, California, Colorado, Connecticut, District of Columbia (invasive), Delaware (invasive), Florida, Georgia, Illinois, Kentucky, Louisiana, Maryland (invasive), Massachusetts, Michigan, Mississippi, Missouri, North Carolina, New Jersey (invasive), New York, Ohio, Pennsylvania (invasive), Rhode Island, South Carolina, Tennessee (invasive), Virginia (invasive), West Virginia (invasive)), Canada (Ontario) (CABI, 2015e; Swearingen et al., 2010; Invasive Plant Atlas of the United States; Invasive.org); Central America and Caribbean: Puerto Rico (CABI, 2015e); South America: Argentina, Brazil, Chile; Oceania: Australia (New South Wales, Tasmania, Western Australia), Vanuatu (ISSG, 2015b; CABI, 2015e) and New Zealand (CABI, 2015e); South America: Chile (CABI, 2015e; ISSG, 2015b), Argentina, Brazil and Puerto Rico (CABI, 2015e) (Figure 4.35c).

No information on the non-native range of *M.* x *giganteus* could be found during a search of available literature.

Distribution in the Netherlands

Figure 4.36 displays all the records for *Miscanthus* spp. in the Netherlands. Most records are classified as *M. sinensis* and have been made in or near urban areas. The first documented record of naturalized *M. sinensis* dates to around 2005 when the species was observed in Leeuwarden and Schijndel. Since this time, observations have been recorded in circa 50 km squares throughout the country. There is one confirmed record of *M. sacchariflorus* for the Netherlands made in 2007 and located near Reusel (Figure 4.36). According to the Nationale Databank Flora en Fauna (NDFF, 2015f), there are no records of *M. floridulus* or *M.* x *giganteus* in the Netherlands.

It should be noted that difficulties in correctly differentiating between *Miscanthus* spp. and a lack of determination keys in Dutch floras, reduces the certainty of individual species distributions. It is likely that at least some records identified in figure 4.36 are actually records of species other than *M. sinensis.* Moreover, a number of additional records of *M. sacchariflorus* have recently appeared within the Nationale Databank Flora en Fauna (NDFF, 2015e), which may be incorrectly identified for the same reasons.

It is unclear which varieties of *Miscanthus* spp. are present in nature. Varieties of *Miscanthus* spp. that are sold as ornamental plants differ from the varieties that are grown for biomass in the Netherlands (L. Trindade, pers. comm.).

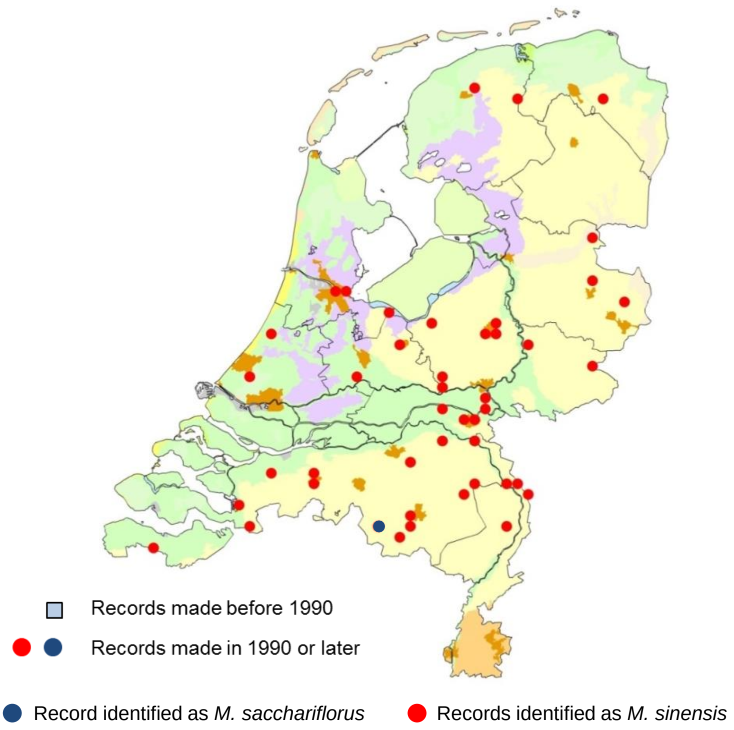

Figure 4.36: Current recorded distribution of *Miscanthus* species in the Netherlands. Source: Nationale Databank Flora en Fauna (NDFF, 2015f).

Colonisation of high conservation value habitats

To date, *Miscanthus* spp. identified as *M. sinensis* have been recorded in the Natura 2000 areas Gelderse Poort at Angeren, the Waal floodplains around Afferden, and at Maasduinen around Well (Table 4.41).

Table 4.41: Number of kilometre squares in Natura 2000 areas where *Miscanthus* species have been recorded in the Netherlands.

Natura 2000 area	Definite	Possible
Gelderse Poort	1	2
Floodplains Waal	1	2
Maasduinen	1	1

The single record for *M. sacchariflorus* lies within an agricultural landscape, not within an area of high conservation value. According to the Nationale Databank Flora en Fauna (2015), there are no current records of *M. floridulus or M.* x *giganteus* in the Netherlands. It should be noted that difficulties in correctly identifying *Miscanthus* spp. reduces the certainty of the genus' recorded distribution.

- Invasion process

Introduction outside cultivated land

The spikelets of *M. floridulus* feature many fine hairs that emanate from the base that facilitate wind dispersion. However, seedlings do not survive the relatively cold climate of Northern France (L. Trindade, pers. comm.), suggesting that crops cultivated here were produced from rhizomes. *M. floridulus* seeds may lose their fertility six months after being dispersed by wind (FuHsing, 2000). *M. floridulus* may also be a potential seed contaminant (QBank, 2015). *M. sacchariflorus* has been unable to spread beyond experimental plots in Northern France (L. Trindade, pers. comm.). No other information on the potential introduction of *M. sacchariflorus* outside agricultural land could be found during the literature search. Some *M. sinensis* varieties produce copious amounts of fertile seed (Meyer & Tchida 1999), a trait that confers a practical advantage in bioenergy systems (Christian et al. 2005; Yu et al. 2009). However, *M. sinensis* seed has the potential to disperse over long distances, and wind and water dispersal is considered to be the primary method of spread for this species in USA (Meyer, 2003). Quinn et al. (2011) stated that farmers and land managers should expect a large transfer of propagules from production fields to surrounding areas. The plant is also able to disperse through vegetative means. In suitable conditions, *M. sinensis* can spread from gardens as rhizomes in garden waste or contaminated soil. Circa four cm long rhizome fragments can be used to propagate the species (Nielsen, 1987) and smaller lengths may give rise to stands outside production plots (Quinn et al., 2011). According to CABI (2015e), all cases of introduction and spread of *M. sinensis* have been through planting as an ornamental and by the species becoming naturalised following garden escapes (CABI, 2015e). Moreover, there are no records of *M. sinensis* in Dutch nature that are associated with escapes from production fields. However, *M. sinensis* has already been introduced to areas outside production fields in several other parts of the world e.g. the Eastern United States, and is considered a serious invader (Quinn et al., 2010; Jørgensen, 2011). In the USA, populations have established hundreds of metres to several kilometres away from production fields within short periods (Quinn et al. 2010; Quinn et al., 2011). *M. sinensis* exists in the Dutch plant trade as an ornamental plant in several varieties named "Prachtriet" (www.plantago.nl).

M. sinensis is increasingly being used as a potential biofuel species in Europe. At the Wageningen University and Research Centre (WUR), the Netherlands, over 300 accessions of *M. sinensis* are being studied for potential biomass crop use. Moreover, in France in 2007, 600 ha have been planted with *Miscanthus* spp. (EPPO, 2015). Observations of a wide range of Miscanthus spp. made by researchers in the botanical garden at Trinity College, Dublin suggested that fertile seed production is common and that individuals previously thought to be sterile, were in fact fertile (Scally et al., 2001; CABI, 2015e). The researchers concluded that the previously observed lack of seed production was due to an insufficient gene pool and variations in climatic conditions. However, it was not specified which species produced seed. Seedlings of *M. sinensis* varieties have been observed in a number of conditions in Germany (Martin Deuter, personal communication in Jørgensen, 2011; Brennenstuhl, 2008 in Schnitzler & Essl, 2015) and in ruderal grassland in the Czech Republic (Pysek et al., 2002). Additional records of *M. sinensis* escape resulting in large populations have been made in Italy (E. Barni, pers. comm. in Schnitzler & Essl, 2015). Moreover, escapes of *M. sinensis* have been noted in the Voralberg valley, Austria, where spread occurred along a river and in France where the species escaped from urban plantations in La Roche-sur-Yon (EPPO, 2015). Therefore, there is evidence to indicate that seed dispersal is also a potential risk in Europe (Jørgensen, 2011). However, in Denmark, *M. sinensis* has not spread from limited areas where it is grown as a thatching material (Stewart et al., 2009; Jørgensen, 2011). In most years, the climate in Denmark is too cold for significant seed production but this may change with future climate change (Jørgensen, 2011).

In thirty years of field research of *M. x giganteus* across Europe, there have been no reports of escape beyond cultivation (Lewandowski et al., 2000; Barney & DiTomaso, 2008). However, limited evidence from Germany suggests that *M. x giganteus* may be able to escape after the fragmentation of rhizomes and vegetative reproduction (Brennenstuhl, 2008; Jørgensen, 2011). Flooding of rivers adjacent to production fields could stimulate spread if scouring and bank destabilisation occurs leading to rhizome fragmentation. Moreover, dispersal models that included the possibility of rhizome dispersal from fields and scouring at field edges demonstrate the potential for long-distance dispersal and establishment of *M. x giganteus* with inadequate management (West et al., 2014). Movement of entire rhizome mats by flood waters has been observed for *Phragmites australis* and *A. donax* (Keller 2000; Khudamrongsawat et al., 2004; Matlaga & Davis, 2013). West et al. (2014) found that clonal expansion from field edges allowed *M. x giganteus* to outgrow buffers of three metres or less within 11 to 15 years. The plant is also sold in the Netherlands as a garden plant from companies such as directplant.nl, palmaverde.nl and plantenbestel.nl.

Establishment

No information on the establishment of *M. floridulus* could be found during a search of available literature. It has been observed that *M. sacchariflorus* was able to form monocultures or near-monocultures in Ontario, Canada (Hager et al., 2015). *M. sinensis* often colonises ruderal, disturbed and urban areas (ISSG, 2015b). The species is often found on roadsides, along railways, power-lines, shores of reservoirs forest edges, sides of reservoirs, and in old fields following fires (CABI, 2015e; ISSG, 2015b; EPPO, 2015). Several traits that make *M. x giganteus* a potentially valuable biomass crop may also increase its ability to establish and become invasive e.g. rapid growth rates, efficient photosynthetic mechanisms, and the ability to re-sprout from rhizomes (Raghu et al., 2006). However, evidence of the capacity for *M.* x *giganteus* to establish outside agricultural plots is limited. In Germany, small (0.5–15 m^2) *M. sacchariflorus* stands and single *M.* x *giganteus* individuals, have been observed that may have established from garden rubbish (Brennenstuhl, 2008; Jørgensen, 2011).

An experiment in California (USA) demonstrated that 33% of planted *M.* x *giganteus* rhizomes survived and established in a lowland riparian site, while nearly 20% survived in a dry upland site. The plants competed effectively with resident vegetation and developed self-sustaining individuals in the lowland riparian area. However, the plants did not survive long term winter flooding in the riparian area even though *M.* x *giganteus* is able to tolerate flooding under warmer conditions (Barney et al., 2012). In a second US experiment, 99.9% of *M.* x *giganteus* seedlings died before reaching maturity in a no-till agricultural field, agricultural field edges, forest understory, forest edges, riparian habitats, and pasture and roadside habitats in Virginia and Georgia. However, drought conditions experienced at the time may have contributed to the high mortality rate (Smith & Barney, 2014).

Spread

M. floridulus spreads slowly using short underground rhizomes (Floridata.com). No other information on the potential spread of *M. floridulus* could be found during the literature search.

In its Canadian non-native range, *M. sacchariflorus* spread was particularly pronounced along roadways and drainages. The high disturbance associated with roadside maintenance in summer and snow removal in winter and by flooding and ice is thought to have facilitated rhizome fragmentation and dispersal (Hager et al., 2015). Certain genotypes are adapted to growing conditions along streams where there is an increased risk of dispersal due to erosion, fragmentation and water transport (Jørgensen, 2011). Moreover, buds on rhizome fragments that are buried in sediment following disturbances such as flooding are able to sprout shoots leading to rapid colonisation (Deng et al., 2013; Chen et al., 2015). In a single year in its native Japan, the size of a *M. sacchariflorus* stand may increase almost six times, from 0.5 to 3 m^2 compared to the Chinese silver grass (*Miscanthus sinensis*), which only doubles in size from 0.08 to 0.17 m^2 (Matumura et al., 1985; Bonin et al., 2014). *M. sacchariflorus* rhizomes are extensive, creeping and may spread several metres in a few years (Anzoua et al., 2011; Jørgensen, 2011; Bonin et al., 2014). However, the rate of spread in Ontario, Canada has been estimated to be less than 2 m per year due to the limitations of vegetative propagation (Hager et al., 2015). Generally, escaped populations of *M. sacchariflorus* in the USA and Europe are small and are not spreading rapidly; however, the establishment of *M. sacchariflorus* appears less advanced in Europe, possibly due to a shorter introduction history and a lower occurrence of planting for biofuels and horticulture (Schnitzler & Essl, 2015). It should be emphasised that there is limited information on how potentially invasive each *M. sacchariflorus* subspecies (by ploidy level and/or location of origin) may be (Bonin et al., 2014).

In its native Japan, *M. sinensis* is a pioneering species in heavily disturbed habitats (Hirata et al., 2007), and forest locations where clear-cutting occurs (Inoue, 2003). This occurs particularly where management intervention prevents transition to forest (e.g. burning) (Stewart et al., 2009; Quinn et al., 2010). *M. sinensis* fruits (caryopses) are known to be dispersed by wind in native grasslands (Ohtsuka et al., 1993; Quinn et al., 2011). *M. sinensis* spread is significantly affected by wind speed (Quinn et al., 2011), and this may be reflected in the results of research examining *M. sinensis* dispersal. A study by Nishiwaki et al. (1993) in native grasslands showed an exponential decline in the number of seeds with distance from the source plant and a maximum seed travel of 20 m. However, another study found that 95% and 0.4% of spikelets dispersed within 50 m and between 300 and 400 m, respectively (Smith & Barney, 2014, EPPO, 2015). Seeds may also be dispersed via machinery and vehicles, spread by hydrochory or in soil (EPPO, 2015; CABI, 2015e).

The *M.* x *giganteus* that has been considered as a biofuel in the United States is considered non-invasive because it is a triploid hybrid and thought to be sterile (Barney & DiTomaso, 2008). However, triploid plants may produce fertile seeds following rare recombination events that result in fertile allopolyploid and diploid gametes (Ramsey & Schemske 1998) and there have been rare reports of *M.* x *giganteus* producing fertile seeds (Linde-Laursen, 1993; Quinn et al., 2011). Moreover, there is no evidence to suggest that *M.* x *giganteus* has been bred for non-shattering panicles (Quinn et al., 2011). *M.* x *giganteus* has the potential to disperse over long distances through the wind dispersal of seeds. Land managers and farmers can expect a large transfer of propagules to surrounding areas from production fields (Quinn et al., 2011), a small percentage of which may be fertile. Quinn et al. (2011) found that 77% of *M.* x *giganteus* seeds landed within 50 m and 4% landed between 300 and 400 m of the source plant. However, these were infertile seeds, lacked an embryo, and were therefore lighter than the fruit of fertile plants. However, 95% and 0.4% of *M. sinensis* seeds, which are approximately the same weight as fertile *M.* x *giganteus* spikelets, dispersed within 50 m and between 300 and 400 m respectively (L. Smith, personal observation in Smith & Barney, 2014). *M.* x *giganteus* may also vegetatively reproduce from rhizomes. However, localised spread as a result of vegetative reproduction is limited to approximately 10 cm per year (U. Jørgensen, personal observation in Jørgensen, 2011). However, rhizomes fragments may be transported by man, soil erosion, flooding, etc. over larger distances (Jørgensen, 2011). Moreover, observations in Germany that *M.* x *giganteus* individuals established outside cultivation (Brennenstuhl, 2008) suggest that establishment resulting from rhizome fragmentation is a viable recruitment pathway in Europe (Matlaga & Davis, 2013).

- Environmental impacts summary

Effects on environmental targets or native species
No information on the effects of parasitism, pathogens, and parasites of either *M. floridulus*, *M. sinensis* or *M.* x *giganteus* or the effect of interbreeding of any *Miscanthus* species on environmental targets or native species could be found during a search of available literature. No information on any negative effects of *M.* x *giganteus* on environmental targets or native species could be found during a search of available literature.

Competition
M. floridulus displays allelopathic properties. In its native Taiwan, a lack of herbaceous understory in *M. floridulus* stands is due primarily to allelopathic effect (Chou & Chung, 1974; Chou, 2009). *M. floridulus* forms dense thickets that outcompetes other plants (NRCS, 2011; Hear.org, 2015a). The species is palatable to cattle but is of little or no use to deer or other wildlife (NRCS, 2011).

Escaped *M. sacchariflorus* has been linked to a decline in richness and diversity of the vegetation and soil seed bank, and altered species composition in Ontario, Canada (Hager et al., 2015). Hager et al. (2015) observed that, on average, species richness was almost three species lower in *M. sacchariflorus* invaded plots compared to non-invaded plots. However, there were more introduced than native species in invaded plots suggesting that plots containing more native species were more resilient to *M. sacchariflorus* invasion. *M. sacchariflorus* also displays allelopathic characteristics that may reduce the competitive ability of native plants. *M. sacchariflorus* buds are positioned near to the soil surface which places them closer to favourable conditions that may trigger the end of dormancy, promote rapid emergence and growth, and establish dominance (Yamasaki, 1990).

DiTomaso & Healy (2007) state that *M. sinensis* has a prolific history of naturalization and environmental degradation. The plant is described as an invasive species in

North America and Europe due to its broad environmental tolerances, fast growth rate and high production of wind dispersed seeds (Tateno, 1995; Barney & DiTomaso, 2008). *M. sinensis* is a fast growing grass that can reduce the photosynthetic capacity of other plants by reducing light availability at the soil surface (D'Antonio & Vitousek, 1992; EPPO, 2015). In Japan, *M. sinensis* establishes in abandoned fields, inhibiting the establishment of oak seedlings by reducing their daily carbon gain and the availability of light. Swearingen et al. (2010) state that in the mid-Atlantic region of the USA, *M. sinensis* forms thickets which prevent the growth of other plants at roadsides, forest edges and clearings (ISSG, 2015b).

Parasitism, pathogens, parasites

Information on the natural enemies of introduced *M. sacchariflorus* is limited. However, the species can carry switchgrass mosaic virus (Agindotan et al., 2013; Hager et al., 2015).

Positive effects on native species

The potential in-field biodiversity effects of *M.* x *giganteus* have been examined in the literature. In general, *M.* x *giganteus* is an allopolyploid hybrid that does not produce fertile seed (Raghu et al., 2006), a trait that has been linked to low potential invasiveness (Heaton et al., 2004; Barney & DiTomaso, 2008; Quinn et al., 2010). *M.* x *giganteus* may provide better habitat than annual crops in intensive agricultural landscapes due to a lack of tilling, reduced use of pesticides and refuge provision, particularly during winter (Semere & Slater, 2007a; Bellamy et al., 2009; Jørgensen, 2011). However, this effect may not persist because of lesser weed abundance (Bellamy et al., 2009; Fargione et al., 2009) and increased canopy cover and dominance of a few weed species with crop age (Semere & Slater, 2007a). For example, in *M.* x *giganteus* fields have been found to feature the greatest diversity of weed vegetation compared with reed canary-grass (*Phalaris arundinacea*) and wheat (Semere & Slater, 2007a). Invertebrates benefit from single initial planting and related tillage, no major chemical inputs; spring harvests and reduced disturbance relative to other cultivation systems (Semere & Slater, 2007b). In a UK experiment, small mammals and most birds, except open-ground species, were more abundant in field margins than in crop fields (Semere & Slater, 2007a). *M.* x *giganteus* fields provide nesting habitat for ground-nesting birds and winter foraging habitat and refuges for a wide range of species (Semere & Slater, 2005; Semere & Slater, 2007b; Semere & Slater, 2007a). Moreover, small mammals have a preference for good ground cover and little land disturbance provided by *M.* x *giganteus* cultivation (Semere & Slater, 2007a). In general, biodiversity effects will depend on the land-use type that *M.* x *giganteus* replaces and crop management practices (Jørgensen, 2011).

Effects on ecosystem function targets

No information on the effects of *M. floridulus* on ecosystem function targets, or the effects of *M. sacchariflorus*, *M. sinensis* or *M.* x *giganteus* on the biotic properties of ecosystems could be found during a search of available literature.

Abiotic properties e.g. nutrient cycling, structural modification

Observation from Ontario, Canada, suggest that low light levels below the *M. sacchariflorus* canopy and the presence of copious amounts of decomposition-resistant leaf litter result in a strong competitive influence over smaller plants (Hager et al., 2015). Hager et al. (2015) measured minimal differences in soil characteristics between sites invaded by *M. sacchariflorus* and uninvaded sites, both subject to similar inputs, suggesting that the influence of *M. sacchariflorus* on nutrient pools is limited.

Potential improvements or reductions in biodiversity will depend on the land use that *M. sinensis* substitutes, together with crop management practices. *M. sinensis* fields may improve biodiversity in intensively agricultural landscapes due to reduced pesticide level, a lack of tilling, and the provision of refuges, particularly during winter (Semere & Slater, 2007b; Bellamy et al., 2009; Jørgensen, 2011).

M. x *giganteus* has a higher water usage than cereal crops such as maize (*Zea mays*). Large scale *M.* x *giganteus* may impact the hydrological cycle and could potentially alter the intensity and spatial distribution of precipitation (Jackson et al., 2005; Vanloocke et al., 2010). Vanloocke et al. (2010) carried out simulations that suggested that 10% *M.* x *giganteus* cover in the US Midwest would result in minimal disruption to the hydrological cycle. However, coverage of 25% or 50% would lead to significant changes in the hydrological cycle (Vanloocke et al., 2010). The planting of crops with higher water usage together with the increased infiltration capacity associate with perennial cropping systems may help mitigate the effects of increased precipitation due to climate change (Rowe et al., 2009; Jørgensen, 2011).

Effects on plant targets in cultivation systems

No information on any effects of *M. sacchariflorus*; the parasitic, interbreeding or parasites and pathogens of *M. floridulus*; the parasitic or interbreeding effects of *M. sinensis;* and the parasitic, interbreeding or competitive effects of *M.* x *giganteus* on plant targets in cultivation systems could be found during a search of available literature.

Competition

In its native Japan, *M. sinensis* is a major herbaceous species of young tree plantations that can suppress planted saplings. Mechanical management within plantations is very labour intensive (Hirata et al., 2007).

M. floridulus is an agricultural weed of rice in south-east Asia (Hear.org, 2015a).

Pathogens or parasites

M. sinensis potentially carries several pathogens, for example, the barley yellow dwarf luteovirus-PAV, barley yellow dwarf luteovirus-MAV and cereal yellow dwarf luteovirus (Harris et al., 2000; ISSG, 2015b; EPPO, 2015). In its native range, *M. sinensis* is known to mediate interactions between crops and their pests (Spencer, 2009).

Western corn rootworm (*Diabrotica virgifera virgifera* LeConte, WCR), a major pest of maize, has been discovered in *M.* x *giganteus* (Spencer & Raghu, 2009; Jørgensen, 2011). This pest species has also been recorded in Europe (Spencer & Raghu, 2009). WCR is responsible for more than $1 billion in annual maize yield losses and management costs in the U.S.A (Rice, 2004; Spencer & Raghu, 2009). Spencer & Raghu (2009) suggested that the impacts of WCR on *M.* x *giganteus* may be limited owing to the perennial nature its abundant roots. However, *M.* x *giganteus* could function as a reservoir allowing a build-up of WCR populations that could then negatively impact other species (Spencer & Raghu, 2009).

Effects on animal health and production targets
No information on the effects of pathogens or parasites of *M. floridulus*, *M. sacchariflorus*, *M. sinensis* or *M.* x *giganteus* on animal health and production targets could be found during a search of available literature. Certain cultivars of *M. sinensis* are used as a feed crop (Stewart et al., 2009).

Human targets
No information on the effects of pathogens or parasites of *M. floridulus*, *M. sacchariflorus*, *M. sinensis* or *M.* x *giganteus* on human targets could be found during a search of available literature. However, silica accumulates in *M. floridulus* leaf margins resulting in sharp edges that are capable of cutting animals or humans (NRCS, 2011).

Effects on other targets
No information on the effects of *M. sacchariflorus* on infrastructure could be found during a search of available literature. The lower leaf blades of *M. floridulus* tend to fall in late summer, increasing the risk of wildfire. The plants are not killed by fire but quickly regenerate from underground rhizomes (NRCS, 2011). Also *M. sinensis* becomes highly flammable when dry and can become a fire hazard when fully senescent (Swearingen et al., 2002; ISSG, 2015b; EPPO, 2015). When on fire burning plant fragments can make control difficult (CABI, 2015e). However, according to Jørgensen (2011), the risk of fire in fully senescent *M.* x *giganteus* is low in the humid climate of Northern Europe.

- Ecological risk assessment with the ISEIA protocol

Pacific island silver grass (Miscanthus floridulus)

The expert team allocated *M. floridulus* a 'medium' ecological risk classification to the category dispersion potential and invasiveness, a ‘likely’ risk classification to the categories adverse impacts on native species and alteration of ecosystem functions and a ‘deficient data (DD)’ risk classification to the category colonization of high value conservation habitats (Table 4.42). The total ecological risk score for the species is 7 out of a maximum of 8. Therefore, *M. floridulus* is classified in the C list of the BFIS list system. The maximum risk score takes into account the limitation on maximum risk score per category that is imposed by the ISEIA protocol if data deficiency occurs or the application of best professional judgement is required (See section 2.4.2). The maximum risk score will, therefore, vary between species. In cases where there is sufficient information, i.e. where there is no data deficiency and best professional judgement is not required, the maximum possible risk score is 12. The rationale for the allocated scores is given in the following paragraphs.

It should be noted that the risk scores for adverse impacts on native species and alteration of ecosystem functions are based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

Table 4.42: Consensus scores for potential risks of Pacific island silver grass (*Miscanthus floridulus*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	**Risk**	**Consensus score**
Dispersion potential or invasiveness	Medium	2
Colonization of high value conservation habitats[a]	DD	1[b]
Adverse impacts on native species	Likely	2
Alteration of ecosystem functions	Likely	2
Ecological risk score		7

[a] Quantitative analysis was focused on Natura 2000 areas may indicate a lower score, however, species may also occur in other areas with high conservation value; [b] Deficient data (DD) scores 1 as this is the minimum that can be awarded per risk category.

Dispersion potential or invasiveness

Classification: **Medium risk**. Information from literature suggests that the climate in the Netherlands is suitable for *M. floridulus* growth. Generally, the species tolerates a broad range of climates and has been grown in Northern France and yielded a higher biomass than *M.* x *giganteus*. However, seedlings do not survive the relatively cold climate of Northern France, suggesting that crops were cultivated from rhizomes and that the plant will only be able to spread via rhizomes in the Netherlands. Moreover, field experiments in Taiwan revealed that the optimum temperatures for biomass accumulation for *M. floridulus* were 30/25 °C (day/night temperature) which suggests that temperature may be sub-optimal for growth in Northern Europe. The species tolerates a wide range of soil conditions, wind and salt spray. To conclude, except when assisted by man, the species doesn't colonize remote places. Natural dispersal rarely exceeds more than 1 km per year. The species can however become locally invasive because of a strong reproduction potential.

Colonization of high value conservation habitats

Classification: **Deficient data**. According to the Nationale Databank Flora en Fauna (2015), there are no current records of *M. floridulus* in the Netherlands. There was no information describing the potential habitat suitability of *M. floridulus* that suggests that the species would or would not colonise habitats of high conservation value in the Netherlands. Therefore there is insufficient information to judge whether *M. floridulus* is able to colonise areas of high conservation value in the Netherlands. However, it should be noted that difficulties in correctly differentiating between *Miscanthus* spp. reduces the certainty of the genus' recorded distribution in the Netherlands.

Adverse impacts on native species

Classification: **Likely**. A lack of herbaceous understory in *M. floridulus* stands, due primarily to allelopathic effect, in Taiwan and the fact that *M. floridulus* forms dense thickets that outcompete other plants suggests that Dutch native species may be outcompeted if *M. floridulus* were to establish in the Netherlands. Selective grazing by deer or other wildlife could add to the relative abundance of *M. floridulus* compared to Dutch native species. There is no evidence of impacts on native species in the Netherlands or climatically similar regions. However, in view of the potential suitability of the Dutch climate for *M. floridulus*, it is likely that the species would establish and adversely impact native species in the Netherlands.

Alteration of ecosystem functions

Classification: **Likely**. *M. floridulus* forms dense thickets that outcompete other plants. Moreover, the lower leaf blades of *M. floridulus* tend to fall in late summer, increasing the risk of wildfire. It is not stated in the literature if this occurs in the Netherlands or climatically similar regions. However, in view of the potential suitability of the Dutch climate for *M. floridulus*, it is likely that the species would establish and alter ecosystem functions in the Netherlands.

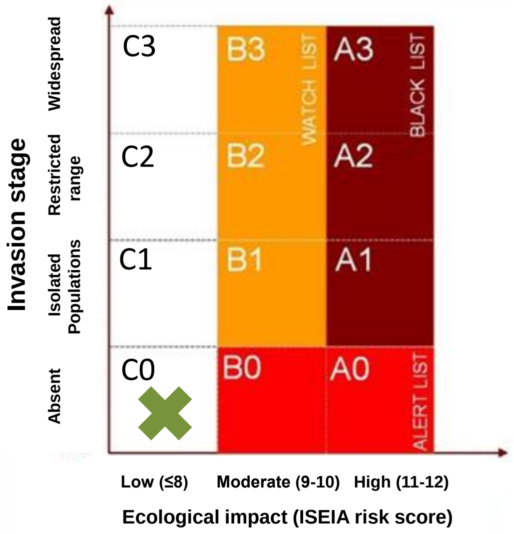

Figure 4.37: Risk classification of Pacific island silver grass (*Miscanthus floridulus*) according to the BFIS list system.

Risk classification according to the BFIS list system

The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.42) in combination with the current recorded distribution in the Netherlands. The species classification for *M. floridulus* is C0 (Figure 4.37). This characterises a non-native species that is absent from the area under assessment, poses a low ecological risk and is not classified in the BFIS list system.

Japanese silver grass (Miscanthus sacchariflorus)

The expert team allocated *M. sacchariflorus* a 'medium' ecological risk classification to the categories dispersion potential or invasiveness and alteration of ecosystem functions, a ‘high’ risk classification to the category adverse impacts on native species and a ‘likely’ risk classification to the category colonization of high value conservation habitats (Table 4.43). The total ecological risk score for the species is 9 out of a maximum of 11. Therefore, *M. sacchariflorus* is classified in the B list of the BFIS list system. The maximum risk score takes into account the limitation on maximum risk score per category that is imposed by the ISEIA protocol if data deficiency occurs or the application of best professional judgement is required (See section 2.4.2). The maximum risk score will, therefore, vary between species. In cases where there is sufficient information, i.e. where there is no data deficiency and best professional judgement is not required, the maximum possible risk score is 12. The rationale for the allocated scores is given in the following paragraphs.

It should be noted that the risk score for colonization of high value conservation habitats is based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

Table 4.43: Consensus scores for potential risks of Japanese silver grass (*Miscanthus sacchariflorus*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	Medium	2
Colonization of high value conservation habitats	Likely*	2
Adverse impacts on native species	High	3
Alteration of ecosystem functions	Medium	2
Ecological risk score		**9**

* Quantitative analysis was focused on Natura 2000 areas may indicate a lower score; however, this species may occur in other areas with high conservation value.

Dispersion potential or invasiveness

Classification: **Medium risk**. A climate match for present conditions and for future climate change using the CLIMEX model suggests that the climate in the Netherlands will not pose a barrier for *M. sacchariflorus* colonisation now and in the future. There is one record of *M. sacchariflorus* for the Netherlands made in 2007 and located near Reusel. *M. sacchariflorus* occurs mainly as a non-native plant in north-western Europe, Denmark, Sweden, the north-eastern United States, and south eastern Canada.

However, *M. sacchariflorus* may not produce viable seed in the cooler climates of Europe, and primarily reproduces vegetatively. The rate of spread in Ontario, Canada has been estimated to be less than 2 m per year due to the limitations of vegetative propagation. In the Netherlands spread occurs through rhizomes only. Moreover, *M. sacchariflorus* has been unable to spread beyond experimental plots in Northern France. Generally, escaped populations of *M. sacchariflorus* in the USA and Europe are small and are not spreading rapidly. In conclusion, except when assisted by man, the species doesn't colonize remote places. Natural dispersal rarely exceeds more than 1 km per year. The species can however become locally invasive because of a strong reproduction potential.

It should be emphasised that there is limited information on the potential invasiveness each *M. sacchariflorus* subspecies (by ploidy level and/or location of origin). Moreover, cold tolerance appears to vary according to genotype and plant origin.

Colonization of high value conservation habitats

Classification: **Likely**. The single record for *M. sacchariflorus* that exists for the Netherlands lies within an agricultural landscape, not within an area of high conservation value. Moreover, there is a lack of evidence in literature regarding the potential for the species to colonise in this habitat type in areas climatically similar to the Netherlands. However, *M. sacchariflorus* is typically found in mesic environments, i.e. areas near wetlands and water. In general, escaped populations of *M. sacchariflorus* occur along rivers and the species is able to spread via hydrochory due to the presence of reproductive rhizomes and its preference for wetland environments. Therefore it is likely that *M. sacchariflorus* will be able to colonise areas of high conservation value, such as river banks and floodplains, in the Netherlands.

Adverse impacts on native species

Classification: **High risk**. *M. sacchariflorus* displays allelopathic characteristics that may reduce the competitive ability of native plants. Moreover, escaped *M. sacchariflorus* has been linked to a decline in richness and diversity of the vegetation and soil seed bank, and altered species composition in Ontario, Canada. On average, species richness was almost three species lower in *M. sacchariflorus* invaded plots compared to non-invaded plots. In conclusion, the development of *M. sacchariflorus* would cause local severe (> 80%) population declines and the reduction of local species richness if it became further established in the Netherlands.

Alteration of ecosystem functions

Classification: **Medium risk**. Observation from Ontario, Canada, suggest that low light levels below the *M. sacchariflorus* canopy and the presence of copious amounts of decomposition-resistant leaf litter result in a strong competitive influence over smaller plants. Observations from the same location revealed minimal differences in soil characteristics between sites invaded by *M. sacchariflorus* and uninvaded sites, both subject to similar inputs, suggesting that the influence of *M. sacchariflorus* on nutrient pools is limited. In conclusion, competition for light and space would cause impacts on ecosystem processes and structures that is moderate and considered as easily reversible.

Risk classification according to the BFIS list system

The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.43) in combination with the current recorded distribution in the Netherlands.

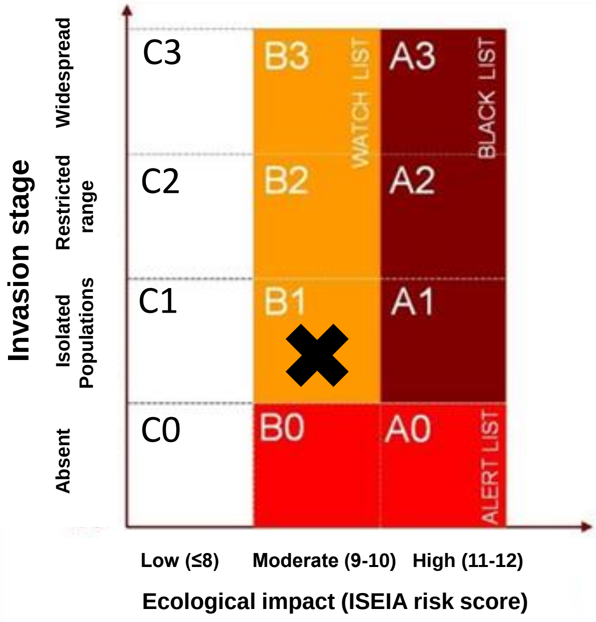

Figure 4.38: Risk classification of Japanese silver grass (*Miscanthus sacchariflorus*) according to the BFIS list system.

The species classification for *M. sacchariflorus* is B1 (Figure 4.38). This characterises a non-native species that has isolated populations in the area under assessment, poses a moderate ecological risk and is place on the watch list of the BFIS list system.

Chinese silver grass (Miscanthus sinensis)

The expert team allocated *M. sinensis* a 'low' ecological risk classification to the categories dispersion potential and invasiveness and colonization of high value conservation habitats, and a ‘likely’ risk classification to the categories adverse impacts on native species and alteration of ecosystem functions (Table 4.44).

The total ecological risk score for the species is 6 out of a maximum of 10. Therefore, *M. sinensis* is classified in the C list of the BFIS list system. The maximum risk score takes into account the limitation on maximum risk score per category that is imposed by the ISEIA protocol if data deficiency occurs or the application of best professional judgement is required (See section 2.4.2). The maximum risk score will, therefore, vary between species. In cases where there is sufficient information, i.e. where there is no data deficiency and best professional judgement is not required, the maximum possible risk score is 12. The rationale for the allocated scores is given in the following paragraphs.

It should be noted that the risk scores for adverse impacts on native species and alteration of ecosystem functions are based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

Table 4.44: Consensus scores for potential risks of Chinese silver grass (*Miscanthus sinensis*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	Low	1
Colonization of high value conservation habitats	Low	1
Adverse impacts on native species	Likely	2
Alteration of ecosystem functions	Likely	2
Ecological risk score		**6**

*Quantitative analysis was focused on Natura 2000 areas may indicate a lower score; however, this species occurs also in other areas with high conservation value.

Dispersion potential or invasiveness

Classification: **Low risk**. *M. sinensis* is a self-incompatible and wind-pollinated plant (Hayashi, 1979; Hayashi et al., 1981; Nakagoshi, 1984; Nechiporenko et al., 1997; Matumura, 1998; Stewart et al., 2009) that produces seeds which are mainly dispersed by wind and reproduces vegetatively through rhizomes (US Forest Service, 2006). Rhizomes allow a moderate horizontal expansion. The species can produce 6.5 x 10-7 to 1.4 x 10-9 seeds per ha during cultivation (Quinn et al., 2011) and establishes seed banks that are viable for at least one year (ISSG, 2015b). Seed has the potential to disperse over long distances. In the USA, populations have established hundreds of metres to several kilometres away from production fields within short periods (Quinn et al., 2010; Quinn et al., 2011). However, during extended field trials in the Netherlands lasting approximately 25 years, no observations of *M. sinensis* spread outside the limits of cultivation fields have been made, and has the least potential for spread relative to other *Miscanthus* spp. due to its limited rhizome production (L. Trindade, unpublished data). Moreover, Clifton-Brown et al. (2001) predicted that soil temperatures in spring in Northern Europe would inhibit germination under present climatic conditions. Establishment of

Miscanthus spp. from seed in spring is unlikely in Northern Europe without crop management practices aimed at raising soil temperature under present climatic conditions. Since 2005, recordings of *Miscanthus* spp. identified as *M. sinensis* have been made in more than 40 km squares throughout the Netherlands (Figure 4.29). However due to difficulties in correctly identifying *Miscanthus* species and varieties that may have originated from either the ornamental plant trade or biomass cultivation, this current recorded distribution should be treated with a high degree of scepticism. Based on the unpublished evidence from experimental cultivation in the Netherlands and evidence from literature suggesting inhibited germination in Northern Europe, it was concluded that *M. sinensis* doesn't spread in the environment because of poor dispersal capacities and a low reproduction potential.

Colonization of high value conservation habitats

Classification: **Low risk**. Recordings of *Miscanthus* spp. have been made in several Natura-2000 areas in the Netherlands (Gelderse Poort at Angeren, the Waal floodplains around Afferden, and at Maasduinen around Well). However, the correct identification of *Miscanthus* at species level is problematic in the Netherlands because of a lack of suitable identification keys. Therefore, it is unclear which varieties of *Miscanthus* spp. are present in nature. Because *M. sinensis* is unable to spread beyond cultivation fields in the Netherlands (L. Trindade, pers. comm.), and evidence of inhibited germination in Northern Europe, it was concluded that *M. sinensis* does not colonise high value conservation habitats.

Adverse impacts on native species

Classification: **Likely**. No information on the potentially parasitic effects of *M. sinensis* or effects relating to the hosting of pathogens or parasites on native species. *M. sinensis* forms thickets which prevent the growth of other plants at roadsides, forest edges and clearings (ISSG, 2015b). It is likely that *M. sinensis* would impact native species adversely if it established in the Netherlands.

Alteration of ecosystem functions

Classification: **Likely**. No information on the effects of *M. sinensis* on the biotic properties of ecosystems is available. However, *M. sinensis* is a robust perennial plant that can reach up to 4 m in height and in Europe reaches heights of 1.0–2.3 m (Clifton-Brown et al., 2001). It is likely that *M. sinensis* will alter ecosystem functions adversely if it established in the Netherlands.

Risk classification according to the BFIS list system

The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.44) in combination with the current recorded distribution in the Netherlands. The species classification for *M. sinensis* is C3 (Figure 4.39). This characterises a non-native species that is, according to records, widespread in the area under assessment, poses a low ecological risk and is not classified within the BFIS list system. However, it should be noted that difficulties in correctly differentiating between *Miscanthus* spp. reduces the certainty of the Netherlands distribution displayed in section 4.83, figure 4.36.

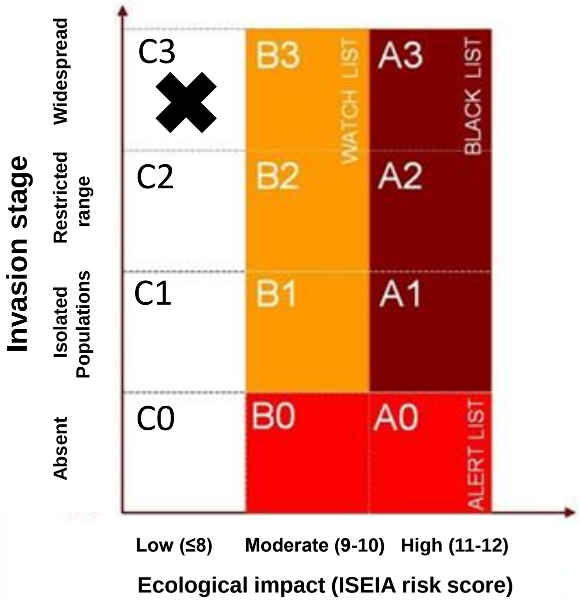

Figure 4.39: Risk classification of Chinese silver grass (*Miscanthus sinensis*) according to the BFIS list system.

Miscanthus (Miscanthus x *giganteus)*

The expert team allocated *M.* x *giganteus* a 'medium' ecological risk classification to the category dispersion potential and invasiveness and a ‘likely’ risk classification to the categories colonization of high value conservation habitats, adverse impacts on native species and alteration of ecosystem functions (Table 4.45). The total ecological risk score for the species is 8 out of a maximum of 9. Therefore, *M.* x *giganteus* is classified in the C list of the BFIS list system. The maximum risk score takes into account the limitation on maximum risk score per category that is imposed by the ISEIA protocol if data deficiency occurs or the application of best professional judgement is required (See section 2.4.2). The maximum risk score will, therefore, vary between species. In cases where there is sufficient information, i.e. where there is no data deficiency and best professional judgement is not required, the maximum possible risk score is 12. The rationale for the allocated scores is given in the following paragraphs.

Table 4.45: Consensus scores for potential risks of miscanthus (*Miscanthus* x *giganteus*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	**Risk**	**Consensus score**
Dispersion potential or invasiveness	Medium	2
Colonization of high value conservation habitats	Likely*	2
Adverse impacts on native species	Likely	2
Alteration of ecosystem functions	Likely	2
Ecological risk score		**8**

*Quantitative analysis was focused on Natura 2000 areas may indicate a lower score; however, species may also occur in other areas with high conservation value.

It should be noted that the risk scores for colonization of high value conservation habitats, adverse impacts on native species and alteration of ecosystem functions are based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

Dispersion potential or invasiveness

Classification: **Medium risk**. In general, the climate in the Netherlands is suitable for the growth of *M.* x *giganteus*; however, the species is probably sensitive to severe Dutch winters. *M.* x *giganteus* is a naturally occurring sterile allopolyploid hybrid (Clark et al., 2015; Lewandowski et al., 2000; Barney & DiTomaso, 2008; Raghu et al., 2006). However, allopolyploidy is not a total guarantee of continued sterility (Raghu et al., 2006). *M.* x *giganteus* may produce over 2.5 billion spikelets ha/yr (Smith & Barney, 2014). Therefore, even low rates of seed viability and survival, seedling survival and seed germination will support rapidly expanding populations in a fertile genotype (Matlaga & Davis, 2013). *M.* x *giganteus* is also able to reproduce vegetatively and vegetative propagation is often associated with invasiveness or directly contributes to it (Raghu et al., 2006). However, dispersion potential and invasiveness will be lower than for *M. sacchariflorus*. To conclude, there is a medium risk that *M.* x *giganteus* will disperse and become invasive in the Netherlands.

Colonization of high value conservation habitats

Classification: **Likely**. According to the Nationale Databank Flora en Fauna (2015f), there are no records of *M. x giganteus* in Dutch nature. However, *Miscanthus* spp. are difficult to differentiate from each other leading to misidentification. In thirty years of field research of *M.* x *giganteus* across Europe, there have been no reports of escape beyond cultivation (Lewandowski et al., 2000; Barney & DiTomaso, 2008). However, limited evidence from Germany suggests that *M. x giganteus* may be able to escape after the fragmentation of rhizomes and vegetative reproduction (Brennenstuhl, 2008; Jørgensen, 2011). It is likely *M. x giganteus* will usually be confined to habitats with a low or medium conservation value and will occasionally colonise high conservation value habitats.

Adverse impacts on native species

Classification: **Likely**. Biodiversity effects in agricultural areas will depend on the land-use type that *M.* x *giganteus* replaces and crop management practices (Jørgensen, 2011). This impact may be positive or negative depending on conditions prior to cultivation. There is an absence of information on the effects of *M.* x *giganteus* on native species in the Netherlands or climatically similar countries. It is likely that *M.* x *giganteus* will have similar impacts on native species to the related *M. sacchariflorus*.

Alteration of ecosystem functions

Classification: **Likely**. *M.* x *giganteus* grows to a maximum of 1 (Radford et al., 1968) to 3 m tall in North America (Gilman, 1957) and produces dense stands. *M.* x *giganteus* is a rhizomatous species (Lewandowski et al., 2000) and around 50% percent of its biomass lies beneath the soil surface. A large area covered by *M.* x *giganteus* may potentially affect the hydrological cycle. It is likely that *M.* x *giganteus* will have similar impacts on ecosystem functions to the related *M. sacchariflorus*.

Risk classification according to the BFIS list system

The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.45) in combination with the current recorded distribution in the Netherlands. The species classification for *M.* x *giganteus* is C0 (Figure 4.40). This characterises a non-native species that is absent from the area under assessment, poses a low ecological risk and is not classified in the BFIS list system. However, it should be noted that difficulties in correctly differentiating between *Miscanthus* spp. reduces the certainty of the genus' distribution in the Netherlands.

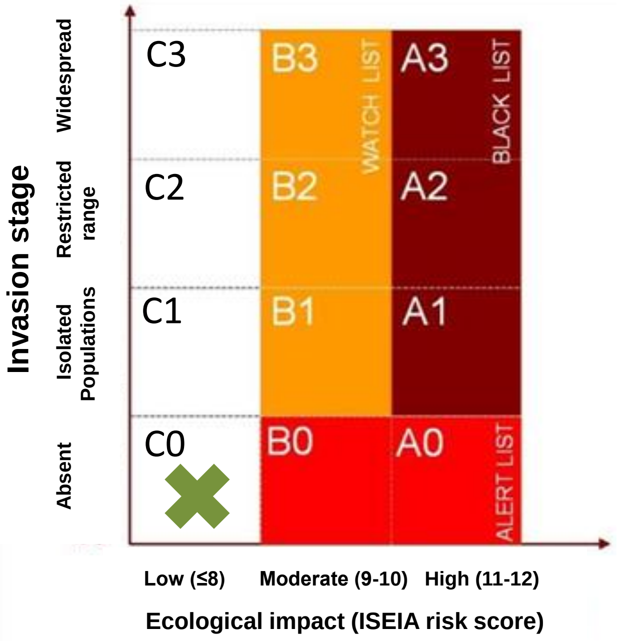

Figure 4.40: Risk classification of miscanthus (*Miscanthus* x *giganteus*) according to the BFIS list system.

- Other risk assessments and classifications

A single risk classification of *M. floridulus* was found for Hawaii. Following application of the Hawaiian Pacific Weed Risk Assessment (HPWRA), the species was allocated to a high risk category (Table 4.46).

Risk classifications for *M. sacchariflorus* exist for Germany and the USA (Table 4.46). In Germany the species was classified as potentially invasive, while in the USA the species was rejected for import and classified as high risk (Nehring et al., 2013; Barney et al., 2015). In their description of *M. sinensis*, the European and

Mediterranean Plant Protection Organisation (EPPO) state that *M. sacchariflorus* may also represent a risk to EPPO countries, although much less information is available on this species (EPPO, 2015).

A summary of risk classifications for *M. sinensis* is presented in table 4.46. *M. sinensis* was added to the European Plant Protection Organisation **(**EPPO) Alert List in 2011. Justification for this was that the plant should be monitored because it had shown invasive behaviour outside the EPPO region and was increasingly being planted in Europe while no risk analyses had been carried (EPPO, 2015). In Germany, *M. sinensis* was assessed using the German-Austrian black list information system (GABLIS) and was placed on a watch list due to its high reproductive and dispersal potential (Nehring et al., 2013). *M. sinensis* was rejected for introduction in Italy following the application of an adapted version of the Australian Weed Risk Assessment (WRA) (Crosti et al., 2010). A risk prioritisation process carried out for New York (USA) categorised *M. sinensis* as a high risk species.

M. sinensis is increasingly being classified as an invasive species by horticulturalists industry, particularly in the USA (Meyer & Tchida, 1999; Peters et al., 2006; Wilson & Knox, 2006), floristic databases (EDDMaps, 2010; USDA NRCS, 2010), state and regional invasive plant councils (SE-EPPC, 2015), and the United States Forest Service (Miller et al., 2004; US Forest Service, 2006).

M. x *giganteus* received low adapted weed risk assessment scores for Florida and the United States in general, primarily due to the plant's infertility (Barney & DiTomaso, 2008; Quinn et al., 2010) (Table 4.46). *M.* x *giganteus* was accepted for introduction, without controls to New Zealand after it was judged to be highly improbable that *M.* x *giganteus* could (1) form self-sustaining populations anywhere in New Zealand; (2) displace or reduce a valued species; (3) cause deterioration of natural habitats; (4) be disease-causing or be a parasite, or be a vector or reservoir for human, plant or animal disease; (5) have any adverse effects on human health and safety or the environment (www.ermanz.govt.nz).

Table 4.46: Overview of risk classifications previously performed for *Miscanthus* species.

Pacific island silver grass (*Miscanthus floridulus*)	**Region**	**Pacific (Hawaii)**			
	Scope	Risk assessment			
	Method	Hawaiian Pacific Weed Risk Assessment (HPWRA)			
	Year	2012			
	Risk classification	**18 (High risk)**			
	Source	Hear.org (2015a)			
Japanese silver grass (*Miscanthus sacchariflorus*)	**Region**	**Germany**	**USA**	**USA**	
	Scope	Risk prioritisation	Risk Assessment	Risk Assessment	
	Method	German-Austrian black list information system (GABLIS)	Australian weed risk assessment (A-WRA)	U.S. plant protection and quarantine risk assessment (PPQ-WRA)	
	Year	2013	2015	2015	
	Risk classification	**Grey list (potentially invasive)**	**Reject**	**High risk**	
	Source	Nehring et al. (2013)	Barney et al. (2015)	Barney et al. (2015)	
Chinese silver grass (*Miscanthus sinensis*)	**Region**	**EPPO region**	**Germany**	**Italy**	**USA (New York)**
	Scope	Risk prioritisation	Risk prioritisation	Risk assessment	Risk prioritisation
	Method	EPPO prioritization process for invasive alien plants	German-Austrian black list information system (GABLIS)	Adapted Australian weed risk assessment	New York non-native plant invasiveness ranking procedure
	Year	2011	2013	2010	2010
	Risk classification	**Alert list**	**Watch list**	**Rejected**	**High (77.78)**
	Source	www.eppo.int	Nehring et al. (2013)	Crosti et al. (2010)	New York invasive species information
Miscanthus (*Miscanthus* x *giganteus*)	**Region**	**USA (general)**	**USA (Florida)**	**New Zealand**	
	Scope	Risk assessment method	Risk assessment method	Risk assessment method	
	Method	Modified Weed Risk Assessment (WRA).	Modified Weed Risk Assessment (WRA).	Considered in accordance with the relevant provisions of the New Zealand Hazardous Substances and New Organisms (HSNO) Act 1996 (the Act) and of the HSNO (Methodology) Order 1998 (the Methodology).	
	Year				
	Risk classification	**Accept (-9)**	**Accept (-8)**	**Approved for introduction, without controls**	
	Source	Hear.org (2015g)	Hear.org (2015g)	www.ermanz.govt.nz	

4.8.4 Switchgrass (*Panicum virgatum*)

- Species description

Switchgrass (*Panicum virgatum*), is a hardy, perennial, rhizomatous grass which can grow to up to 1.8 to 2.2 m tall. Its rhizomes are elongated and scaly (Figure 4.41). The stems extend from 60 to 300 cm, feature glabrous or bearded nodes and lack lateral branches. The leaf to sheaths are glabrous and the ligule is a ciliolate membrane, approximately 1.5 to 3 mm in length. The glabrous or pilose leaf to blades are 10 to 60 cm long, 3 to 15 mm wide and red tinged. The inflorescence is an open and ovate panicle, approximately 15 to 55 cm long. The spikelets are solitary and pedicelled, comprising a single basal sterile floret and one fertile floret with no rhachilla extension. The spikelets themselves are ovate, 0.3 to 0.5 cm long and compressed dorsally. The glumes reach the apex of florets and are thinner than the fertile lemma. The five veined, ovate lower glume are clasping, 0.66 to 0.75 times as long as the spikelet, membranous and without keels. The seven veined, membranous, upper glume is ovate, the same length as the spikelet, and without keels. Both the upper and lower glume apexes are acuminate. The basal male florets are sterile and feature palea. The lemma of the lower sterile floret is similar to that of the upper glume (ovate, five veined, membranous, acuminate) and the same length as the spikelet. The dorsally compressed, fertile lemma are ovate, indurate, pallid, shiny, 2.5 to 3.5 mm long, and without a keel. The lemma features involute margins and an acute apex. The palea are involute and indurate. Three anthers are present. The caryopsis fruit has an adherent pericarp (Ecocrop, 2015d). A large number of cultivars, improved, and selected materials of *P. virgatum* are available. In the USA alone 24 cultivars are available, originating from different states (Jimmy Carter Plant Materials Center, 2011).

Figure 4.41: Switchgrass (*Panicum virgatum*). (Source: Chhe, 2009; Wikimedia Commons).

Species taxonomy

Table 4.47: Nomenclature and taxonomical status of Switchgrass (*Panicum virgatum*).

Scientific name:
Panicum virgatum L. (1753)

Synonyms:
Chasea virgata (L.) Nieuwl.
Eatonia purpurascens Raf.
Ichnanthus glaber Link ex Steud., pro syn.
Milium virgatum (L.) Lunell
Milium virgatum var. elongatum (Vasey) Lunell
Panicum buchingeri E.Fourn.
Panicum coloratum Walter, nom. illeg.
Panicum giganteum Scheele
Panicum glaberrimum Steud.
Panicum ichnanthoides E.Fourn.
Panicum kunthii E.Fourn., nom. illeg.
Panicum pruinosum Bernh. ex Trin., pro syn.
Panicum virgatum var. *breviramosum* Nash
Panicum virgatum var. *confertum* Vasey
Panicum virgatum subsp. *cubense* (Griseb.) Borhidi
Panicum virgatum var. *cubense* Griseb.
Panicum virgatum var. *diffusum* Vasey
Panicum virgatum var. *elongatum* Vasey
Panicum virgatum var. *glauciphyllum* Cassidy
Panicum virgatum var. *obtusum* Alph.Wood
Panicum virgatum var. *scorteum* H.P.Linder
Panicum virgatum var. *spissum* H.P.Linder
Panicum virgatum var. *thyrsiforme* H.P.Linder

Taxonomic tree (Catalogue of Life, 2015):
Kingdom: Plantae
Phylum: Tracheophyta
Class: Liliopsida
Order: Poales
Family: Poaceae
Genus: *Panicum*
Species: *Panicum virgatum*

Preferred Dutch name:
Vingergrass (unofficial name)

Preferred English name:
Switchgrass

Other Dutch names:
Pluimgierst, parelgierst

Other English names:
Tall panic grass, Wobsqua grass, lowland switchgrass, blackbent, tall prairie grass, wild redtop, thatch grass

Life cycle
P. virgatum growth begins in late spring (Ecocrop, 2015d).

Reproductive capacity
P. virgatum reproduces by setting seeds and vegetatively. Its perennial life form allows stands to last indefinitely once established (Ecocrop, 2015d). Seed production may give *P. virgatum* an even greater invasive potential than Miscanthus, a plant it shares many traits with (Raghu et al., 2006).

- Habitat summary

P. virgatum tolerates the following climates: tropical wet & dry, tropical wet, steppe or semiarid, subtropical humid, subtropical dry summer, subtropical dry winter, temperate oceanic, temperate continental, temperate with humid winters and temperate with dry winters (Ecocrop, 2015d). Considerable genotypic and phenotypic variability ensures this species is adapted across a wide geographic and environmental range (Parish & Fike, 2005). For example, *P. virgatum* is distributed widely across North America, from 5 to 25 ^{o}C mean average temperature and 300 to 1500 mm mean average precipitation (Hartman et al., 2011). Moreover, *P. virgatum* is a C4 photosynthetic plant, which is advantageous in drought and high temperature conditions (Ecocrop, 2015d). However, Barney & DiTomaso (2010a) suggest that it is unlikely that *P. virgatum* will establish unless it has access to water at all times (Barney et al., 2012).

The physiological conditions tolerated by *P. virgatum* are listed in table 4.48. *P. virgatum's* temperature requirement ranges from 11 to 32 ^{o}C (optimal) and 6 to 36 ^{o}C (absolute limit) (Ecocrop, 2015d). *P. virgatum* appears to be extremely winter hardy as no winterkill occurred in any switchgrass varieties in North America in 2004, even though winter temperatures in December dipped to -28 ^{o}C (Fransen et al., 2006). However, Ecocrop (2015d) suggests that a temperature of -10 ^{o}C is sufficient to kill *P. virgatum* during rest. Lowry et al. (2014) suggested that adaptation to low temperature in *P. virgatum* depends on plant phenology and population origin. The plant is reported to tolerate minimum temperatures of -1 ^{o}C during early growth (Ecocrop, 2015d). *P. virgatum* prefers high light intensities, and is able to grow in full sunlight (Ecocrop, 2015d). Rainfall for optimal *P. virgatum* growth is reported to be between 500 and 1100 mm annually. *P. virgatum* can tolerate a minimum of 300 mm and maximum of 2700 mm annual rainfall (Ecocrop, 2015d).

P. virgatum grows best in well drained to dry soils of light texture and low to moderate fertility (Ecocrop, 2015d). Optimal soil depth for *P. virgatum* lies between 50 and 150 cm but the plant is able to tolerate soil depths of 20 to 50 cm (Ecocrop, 2015d). *P. virgatum* is reported to be able to tolerate pHs ranging from 4.9 to 8.2 and grows optimally in soils ranging from pH 6.0 to 7.0 (Ecocrop, 2015d). *P. virgatum* is able to tolerate soil salinities to a maximum of 4 dS/m (Ecocrop, 2015d).

Table 4.48: Physiological conditions tolerated by switchgrass (*Panicum virgatum*).

Parameter	Optimal	Absolute limit	References
Temperature requirement (^oC)	17-32	5-36	Hartman et al. (2011); Ecocrop (2015d)
Killing temperature during rest (^oC)	-	-10 to -28	Fransen et al. (2006); Ecocrop (2015d)
Killing temperature early growth (^oC)	-	-1	Ecocrop (2015d)
Light intensity	Very bright	Very bright – clear skies	Ecocrop (2015d)
Rainfall (annual - mm)	500-1100	300-2700	Hartman et al. (2011); Ecocrop (2015d)
Soil pH	6.0-7.0	4.9-8.2	Ecocrop (2015d)
Soil depth (cm)	50-150	20-50	Ecocrop (2015d)
Soil texture	Light	Light	Ecocrop (2015d)
Soil fertility	Moderate	Low	Ecocrop (2015d)
Soil salinity (dS/m)	<4	4	Ecocrop (2015d)
Soil drainage	well (dry spells), excessive (dry/moderately dry)	well (dry spells), excessive (dry/moderately dry)	Ecocrop (2015d)

Climate modelling suggests that future climate changes will allow *P. virgatum* to extend its distribution to north-eastern United States and that middle and northern latitudes of Canada will become increasingly favourable to *P. virgatum* over this century (Barney & DiTomaso, 2010a; Ahrens et al., 2014). However, Fay et al. (2012), discovered that aboveground net primary productivity of *P. virgatum* was not affected by a 250 to 500 μl^{-1} gradient in atmospheric CO_2. Atmospheric CO_2 levels are expected to exceed 500 μl^{-1} by 2050 (Forster et al., 2007).

- Recorded distribution

Native range
P. virgatum's native range extends to most of North America, east of the Rocky Mountains, excluding California (Barney et al., 2012).

Cultivated range
No information on the cultivated range of *P. virgatum* could be found during a search of available literature.

Non-native range
No information on the non-native range of *P. virgatum* could be found during a search of available literature.

Distribution in the Netherlands
P. virgatum was first documented in Dutch nature in 2003 when the species was recorded in Almkerk along a shoreline in a nature area. The later finds were all documented within urban areas. To date, plants have been recorded in Amsterdam, Utrecht and Doetinchem (Figure 4.42). It is unclear whether these records indicate natural spread or if they are the result of repeated introductions.

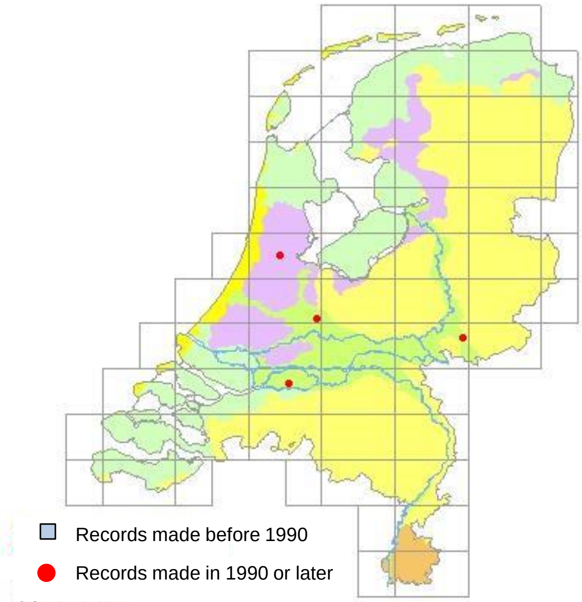

Figure 4.42: Current recorded distribution of switchgrass (*Panicum virgatum*) in the Netherlands. Source: Nationale Databank Flora en Fauna (NDFF, 2015j).

Colonisation of high conservation value habitats
P. virgatum has not been recorded in any Natura 2000 areas in the Netherlands.

- Invasion process

Introduction outside cultivated land
In the Netherlands introductions of *P. virgatum* are attributed to seed contamination in bird food. To date, *P. virgatum* has not been cultivated in the Netherlands. However, in the United States, where *P. virgatum* is cultivated, there is a high possibility of contamination of planting and harvesting equipment in *P. virgatum* fields, and seed spillage during transportation from field to energy-conversion facilities increases the probability of invasion (Barney & DiTomaso, 2008). Parrish & Fike (2005) state that *P. virgatum* has many traits that make escape from cultivation more likely i.e. broad environmental tolerance, high seed production, the ability to regenerate from vegetative fragments and rapid growth rates. *P. virgatum* is present in the Dutch plant trade in the form of several ornamental varieties named "Vingergras" (www.plantago.nl).

Establishment
Experiments show that *P. virgatum* produces robust individuals in an environment where all resident vegetation has been removed. These individuals are better capable of competing with recurrent resident vegetation in the second year (Lockwood et al., 2009). *P. virgatum* was able to naturalise in the presence of resident vegetation, but showed poor performance suggesting that they would not become locally dominant but could act as a source population for establishment elsewhere (Lockwood et al., 2009; Barney et al., 2012).

Spread

P. virgatum and Johnsongrass (*Sorghum halepense* L.) share very similar characteristics that typify an ideal biofuel feedstock as well as invasive plants species (Table 4.49). *S. halepense* is distributed widely in the Netherlands (Nationale Databank Flora en Fauna (NDFF, 2015k)). *S. halepense* escaped following cultivation and has since become one of the most damaging weeds in the world and is a listed noxious weed in 19 U.S. states (Warwick & Black, 1983; Barney & Ditomaso, 2008). It is unknown whether *P. virgatum* spreads through root fragments or if the species can spread by seed in the Netherlands.

Table 4.49: Characteristics of switchgrass (*Panicum virgatum*) and invasive johnsongrass (*Sorghum halepense* L.) (Adapted from Barney & DiTomaso, 2008).

Agronomic/invasive characteristic	**Proposed biofuel**	**Weedy associate**
	Panicum virgatum	*Sorghum halepense*
C4	+	+
Perennial	+	+
Rapid growth rate	+/-	+
Grows at high densities	+	+
High yielding (aboveground biomass)	+	+
Drought tolerant	+/-	-
High water-use efficiency	+	?
Hosts few pests/diseases	+	+
Tolerates soil disturbance	+	+
Reallocates nutrients to perennating structures	+	+

+: characteristic present; -: characteristic absent; +/- some ecotypes possess the characteristic; ?: insufficient data.

- Environmental impacts summary

Effects on environmental targets or native species

No information on the effects of parasitism, pathogens, parasites or interbreeding of *P. virgatum* on environmental targets or native species could be found during a search of available literature.

Competition

The results of a Chinese study indicated that *P. virgatum* has allelopathic potential; however, this could not be linked to the successful establishment of *P. virgatum* in the region (Shui et al., 2010). A second study in California, USA suggested that riparian areas, particularly disturbed low competition areas, are capable of supporting the establishment of *P. virgatum* (Barney et al., 2012).

Effects on ecosystem function targets

No information on the effects of *P. virgatum* on ecosystem function targets could be found during a search of available literature.

Effects on plant targets in cultivation systems

No information on the effects of *P. virgatum* on plant targets in cultivation systems could be found during a search of available literature.

Effects on animal health and production targets
No information on the effects of *P. virgatum* on animal health and production targets could be found during a search of available literature.

Human targets
No information on the effects of *P. virgatum* on human targets could be found during a search of available literature.

Effects on other targets
No information on the effects of *P. virgatum* on infrastructure could be found during a search of available literature.

- Ecological risk assessment with the ISEIA protocol

The expert team allocated *P. virgatum* a 'high' ecological risk classification to the category dispersion potential and invasiveness, a ‘medium’ risk classification to the category high value conservation habitats, an ‘unlikely’ adverse impacts on native species, and a ‘likely’ risk classification to the category alteration of ecosystem functions (Table 4.50).

The total ecological risk score for the species is 8 out of a maximum of 10. Therefore, *P. virgatum* is classified in the C list of the BFIS list system. The maximum risk score takes into account the limitation on maximum risk score per category that is imposed by the ISEIA protocol if data deficiency occurs or the application of best professional judgement is required (See section 2.4.2). The maximum risk score will, therefore, vary between species. In cases where there is sufficient information, i.e. where there is no data deficiency and best professional judgement is not required, the maximum possible risk score is 12. The rationale for the allocated scores is given in the following paragraphs.

Table 4.50: Consensus scores for potential risks of switchgrass (*Panicum virgatum*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	High	3
Colonization of high value conservation habitats	Medium	2
Adverse impacts on native species	Unlikely	1
Alteration of ecosystem functions	Likely	2
Ecological risk score		**8**

* Quantitative analysis was focused on Natura 2000 areas may indicate a lower score; however, this species may also occur in other areas with high conservation value.

It should be noted that the risk scores for adverse impacts on native species and alteration of ecosystem functions are based on expert judgement due to lack of data.

Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

Dispersion potential or invasiveness

Classification: **High risk**. From 2003 to date, the species distribution in the Netherlands has remained limited and most records have been made in urban areas. It is unclear whether these records indicate natural spread or if they are the result of repeated introductions. *P. virgatum* reproduces by setting seeds and vegetatively through root fragmentation, but does not produce rhizomes. Its perennial life form allows stands to last indefinitely once established. Seed production may give *P. virgatum* an even greater invasive potential than Miscanthus, a plant it shares many traits with. It is unknown whether *P. virgatum* spreads through root fragments or if the species can spread by seed in the Netherlands. The species displays a high potential reproductive potential, broad environmental tolerance and characteristics that increase the potential for invasiveness (similar to *Sorghum halepense*). Therefore, it was concluded that *P. virgatum* is highly fecund, can easily disperse through active or passive means over distances > 1 km/year and initiate new populations.

Colonization of high value conservation habitats

Classification: **Medium risk**. *P. virgatum* was first recorded in a nature area along a shoreline in Almkerk, the Netherlands. All subsequent records have been in urban areas and no records have been made in Natura 2000 areas. However, *P. virgatum* has shown a capacity to colonize nature areas in the Netherlands and may do so again in the future. Moreover, observations from California, USA suggested that riparian areas, particularly disturbed low competition areas, are capable of supporting the establishment of *P. virgatum*. Therefore, *P. virgatum* poses a medium risk to high value conservation habitats in the Netherlands.

Adverse impacts on native species

Classification: **Unlikely**. Experimentation suggests that *P. virgatum* is a relatively poor competitor and would only dominant at locations of recent disturbance. These experiments were undertaken in California under conditions not found in the Netherlands. No *Panicum* species are native to the Netherlands suggesting that *P. virgatum* will not interbreed with native species. Therefore, it seems unlikely that *P. virgatum* will impact native species in the Netherlands.

Alteration of ecosystem functions

Classification: **Likely**. Seed production may give *P. virgatum* an even greater invasive potential than Miscanthus, a plant it shares many traits with. Moreover, *P. virgatum*’s perennial life form allows stands to last indefinitely once established. Therefore, it is likely that *P. virgatum* will negatively affect ecosystem functions in the Netherlands.

Risk classification according to the BFIS list system

The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.50) in combination with the current recorded distribution in the Netherlands. The species classification for *P. virgatum* is C1 (Figure 4.43). This characterises a non-native species that has isolated populations in the area under assessment, poses a low ecological risk and is not classified in the BFIS list system.

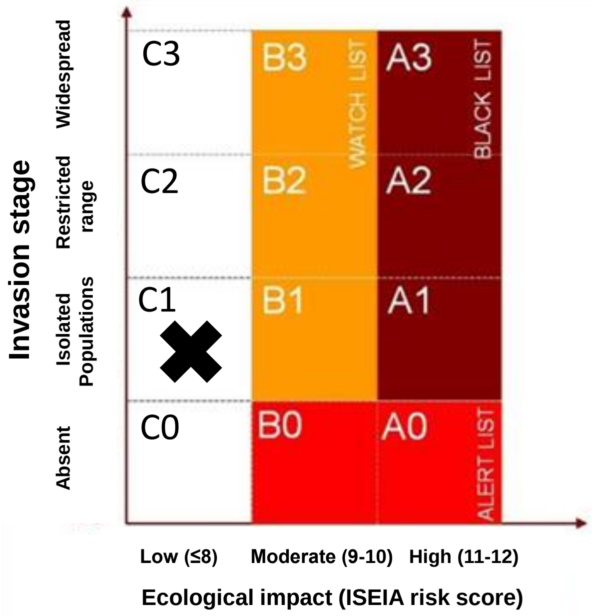

Figure 4.43: Risk classification of switchgrass (*Panicum virgatum*) according to the BFIS list system.

- Other risk assessments and classifications

P. virgatum has been risk assessed for Italy and Hawaii and was rejected for introduction in both cases (Table 4.51). Initially, it was rejected for introduction from California (USA), however, the plant was re-assessed using a sterile genotype and was accepted (Barney et al., 2012). This suggests that *P. virgatum* invasion risk can be explained mainly through fertile seed dispersal (Barney & Ditomaso, 2008). Australian authors stated that many *Panicum* species are weeds and that it is highly likely that *P. virgatum* would become invasive if it was planted in Australia (Low & Booth, 2007).

Table 4.51: Overview of risk classifications previously performed for switchgrass (*Panicum virgatum*).

	Italy	Pacific (Hawaii)	California (USA)
Scope	Risk assessment method	Risk assessment method	Risk assessment method applied to sterile genotype
Method	Modified Australian Weed Risk Assessment System (AWRAS).	Modified Australian Weed Risk Assessment System (AWRAS).	Modified Australian Weed Risk Assessment System (AWRAS).
Year	2010	Unknown	2008
Risk classification	**Rejected following further evaluation (4)**	**High risk (11)**	**Accepted (-1)**
Source	Crosti et al. (2010)	Hear.org (2015h)	Barney et al. (2008)

4.8.5 *Phyllostachys* species

- Genus description

Plants in the genus *Phyllostachys* are medium-sized and large evergreen bamboos that usually spread by rhizomes, but in cooler climates can be more clump forming (Figure 4.44). *Phyllostachys* species spread by producing culms from the nodes of long, continuous rhizomes and are, therefore, often referred to as ‘running bamboos’ (DeBarros & Senack, 2013). The hollow, grooved culms often zigzag from node to node (www.finegardening.com). On smaller stems, the culm is flattened with a D-shaped cross-section between branch-bearing nodes. Two unequal branches occur at nodes located half way up the culm, occasionally a weak third branch develops between the two main branches. An exception to this may be robust specimens of *P. nigra* that may develop three branches of similar size. In general, individual branches may sometimes grow in the lower part of the culm (DeBarros & Senack, 2013). The leaves are yellow-green, light green, or dark green in colour arising from the culms (www.finegardening.com).

Figure 4.44: *Phyllostachys* species A) *Phyllostachys bissetii;* B) Black bamboo (*Phyllostachys nigra*); C) Japanese timber bamboo (*Phyllostachys reticulata*). Source: Wikimedia Commons.

Species taxonomy

Table 4.52: Nomenclature and taxonomical status of *Phyllostachys* species.

Scientific name: *Phyllostachys bissetii* McClure,	*Phyllostachys nigra* (Lodd. ex Lindl.) Munro (1868)	*Phyllostachys reticulata* (Rupr.) K.Koch (1873)
Synonyms: Not applicable	*Bambusa nigra* Lodd. ex Lindl. *Phyllostachys puberula* var. *nigra* (Lodd. ex Lindl.) J. Houz. *Phyllostachys henionis* Mitford *Bambusa nigra* Lodd. ex Lindl. *Bambusa puberula* Miq. *Phyllostachys boryana* Mitford *Phyllostachys henonis* Mitford *Phyllostachys puberula* (Miq.) Munro *Phyllostachys puberula* var. boryana Makino *Phyllostachys nigra* f. *boryana* (Mitford) Makino (For a full list of synonyms see www.theplantlist.org)	*Phyllostachys bambusoides* *Bambos kinmeitsch* Siebold *Bambusa mazelii* (Rivière & C.Rivière) W.Watson *Bambos metake* Siebold *Bambusa bifolia* Siebold ex Munro *Bambusa quilioi* Rivière & C.Rivière *Bambusa marliacea* Mitford *Bambusa duquilioi* Carrière *Phyllostachys reticulata* f. *shouzhu* *Phyllostachys reticulata* f. *nigrostriatal* (For a full list of synonyms see WCSP, 2015)
Taxonomic tree (WCSP, 2014): Kingdom: Plantae Phylum: Tracheophyta Class: Liliopsida Order: Poales Family: Poaceae Genus: *Phyllostachys* Species: *Phyllostachys bissetii*	Kingdom: Plantae Phylum: Tracheophyta Class: Liliopsida Order: Poales Family: Poaceae Genus: *Phyllostachys* Species: *Phyllostachys nigra*	Kingdom: Plantae Phylum: Tracheophyta Class: Liliopsida Order: Poales Family: Poaceae Genus: *Phyllostachys* Species: *Phyllostachys reticulata*
Preferred Dutch name: Haagbamboe (unofficial name)	Zwarte bamboe (unofficial name)	Bamboe (unofficial name)
Preferred English name: Not applicable	Black bamboo	Japanese timber bamboo
Other Dutch names: Not applicable	Zwarte lakbamboe, lakbamboe	Not applicable
Other English names: Running bamboo, David Bisset's bamboo, Bisset's Bamboo	Whangee cane, kuro-chiku	Madake, timber bamboo, giant timber bamboo

Life cycle

P. bissetii and *P. nigra* flower very infrequently at intervals of many years (Plants for a Future.org). During flowering, a large proportion of *P. bissetii*'s resources are used for seed production resulting in severe weakening and sometimes death. However, plants will usually recover after a few years (Plants for a Future, 2015). *P. bissetii* is an evergreen bamboo (Greenway, 1999), and is one of the earliest members of *Phyllostachys* to produce new growth in the spring (Farrelly, 1996). No information on the life cycle of *P. reticulata* was found during the literature survey.

Reproductive capacity

P. bissetii flowers infrequently, therefore reproduction occurs mainly through vegetative means either using rhizomes or when cuttings are discarded (Van der Lugt et al., 2009; Hear.org, 2015e). Flowers of both *P. bissetii* and *P. nigra* are hermaphrodite and are wind pollinated (Plants for a Future, 2015). No information on the reproductive capacity of *P. reticulata* was found during the literature survey.

- Habitat summary

In the United Kingdom, *P. bissetii* is classified as an H5 species meaning it is hardy in most places throughout the UK, even in the severest winter to -10 to -15 ^{o}C (RHS, 2015) (Table 4.53). Scurlock et al. (2000) state that the plant is hardy to -23 ^{o}C, and is the first of the major commercial species of bamboo to initiate spring growth. However, Huxley et al. (1992) state that it dislikes exposure to hard frosts. *P. bissetii* grows in light woodland, in semi- or no shade, on sandy, loamy or clay soils, and tolerates acid, neutral and alkaline soils. The plant can withstand strong winds but not maritime exposure. However, it requires moist soil. (Plants for a Future, 2015).

P. nigra grows in sheltered locations in full sun or partial shade (Royal Horticultural Society, 2015); however it appears to prefer shady locations in its native China (Tingwu et al., 2007). It colonises open forests on slopes and in valleys to a maximum elevation of 1100 to 1200 m (eFloras, 2015; EOL, 2015) (Table 4.53). The plant is classified as an H5 species in the United Kingdom, meaning that is hardy in most places throughout the U.K., even in severe winters with temperatures of -15 to -10 ^{o}C (Royal Horticultural Society, 2015). However, Huxley et al. (1992) states that *P. nigra* dislikes prolonged exposure to hard frosts. *P. nigra* prefers loamy, moist but well-drained acid, neutral and alkaline soils (Royal Horticultural Society, 2015). A horticultural website recommends that when cultivated, soils of pH 5.6 to 6.5 will achieve the most success (davesgarden.com). Observations from its native range suggest that living *P. nigra* density, average diameter at breast height (DBH) and branching height tended to increase in order of soil type: sandy soils < light loam < medium loam < heavy loam (Tingwu et al., 2007). Moreover, plant density tended to decrease with increasing soil depth (Tingwu et al., 2007).

In its native range, *P. reticulata* inhabits open or degraded forests below 1800 m from the Yangtze to the Wuling Mountains, and is widely planted (EOL, 2015). In growth experiments in an Italian botanical garden, spring growth was initiated in bamboos of the genus *Phyllostachys* when mean air temperature reached 14 to 16 ^{o}C (Gratani et al., 2008). Koyama and Uchimura (1995) observed that *P. reticulata* net photosynthesis increased until air temperature reached 27°C, decreasing rapidly thereafter. The compensation point where respiration rate equals photosynthetic rate is approximately 40°C for this species (Kleinhenz & Midmore, 2001). Observations in a Japanese botanical garden under extreme winter conditions indicated that *P. reticulata* had a poor in cold-resistance performance in comparison with other bamboo species including *Phyllostachys bissetii*. In this experiment it was observed that microclimate had an important impact on the overwintering performance of bamboos including *P. reticulata*, and mortality of newly planted bamboo may be expected during Japanese winters (Jinge & Jinong, 2012). According to CABI

(2015g), *P. reticulata* tolerates an absolute minimum temperature of -21 ºC, a mean annual temperature of 15 to 30 ºC, and a mean minimum and maximum temperature of the hottest month and coldest month of 25 to 35 ºC and -15 to 20 ºC, respectively (Table 4.53). *P. reticulata* occurs at locations where mean annual rainfall does not drop below 1500 mm and prefers medium to heavy textured, free draining soils of acid, neutral or alkaline pH (CABI, 2015g).

Table 4.53: Physiological conditions tolerated by *Phyllostachys* species.

Species	**Parameter**	**Data origin**	**Occurrence**	**References**
Japanese timber bamboo (*Phyllostachys reticulata*)	Absolute minimum temperature (ºC)	Unknown	-21	CABI (2015g)
	Mean annual temperature (ºC)	Unknown	15 to 30	CABI (2015g)
	Mean maximum temperature of hottest month (ºC)	Unknown	25 to 35	CABI (2015g)
	Mean minimum temperature of coldest month (ºC)	Unknown	-15 to 20	CABI (2015g)
	Substrate	Unknown	Medium to heavy textured, free draining	CABI (2015g)
	pH	Unknown	Acid, neutral, alkaline	CABI (2015g)
	Minimum mean annual rainfall (mm)	Unknown	1500	CABI (2015g)
Black bamboo (*Phyllostachys nigra*)	Hardiness (^{o}C)	United Kingdom	-10 to -15	Royal Horticultural Society (2015)
	pH	Unknown	5.6 to 6.5	davesgarden.com
	Elevation (m)	Unknown	1100-1200	eFloras (2015); EOL (2015)
Phyllostachys bissetii	Hardiness (^{o}C)	Unknown	-10 to -23	RHS (2015); Scurlock et al. (2000)

- Recorded distribution

Native range

P. bissetii and *P. nigra* are native to China (pfaf.org; Royal Horticultural Society, 2015) (Figure 4.45a). *P. reticulata* is native to both China and Japan (EOL, 2015; CABI, 2015g) (Figure 4.45b).

Cultivated range

P. bissetii is cultivated in the U.S.A, Germany and the United Kingdom (Tropicos.org; GBIF.org; Palmcentre.co.uk). *P. nigra* is cultivated in China, Japan, Korea, India, Vietnam, the Philippines and in Europe (USDA, 2015g). According to CABI (2015g), *P. reticulata* is widely cultivated throughout the world.

Non-native range

P. nigra is non-native to the USA and Hawaii, Australia, Tanzania, New Zealand (Hear.org, 2015d), Portugal (De Almeida & Freitas, 2012), Austria (Essl et al., 2002; Hear.org, 2015d), France (Muller, 2004; Hear.org, 2015d), the British Isles (Ryves et al., 1996; Hear.org, 2015d) and Italy (Van Valkenburg et al., 2014). This species has been widely planted for ornamental purposes in the Mediterranean and is becoming established (Tutin, 1980; Plants for a Future.org) (Figure 4.45a). *P. reticulata* is non-native to the USA (EOL, 2015; CABI, 2015g), Cuba, India, France and Australia

(CABI, 2015g), Italy (Van Valkenburg et al., 2014) and New Zealand (www.hear.org, 2015c) (Figure 4.45b). No information on the non-native range of *P. bissetii* could be found during the literature review.

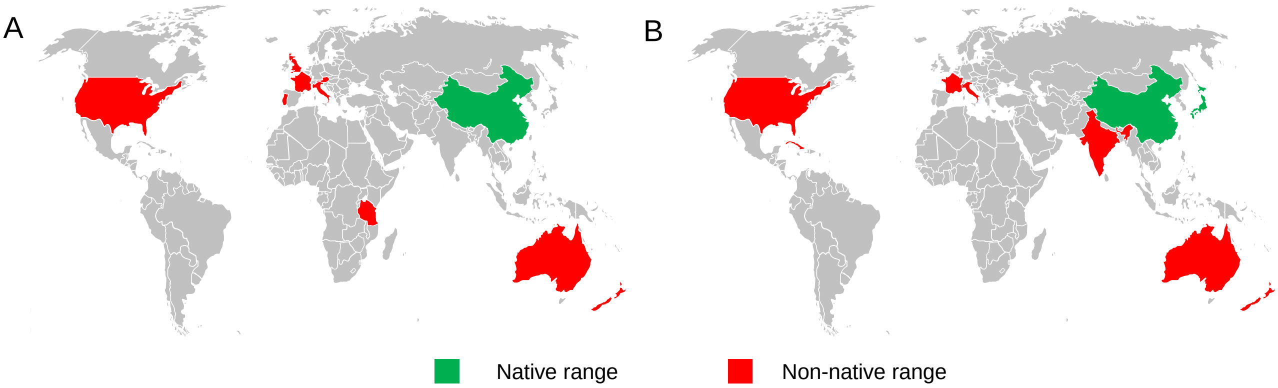

Figure 4.45: Current global recorded distribution of A) black bamboo (*Phyllostachys nigra*); B) Japanese timber bamboo (*Phyllostachys reticulata*). Sources: Ryves et al. (1996); Essl et al. (2002); Muller (2004); de Almeida & Freitas (2012); Van Valkenburg et al. (2014); Hear.org (2015c,d); Plants for a Future.org; EOL (2015); CABI (2015g).

Distribution in the Netherlands

According to the Nationale Databank Flora en Fauna (NDFF, 2015f), there are no current records of *P. bissetii*, *P. nigra* or *P. reticulata* in the Netherlands. It should be noted that the identification of bamboo species is difficult and that many varieties of these species are sold as ornamental plants in the Netherlands.

Colonisation of high conservation value habitats

According to the Nationale Databank Flora en Fauna (NDFF, 2015f), there are no current records of *P. bissetii*, *P. nigra* or *P. reticulata* in the Netherlands.

- Invasion process

Introduction outside cultivated land

P. bissetii flowers infrequently, therefore reproduction occurs mainly through vegetative means either using rhizomes or when cuttings are discarded (Van der Lugt et al., 2009; Hear.org, 2015e). Flowers are hermaphrodite and are wind pollinated (Plants for a Future, 2015). The dumping of garden waste may be a route of introduction for *P. nigra* (Hear.org, 2015d) and *P. reticulata*.

Establishment

Compared to *P. nigra* and *P. reticulata*, *P. bissetii* is the first to initiate spring growth. It is also the fastest growing and the most invasive of these three species (Scurlock et al., 2000).

Spread

P. bissetii spreads by rhizomes and, on the Pacific Cook islands, can form extensive, dense stands that are extremely difficult to control (Space & Flynn, 2002). *P. reticulata* propagation occurs via root spread. No information on the capacity of *P. nigra* to spread could be found during the literature survey.

- Environmental impacts summary

Effects on environmental targets or native species

No information on the effects of parasitism or interbreeding by *P. bissetii*, *P. nigra* or *P. reticulata*, the hosting of pathogens or parasites by *P. bissetii*, *P. nigra* and competition by *P. reticulata* or *P. bissetii* on environmental targets or native species were found during the literature survey.

Competition

Generally, bamboos exhibit enormous growing speeds. In tropical countries, bamboos grow up to 30 metres in six months (Van der Lugt et al., 2009). The record growth speed measured for a bamboo stem is 1.20 metres per day (Martin, 1996). Loope et al. (1992) stated that the status of *P. nigra* should be carefully monitored in Hawaii since bamboo thickets result in elimination of virtually all native plant and animal species. In Hawaii, *P. nigra* displaces native vegetation and virtually no other plants grow within *P. nigra* groves (Motooka et al., 2003).

Hosting pathogens or parasites

P. reticulata is a potential host to the carpenter bee (*Xylocopa tranquebarorum*) which in turn hosts the symbiotic mite *Sennertia alfkeni. X. tranquebarorum* which is an established, non-native species in Japan. The violet carpenter bee (*Xylocopa violacea*) is a native vulnerable species present on the Dutch red list (Naturalis, 2015) and is associated with the bee mite *Sennertia cerambycina*. Introduced mites may lead to the collapse of the interaction between endemic *X. violacea* and *S. cerambycina*, perhaps as a result of a mite host switch. If a host switch occurs, potential negative impacts on *X. violacea* may occur and eradicating the mite will be nearly impossible without eradicating the native Dutch bee species. However, *X. tranquebarorum* appears to nest preferably in dry, processed plant hosts reducing the chance of introduction with live cuttings (Okabe et al., 2010).

Effects on ecosystem function targets

No information on the effects of *P. bissetii* or *P. nigra* on ecosystem function targets, or on the effect of *P. reticulata* on the biotic properties of ecosystem functioning could be found during the literature survey.

Abiotic properties e.g. nutrient cycling, structural modification

The reported leaf area index of mature stands of *P. reticulata* is 11.6 (Isagi et al., 1993), resulting in the absorption of up to 95% of incident solar radiation (Qiu et al., 1992; Song et al., 2011). Suzaki & Nakatsubo (2001) observed that relative photon flux density (RPFD) under evergreen bamboo exceeded that of coniferous forests (approximately 1% throughout the year) but was less than that of deciduous forests (<5% in the Summer rising to approximately 50% in Winter). Plant diversity reportedly declines in bamboo stands (Kobayashi et al., 1999; Suzaki & Nakatsubo, 2001). For example, Suzaki & Nakatsubo (2001) observed that the percentage of herbaceous plants tended to increase with decreasing bamboo density. Reductions in plant diversity are probably due to limited light conditions under the bamboo canopy (Nakatsubo & Suzaki, 1998).

Effects on plant targets in cultivation systems

No information on the effects of *P. reticulata* or *P. bissetii* on plant targets in cultivation systems could be found during the literature survey. There is no evidence to suggest that *P. nigra* is an agricultural weed (Hear.org, 2015d).

Effects on animal health and production targets

No information on the effects of *P. bissetii* or *P. reticulata* on animal health and production targets could be found during the literature survey.

Hazardous upon contact, host

There is no evidence to suggest that *P. nigra* is hazardous upon contact (Hear.org, 2015d).

Human targets

No information on the effects of *P. bissetii* on human targets could be found during the literature survey. No information on the effects on pathogens or parasites of *P. nigra* on human targets could be found during the literature survey. However, there is no evidence to suggest that *P. nigra* is hazardous upon contact (Hear.org, 2015d). No information on the direct effects of *P. reticulata* on contact with human targets could be found during the literature survey. In their native China, *P. reticulata* is a potential host to the carpenter bee (*Xylocopa tranquebarorum*). The average inner diameter of the nest of the carpenter bee (13–15 cm) is nearly equivalent to the inner diameter of *P. reticulata* (Okabe et al., 2010). Impacts on human targets as a result of stings can be expected in agricultural fields and perhaps in botanical gardens. However, *X. tranquebarorum* appears to nest preferably in dry, processed plant hosts, reducing the chance of introduction with live cuttings (Okabe et al., 2010).

Effects on other targets

No information on the effects of *P. bissetii*, *P. nigra* or *P. reticulata* on other targets i.e. infrastructure, could be found during the literature survey.

- Ecological risk assessment with the ISEIA protocol

Phyllostachys bissetii

The expert team allocated *P. bissetii* a 'likely' ecological risk classification to the categories dispersion potential and invasiveness, adverse impacts on native species and alteration of ecosystem functions, and a ‘data deficient (DD)’ risk classification to the category colonization of high value conservation habitats (Table 4.54). The total ecological risk score for the species is 7 out of a maximum of 7. Therefore, *P. bissetii* is classified in the C list of the BFIS list system. The maximum risk score takes into account the limitation on maximum risk score per category that is imposed by the ISEIA protocol if data deficiency occurs or the application of best professional judgement is required (See section 2.4.2). The maximum risk score will, therefore, vary between species. In cases where there is sufficient information, i.e. where there is no data deficiency and best professional judgement is not required, the maximum possible risk score is 12. The rationale for the allocated scores is given in the following paragraphs.

It should be noted that the risk scores for dispersion potential and invasiveness, adverse impacts on native species and alteration of ecosystem functions are based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

Table 4.54: Consensus scores for potential risks of *Phyllostachys bissetii* in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	Likely	2
Colonization of high value conservation habitats[a]	DD	1[b]
Adverse impacts on native species	Likely	2
Alteration of ecosystem functions	Likely	2
Ecological risk score		**7**

[a] Quantitative analysis was focused on Natura 2000 areas may indicate a lower score; however, species may also occur in other areas with high conservation value. [b] Deficient data (DD) scores 1 as this is the minimum that can be awarded per risk category.

Dispersion potential or invasiveness

Classification: **Likely**. *P. bissetii* is cultivated in neighbouring countries to the Netherlands and is a winter hard species in the U.K. However, there is no evidence to suggest that the species has escaped cultivation in these countries. The species flowers highly infrequently and reproduces vegetatively. The species is invasive on the Cook Islands that are climatically very different from the Netherlands. However, due to its relatively high invasiveness compared to other bamboo species, the precautionary principle was applied and it is considered likely that *P. bissetii* could disperse and become at least locally invasive in the Netherlands.

Colonization of high value conservation habitats
Classification: **Data deficient**. According to the Nationale Databank Flora en Fauna (NDFF, 2015f), there are no current records of *P. bissetii* in the Netherlands. There is no evidence to suggest that the species has escaped cultivation in neighbouring countries. There is therefore not enough information to allow an assessment of the potential colonisation of high value conservation habitats in the Netherlands.

Adverse impacts on native species
Classification: **Likely**. There is no evidence from countries that are climatically similar to the Netherlands to suggest that *P. bissetii* establishment will have an adverse impact on Dutch native species. However, due to its relatively high invasiveness and early growth initiation in spring relative to other bamboo species the precautionary principle was applied and it was considered likely that *P. bissetii* would impact negatively on Dutch native species if it became established. There are no *Phyllostachys* species native to the Netherlands, therefore genetic effects are unlikely.

Alteration of ecosystem functions
Classification: **Likely**. Due to its size, rapid growth and dense stands, it is likely that *P. bissetii* would negatively impact abiotic ecosystem functions through light interception and interrupt natural succession if it were to establish in the Netherlands.

Black bamboo (Phyllostachys nigra)

The expert team allocated *P. nigra* a 'medium' ecological risk classification to the category dispersion potential and invasiveness, a ‘deficient data (DD)’ risk classification to the category colonization of high value conservation habitats and a ‘likely’ risk classification to the categories adverse impacts on native species and alteration of ecosystem functions (Table 4.55). The total ecological risk score for the species is 7 out of a maximum of 8. Therefore, *P. nigra* is classified in the C list of the BFIS list system. The maximum risk score takes into account the limitation on maximum risk score per category that is imposed by the ISEIA protocol if data deficiency occurs or the application of best professional judgement is required (See section 2.4.2). The maximum risk score will, therefore, vary between species. In cases where there is sufficient information, i.e., where there is no data deficiency and best professional judgement is not required, the maximum possible risk score is 12. The rationale for the allocated scores is given in the following paragraphs.

It should be noted that the risk scores for adverse impacts on native species and alteration of ecosystem functions are based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

Table 4.55: Consensus scores for potential risks of black bamboo (*Phyllostachys nigra*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	Medium	2
Colonization of high value conservation habitats[a]	DD	1[b]
Adverse impacts on native species	Likely	2
Alteration of ecosystem functions	Likely	2
Ecological risk score		**7**

[a] Quantitative analysis was focused on Natura 2000 areas may indicate a lower score, however, species may also occur in other areas with high conservation value; [b] Deficient data (DD) scores 1 as this is the minimum that can be awarded per risk category.

Dispersion potential or invasiveness

Classification: **Medium risk**. *P. nigra's* non-native range extends to neighbouring countries to the Netherlands. The plant is hardy and is possibly dispersed by human vectors. On the other hand, the species flowers highly infrequently and further information about its reproductive capacity could not be found during the literature review. However, the precautionary principle was applied and it is considered that *P. nigra* would disperse and become at least locally invasive in the Netherlands.

Colonization of high value conservation habitats

Classification: **Deficient data**. According to the Nationale Databank Flora en Fauna, 2015, there are no current records of *P. nigra* in the Netherlands. There is no evidence to suggest that the species has escaped cultivation in neighbouring countries. There is therefore not enough information to allow an assessment of the potential colonisation of high value conservation habitats in the Netherlands.

Adverse impacts on native species

Classification: **Likely**. *P. nigra* is hardy in climates featuring severe winters with temperatures of -15 to -10 ^{o}C (Royal Horticultural Society, 2015). However, there is no evidence to illustrate *P. nigra*'s competitive ability or invasiveness potential in colder climates. *P. nigra* has been shown to be invasive and outcompete native species on Hawaii; however there is no climatic match between the Netherlands and this U.S. state. *P. nigra's* non-native range extends to neighbouring countries to the Netherlands. Therefore, the precautionary principle was applied and it was concluded that it is likely that *P. nigra* could impact negatively on native species in the Netherlands through competition. There are no *Phyllostachys* species native to the Netherlands, therefore genetic effects are unlikely.

Alteration of ecosystem functions

Classification: **Likely**. Due to its size and dense stands, it is likely that *P. nigra* would negatively impact ecosystem abiotic functions through light interception and interrupt natural succession if it were to establish in the Netherlands.

Japanese timber bamboo (Phyllostachys reticulata)

The expert team allocated *P. reticulata* a 'likely' ecological risk classification to the categories dispersion potential and invasiveness and adverse impacts on native species, a 'medium' ecological risk classification to the category alteration of ecosystem functions, and a ‘data deficient (DD)’ risk classification to the category colonization of high value conservation habitats (Table 4.56).

The total ecological risk score for the species is 7 out of a maximum of 8. Therefore, *P. reticulata* is classified in the C list of the BFIS list system. The maximum risk score takes into account the limitation on maximum risk score per category that is imposed by the ISEIA protocol if data deficiency occurs or the application of best professional judgement is required (See section 2.4.2). The maximum risk score will, therefore, vary between species. In cases where there is sufficient information, i.e. where there is no data deficiency and best professional judgement is not required, the maximum possible risk score is 12. The rationale for the allocated scores is given in the following paragraphs.

It should be noted that the risk scores for dispersion potential and invasiveness and adverse impacts on native species are based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

Table 4.56: Consensus scores for potential risks of Japanese timber bamboo (*Phyllostachys reticulata*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	Likely	2
Colonization of high value conservation habitats[a]	DD	1[b]
Adverse impacts on native species	Likely	2
Alteration of ecosystem functions	Medium	2
Ecological risk score		**7**

[a] Quantitative analysis was focused on Natura 2000 areas may indicate a lower score, however, species may also occur in other areas with high conservation value; [b] Deficient data (DD) scores 1 as this is the minimum that can be awarded per risk category.

Dispersion potential or invasiveness

Classification: **Likely**. The Netherlands receives on average 800 mm of rainfall per year which suggests that even though temperatures in the Netherlands would not form a barrier to establishment in nature, the relative lack of rainfall would. However, *P. reticulata* is non-native to Italy that has a drier climate than the Netherlands and France and New Zealand that have similar temperate climates the Netherlands. Propagation occurs via root spread. Due to conflicting evidence the precautionary principle was applied and it is considered likely that *P. reticulata* would disperse and become at least locally invasive in the Netherlands.

Colonization of high value conservation habitats

Classification: **Deficient data**. According to the Nationale Databank Flora en Fauna, 2015, there are no current records of *P. reticulata* in the Netherlands. There is no evidence to suggest that the species has escaped cultivation in neighbouring countries. There is therefore not enough information to allow an assessment of the potential colonisation of high value conservation habitats in the Netherlands.

Adverse impacts on native species

Classification: **Likely**. Due to *P. reticulata*'s dense tall stands it is considered likely that the species will have an adverse effect on Dutch native species. Okabe et al. (2010) do not state unambiguously that *P. reticulata* is host to the violet carpenter bee (*X. tranquebarorum*).

Alteration of ecosystem functions

Classification: **Medium risk**. The risk that *P. reticulata* would negatively affect abiotic ecosystem processes in the Netherlands is medium due to the potential for light interception that would lead to a disruption in natural succession. However, a severe effect would only materialize if high densities of the species were to occur, a scenario that is unlikely due to the suboptimal climatic conditions in the Netherlands.

Risk classification of Phyllostachys species *according to the BFIS list system*

The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Tables 4.54, 4.55, 4.56) in combination with the current recorded distribution in the Netherlands. The species classification for *P. bissetii*, *P. nigra* and *P. reticulata* is C0 (Figure 4.46). This characterises non-native species that are absent from the area under assessment, pose a low ecological risk and are not classified in the BFIS list system.

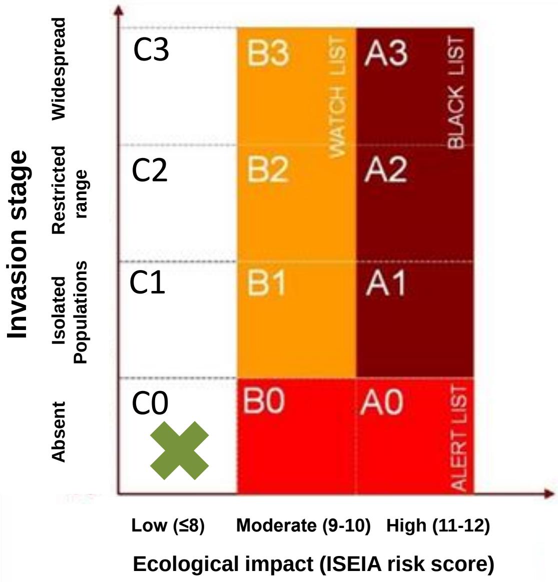

Figure 4.46: Risk classification of *Phyllostachys* species according to the BFIS list system.

- Other risk assessments and classifications

A risk assessment carried out for the Pacific islands using a modified version of the Australian weed risk assessment classified *P. nigra* as high risk (12) (Table 4.57).

Table 4.57: Overview of risk classifications previously performed for black bamboo (*Phyllostachys nigra*).

	Pacific islands
Scope	Risk assessment method
Method	Modified Weed Risk Assessment (WRA).
Year	2011
Risk classification	**High risk**
Source	Hear.org (2015d)

P. bissetii is classified as invasive in the Cook Islands. According to Space & Flynn (2002), it is a very aggressive running bamboo that has already spread widely on Mangaia, the Cook Islands. No risk assessments or classifications of *P. reticulata* were found during the literature survey.

4.8.6 Sorghum (*Sorghum bicolor* var. sweet)

- Species description

Sorghum bicolor is a grass and cereal crop with a single cane like stem that reaches a height of 1 to 5 m (Figure 4.47). The root system is very strong and covered by a layer of heavy disilicate. The fibrous, spreading root system consists of a primary and secondary root, and supporting roots. Secondary roots grow once three to four leaves are produced. Mature sorghum roots are adventitious and have numerous lateral branches extending in all directions. Roots may spread to at least 1.5 m from the plant and are most abundant in the top 90 cm of the soil, although they may extend to 180 cm deep. The stem features 10 to 20 clearly protruding nodes that each produce a leaf. The leaves are opposite, arranged in a cross shape, 30-135 cm long and 6-13 cm wide, and consist of a sheath, blade and ligule. The long sheath is attached closely to a large section of the internode. The leaf blade is wide, serrated, and strap-like with a smooth surface that is covered with a waxy powder. The flowers are gathered in an apical panicle consisting of many reddish spikelets. The oblong shaped grain is a caryopsis, consisting of the seed coat, testa, endosperm and embryo. Seeds can be round, flat-round, oval, ellipse, and are covered by glumes. Seeds vary widely in colour and can be brown, red-brown, dark brown, white, light yellow, pink etc. (Ecocrop, 2015e).

Figure 4.47: Sorghum (*Sorghum bicolor*) (Source: Pethan, Utrecht University botanical gardens; Wikimedia Commons).

Species taxonomy

Table 4.58: Nomenclature and taxonomical status of Sorghum (*Sorghum bicolor* var. sweet).

Scientific name:
Sorghum bicolor (L.) Moench (1794)

Synonyms:
Sorghum vulgare Pers.

Taxonomic tree (Ecocrop, 2015e):
Kingdom: Plants
Phylum: Spermatophyta
Class: Liliopsida
Order: Cyperales
Family: Poaceae
Genus: *Sorghum*
Species: *Sorghum bicolor* var. sweet

Preferred Dutch name:
Kafferkoren

Preferred English name:
Sorghum

Other Dutch names:
Suikergierst; suikersorghum, sorghumgierst

Other (English) names:
Sorgho, Sorgo, Great millet, Milo, Jowar, Cholam, Guinea corn, Durra, Mtama, Jowal, Jolar, Cholam, Koaliang.

Life cycle

S. bicolor var. sweet is a short-term perennial or annual grass. The majority of sorghums take 90 to120 days to mature, flowering occurs after 60 to 70 days and grain maturity reached in 90 to 120 days (Ecocrop, 2015e).

Reproductive capacity

S. bicolor var. sweet is self-pollinated or cross-pollinated by the wind (World Crops Database, 2015), although sterile varieties have been developed (Ecocrop, 2015e). It can produce grain yields of 1500-7500 kg/ha (Ecocrop, 2015e).

- Habitat summary

According to Ecocrop (2015e), the following habitats are suitable for *S. bicolor* var. sweet: tropical wet & dry, desert or arid, steppe or semiarid and subtropical humid. *S. bicolor* var. sweet is quite drought resistant. The waxy covered leaves help reduce evaporation and the leaf blade rolls up in dry conditions reducing the surface area exposed further reducing water loss (World Crops Database, 2015). Moreover, mature roots incorporate a silicon column which prevents the root system from collapsing during drought periods (Ecocrop, 2015e).

The physiological conditions tolerated by *S. bicolor* var. sweet are listed in table 4.59. *S. bicolor* var. sweet's temperature requirement ranges from 27 to 35 ^{o}C (optimal) and 8 to 40 ^{o}C (absolute limit) (Ecocrop, 2015e). *S. bicolor* var. sweet prefers high light intensities, and is able to grow in full sunlight at latitudes of 35^{o} to 40^{o} and at a maximum altitude of 2500 m (Ecocrop, 2015e). Rainfall for optimal *S. bicolor* var. sweet growth is reported to be between 500 and 1000 mm annually. *S. bicolor* var. sweet can tolerate a minimum of 300 mm and maximum of 3000 mm annual rainfall (Ecocrop, 2015e).

S. bicolor var. sweet is able to grow in poorly drained to dry soils of varied texture and low to moderate fertility (Ecocrop, 2015e). Optimal soil depth for *S. bicolor* var. sweet lies between 50 and 150 cm (Ecocrop, 2015e). *S. bicolor* var. sweet is reported to be able to tolerate pHs ranging from 5 to 8.5 and grows optimally in soils ranging from pH 6.0 to 7.0 (Ecocrop, 2015e). *S. bicolor* var. sweet is able to tolerate soil salinities of between 4 and 10 dS/m (Ecocrop, 2015e).

Table 4.59: Physiological conditions tolerated by *Sorghum bicolor* var. sweet.

Parameter	Optimal	Absolute limit	References
Temperature (^{o}C)	7-35	8-40	Ecocrop (2015e)
Light intensity	Very bright	Clear skies	Ecocrop (2015e)
Rainfall (annual - mm)	500-1000	300-3000	Ecocrop (2015e)
Latitude (Degrees)	N.A.	35-40	Ecocrop (2015e)
Altitude (m)	N.A.	2500	Ecocrop (2015e)
Soil pH	6-7	5-8.5	Ecocrop (2015e)
Soil depth (cm)	50-150	50-150	Ecocrop (2015e)
Soil texture	Heavy, medium	Heavy, medium, light	Ecocrop (2015e)
Soil fertility	Moderate	Low	Ecocrop (2015e)
Soil salinity (dS/m)	<4	4-10	Ecocrop (2015e)
Soil drainage	Well (dry spells)	Poorly (saturated >50% of year), well (dry spells), excessive (dry/moderately dry)	Ecocrop (2015e)

- Recorded distribution

Native range

S. bicolor is probably native to south of the Sahara in Africa, (World Crops Database, 2015) or to north-east Africa, east of longitude 25°E and north of latitude 10°N. (Ecocrop, 2015e).

Cultivated range

S. bicolor is used for human consumption in the semiarid tropical areas of Asia and Africa. However, it is more important as a fodder crop in Australia and the Americas (World Crops Database, 2015). In East Africa, *S. bicolor* is usually grown at altitudes between 900 and 1500 m, more cool tolerant varieties are grown between 1600 and 2500 m (Ecocrop, 2015e).

Non-native range

No information on the non-native range of *S. bicolor* var. sweet could be found during the literature search.

Distribution in the Netherlands

The first records of naturalized *S. bicolor* in the Netherlands date back to the early 1980s. Since that time records have been made in more than 50 km squares (Figure 4.48). It should be noted that there is no reference in the NDFF database referring to which varieties of *S. bicolor* have been recorded in the Netherlands. Considering that the absolute temperature minimum for *Sorghum bicolor* var. sweet is 8 °C, the records displayed in figure 4.55 should be treated with caution. However, most of these have been one time observations which suggests that the species has been unable to permanently established. Most observations have been made in urban areas. Therefore, the presence of the plant is likely to depend on the human introduction of seeds. Sites where *S. bicolor* has been recorded include vacant lots, roadsides and in the unpaved areas surrounding trees planted in the pavements of urban areas, harbours and industrial areas. Many records were made after seeds were spilled during transportation or birdseed was scattered.

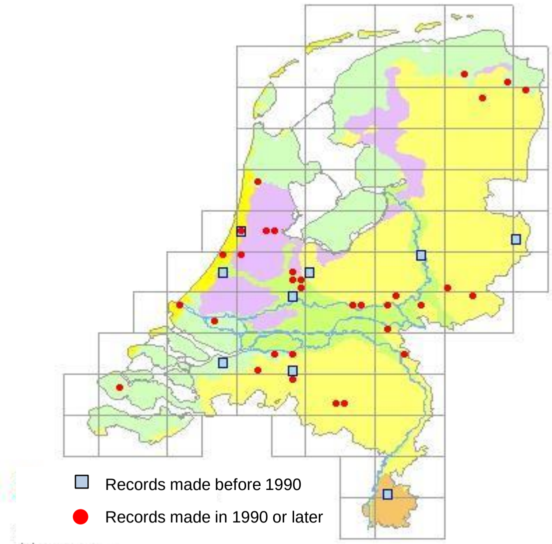

Figure 4.48: Current recorded distribution of Sorghum (*Sorghum bicolor*) in the Netherlands (Source: Nationale Databank Flora en Fauna, 2015).

Colonisation of high conservation value habitats

No confirmed recordings of *S. bicolor* exist for Natura 2000 areas in the Netherlands.

- Invasion process

Introduction outside cultivated land

S. bicolor seeds are traded in the Netherlands. The seeds are used to feed cattle and poultry. The dried flower heads are used in flower arrangements. The seeds are also a part of the seed mixture for field margins and mixtures sown after harvesting of a main crop to prevent leaching of fertilizers.

Establishment
New cultivars of *S. bicolor* var. sweet are being developed that incorporate traits such as a higher resistance to pests, faster development with high grain and biomass yield and resistance to grain molds (Ecocrop, 2015e), all of which may increase the plants ability to establish if it were to escape cultivation.

Spread
No information on the spread of *S. bicolor* var. sweet outside cultivated land could be found during a search of available literature.

- Environmental impacts summary

It should be emphasised that the taxa whose potential impacts are described in the following paragraphs are not always clearly identified in the literature.

Effects on environmental targets or native species
No information on the effects of competition, parasitism, pathogens or parasites of *S. bicolor* var. sweet on environmental targets or native species could be found during a search of available literature.

Interbreeding
S. bicolor is able to hybridize with johnsongrass (*Sorghum halepense*) (Arriola & Ellstrand, 1996), an exotic species that has been established in the Netherlands for between 10 and 100 years (Naturalis, 2015). *S. halepense* is one of the world's worst weed species (Ellstrand, 2001). During experimental observations, Arriola & Ellstrand (1996) discovered *S. bicolor* x *halepense* hybrids between 0.5 and 100 m from an *S. bicolor* field, suggesting that transgenes can be spread as a result of hybridization and that traits are beneficial to weeds can be expected to persist and spread (Arriola & Ellstrand, 1996). To illustrate the impact this may cause, *S. bicolor* has been transformed with an herbicide resistance marker gene (Casas et al., 1993). Although this genetically modified strain is not commercially available, introduction of this gene to *S. halepense* would be highly concerning given this plants ability to reproduce vegetatively (Arriola & Ellstrand, 1996). Moreover, in the USA low numbers of cultivar-specific alleles have been found in *S. halepense* populations with no recent exposure to cultivated sorghum, suggesting that introgressed sorghum alleles may disperse across long distances (Morrell et al., 2005). The U.S. Department of Agriculture recommends the use of sterile sorghum cultivars and the control *S. halepense* infestations to prevent the crossing of cultivated *S. bicolor* with *S. halepense* (Dial, 2012).

Effects on ecosystem function targets
No information on the effects of *S. bicolor* var. sweet on the biotic or abiotic properties of ecosystems could be found during a search of available literature.

Effects on plant targets in cultivation systems
No information on the effects of *S. bicolor* var. sweet on plant targets in cultivation systems could be found during a search of available literature.

Effects on animal health and production targets
No information on the effects of parasitism, pathogens or parasites of *S. bicolor* var. sweet on animal health and production targets could be found during a search of available literature.

Hazardous upon contact, host
S. bicolor contains the poisonous glucoside 'dhurrin' from germination which disappears as grain develops (Ecocrop, 2015e).

Human targets
No information on the effects of *S. bicolor* var. sweet on human targets could be found during a search of available literature.

Effects on other targets
No information on the effects of *S. bicolor* var. sweet on infrastructure could be found during a search of available literature.

- Ecological risk assessment with the ISEIA protocol

The expert team allocated *S. bicolor* var. sweet a 'low' ecological risk classification to the categories dispersion potential and invasiveness, colonization of high value conservation habitats and adverse impacts on native species, and an ‘unlikely’ risk classification to the category alteration of ecosystem functions (Table 4.60).

The total ecological risk score for the species is 4 out of a maximum of 11. Therefore, *S. bicolor* var. sweet is classified in the C list of the BFIS list system, irrespective of fertility. The maximum risk score takes into account the limitation on maximum risk score per category that is imposed by the ISEIA protocol if data deficiency occurs or the application of best professional judgement is required (See section 2.4.2). The maximum risk score will, therefore, vary between species. In cases where there is sufficient information, i.e. where there is no data deficiency and best professional judgement is not required, the maximum possible risk score is 12. The rationale for the allocated scores is given in the following paragraphs.

It should be noted that the risk score for alteration of ecosystem functions is based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

Table 4.60: Consensus scores for potential risks of Sorghum (*Sorghum bicolor* var. sweet) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	Low	1
Colonization of high value conservation habitats	Low*	1
Adverse impacts on native species	Low	1
Alteration of ecosystem functions	Unlikely	1
Ecological risk score		**4**

* Quantitative analysis was focused on Natura 2000 areas may indicate a lower score; however, this species may also occur in other areas with high conservation value.

Dispersion potential or invasiveness

Classification: **Low risk**. According to Ecocrop (2015e), temperate climates are not suitable for *S. bicolor* var. sweet, and its temperature requirement ranges from 27 to 35 ^{o}C (optimal) and 8 to 40 ^{o}C (absolute). Moreover, *S. bicolor* is probably native to south of the Sahara in Africa, (World crops database, 2015) or to north-east Africa, supporting the view that the Netherlands may provide a suboptimal climate for this species. The species *S. bicolor* has been widely recorded in the Netherlands. The first records of naturalized *S. bicolor* in the Netherlands date back to the early 1980s. Since that time records have been made in more than 50 km squares, mostly in urban areas. However, most of these have been one time observations which suggests that the species has been unable to permanently establish. *S. bicolor* var. sweet is self-pollinated or cross-pollinated by the wind (World crops database, 2015), although sterile varieties have been developed (Ecocrop, 2015e). The plant displays a high seed production. The presence of the plant is likely to depend on the human introduction of seeds and not sexual reproduction. For example, in agricultural fields in the Netherlands, additional individuals of *S. bicolor* var. sweet have to be planted every year to maintain the cultivated population. It was concluded that *S. bicolor* var. sweet is unlikely to become invasive in the USA (Gordon et al., 2011). Therefore, *S. bicolor* var. sweet was judged to pose a low risk of dispersal and invasiveness in the Netherlands.

Colonization of high value conservation habitats

Classification: **Low risk**. Most observations of *S. bicolor* have been made in urban areas in the Netherlands and likely depend on the human introduction of seeds. Therefore, *S. bicolor* poses a low risk for colonization of high value conservation habitats in the Netherlands.

Adverse impacts on native species

Classification: **Low risk**. *S. bicolor* var. sweet poses a low risk to native species in the Netherlands because it is an annual species.

Alteration of ecosystem functions

Classification: **Unlikely**. *S. bicolor* is a short-term perennial or annual grass and cereal crop with a single cane like stem that reaches a height of 1 to 5 m. Moreover, it is unknown whether a hybrid of *S. bicolor* and *S. halepense* will negatively affect ecosystem functions in the Netherlands. It is unlikely that *S. bicolor* var. sweet will impact on ecosystem functioning in the Netherlands due to its limited potential spread.

Risk classification according to the BFIS list system

The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.60) in combination with the current recorded distribution in the Netherlands. The species classification for *S. bicolor* var. sweet is C1 (Figure 4.49). This characterises a non-native species that is present in isolated populations in the area under assessment, poses a low ecological risk and is not classified in the BFIS list system. It should be emphasised that the literature often does not differentiate between different cultivars and that some of the information used in this risk assessment is relevant to *S. bicolor* and may not describe the characteristics of *S. bicolor* var. sweet. Moreover, the recorded distribution of *S. bicolor* is used to classify the species as no differentiation between cultivars is made in the NDFF database.

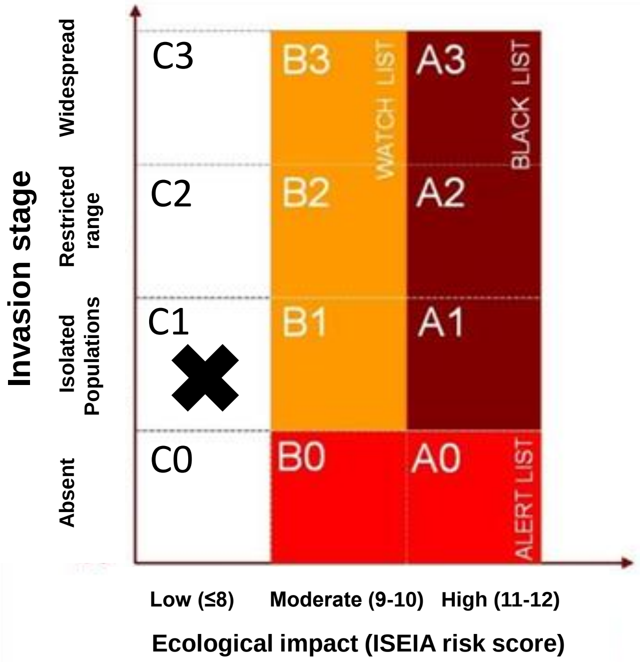

Figure 4.49: Risk classification of Sorghum (*Sorghum bicolor* var. sweet) according to the BFIS list system.

- Other risk assessments and classifications

S. bicolor var. sweet was evaluated for potential invasiveness using modified versions of the Australian Weed Risk Assessment system (WRA) in Florida and the US (Table 4.61). However, these assessments were complicated by the numerous taxa identified as *S. bicolor*. It was concluded that *S. bicolor* var. sweet is unlikely to become invasive in the USA (Gordon et al., 2011). *S. bicolor* was rejected using a secondary screening procedure developed by Daehler et al. (2004) following assessment using the AWRAS for Mediterranean Italy (Crosti et al., 2010). The secondary screening procedure was applied after *S. bicolor* was classified as needing further evaluation following initial application of the Australian Weed Risk Assessment System (AWRAS). An Australian WRA also concluded that the taxon required further evaluation (Gordon et al., 2011). However, the *S. bicolor* variety examined was not specified in either the Italian or Australian risk assessment.

Table 4.61: Overview of risk classifications previously performed for *Sorghum bicolor* var. sweet.

	USA (Florida)	**USA (general)**	**Italy***	**Australia***
Scope	Risk assessment method	Risk assessment method	Risk assessment method	Risk assessment method
Method	Modified Weed Risk Assessment (WRA).	Modified Weed Risk Assessment (WRA).	Modified Weed Risk Assessment (WRA).	Weed Risk Assessment (WRA).
Year	2011	2011	2010	2002
Risk classification	**Accept (2)**	**Accept (3)**	**Rejected following secondary screening (6)**	**Requires further evaluation (6)**
Source	Gordon et al. (2011)	Gordon et al. (2011)	Crosti et al. (2010)	Gordon et al. (2011)

* *S. bicolor* variety not specified.

Gordon et al. (2011) noted that *S. bicolor* var. sweet has been cultivated in south-eastern USA for over a century (Winberry, 1980), and has not demonstrated the invasive characteristics of other Sorghums such as shattercane (*Sorghum bicolor* (L.) Moench var. *drummondii*). However, it was recommended that, due to the limited and sometimes vague available information, cultivation of *S. bicolor* var. sweet should monitored for potential changes in fertility and other traits (Simberloff, 2008; Gordon et al., 2011).

4.8.7 Shattercane (*Sorghum bicolor* var. *drummondii*)

- Species description

Shattercane (*Sorghum bicolor* var. *drummondii*) is a tall, erect, leafy, medium coarse, annual grass with many unbranched stems that reach 1 to 4 m high (Defelice, 2006; Ecocrop, 2015f) (Figure 4.50). The root system is deep, fibrous and extensive (Ecocrop, 2015f). The lanceolate and flat leaf blades grow from 0.8 to 6 cm wide, and up to 50 cm long and are usually glabrous except at the base, with a prominent mid-vein. The round-backed leaf sheaths are glabrous apart from the possible exception of the tip. There is a short, membranous ligule with a hairy margin. The inflorescence, which is normally a contracted panicle, varies from a dense to a loose and pendulous form. The panicle grows to a maximum of 30 cm long and 15 cm wide and features multiple two to six noded racemes that form varyingly crowded, usually pendulous branches.

The plant features either staminate (male) or sterile spikelets that incorporate five to nine nerved narrowly ovate glumes that are hairy along the margins with awnless lemmas. The glumes are most frequently purplish brown or nearly black in colour with scattered white granules, but can also be yellow or yellowish brown. At maturity, the racemes easily break at the base of the spikelets (shatter). The shiny grains are enclosed in the glumes at maturity. The 0.2 to 0.6 cm long grains are oblong-ovate to nearly circular in shape and coloured in a dull brown (Dahlberg, 2000; Davis, 1993; De Wet, 1978; Clark & Rosenow, 1992; Defelice, 2006).

Figure 4.50: Shattercane (*Sorghum bicolor* var. *drummondii*). (Source: Markus Hagenlocher, 2007; Wikimedia Commons).

Species taxonomy

Table 4.62: Nomenclature and taxonomical status of shattercane (*Sorghum bicolor* var. *drummondii*).

Scientific name:
Sorghum bicolor var. *drummondii* (Nees ex Steud.) Millspp. & Chase (1903)
Synonyms:
Andropogon drummondii Nees ex Steud.
Andropogon halepensis var. *sudanensis* (Piper) Suess.
Andropogon sorghum var. *drummondii* (Nees ex Steud.) Hack.
Andropogon sorghum var. *hewisonii* Piper
Andropogon sorghum subsp. *niloticus* Piper
Andropogon sorghum var. *nitens* Busse & Pilg.
Andropogon sorghum subsp. *sudanensis* Piper
Andropogon sorghum var. *transiens* Hack.
Andropogon sudanensis (Piper) Leppan & Bosman
Holcus sorghum var. *drummondii* (Nees ex Steud.) Hitchc.
Holcus sorghum subsp. *sudanensis* (Piper) Hitchc.
Holcus sorghum var. *transiens* (Hack.) Honda
Holcus sudanensis (Piper) L.H.Bailey
Sorghum bicolor subsp. *drummondii* (Nees ex Steud.) de Wet ex Davidse
Sorghum bicolor var. *drummondii* (Nees ex Steud.) Mohlenbr.
Sorghum elliotii Stapf, nom. illeg.
Sorghum halepense var. *sudanense* (Piper) Soó
Sorghum hewisonii (Piper) Longley
Sorghum saccharatum var. *sudanense* (Piper) Kerguélen
Sorghum sudanense (Piper) Stapf
Sorghum vulgare var. *drummondii* (Nees ex Steud.) Chiov.
Sorghum vulgare var. *sudanense* (Piper) Hitchc.

Taxonomic tree (Catalogue of Life, 2015):
Kingdom: Plantae
Phylum: Tracheophyta
Class: Liliopsida
Order: Poales
Family: Poaceae
Genus: *Sorghum*
Species: *Sorghum bicolor* var. *drummondii*

Preferred Dutch name:
Sudangras (unofficial)

Preferred English name:
Shattercane

Other Dutch names:
Not available

Other English names:
Wildcane, Sudan grass (cultivated form)

Life cycle
In an experimental field in Nebraska USA, *S. bicolor* var. *drummondii* flowered 56 to 69 days after planting, viable seeds were produced 10 days after the appearance of anthers (Defelice, 2006).

Reproductive capacity
In agricultural systems, seed yield of *S. bicolor* var. *drummondii* is about 0.5 t/ha (Ecocrop, 2015f). Every panicle can develop from 500 to 1,500 seeds, and plants usually produce one to six panicles each (Horak & Mosier 1994; Defelice, 2006).

- Habitat summary

S. bicolor var. *drummondii* can be grown in the following climates: tropical wet & dry, tropical wet, subtropical humid, subtropical dry summer and subtropical dry winter (Ecocrop, 2015f). It is found between sea level and 300 m in Australia. *S. bicolor* var. *drummondii* does extremely well in temperate, adequately watered conditions (Defelice, 2006). The plant is also adapted to warm conditions with low humidity, but responds well to irrigation under these circumstances (Ecocrop, 2015f).

The physiological conditions tolerated by *S. bicolor* var. *drummondii* are listed in table 4.63*. S. bicolor* var. *drummondii*'s temperature requirement ranges from 21 to 33 ^{o}C (optimal) and 12 to 38 ^{o}C (absolute limit) (Ecocrop, 2015f). *S. bicolor* var. *drummondii* is reported to tolerate minimum temperatures of -3 ^{o}C at rest and -1 ^{o}C during early growth. However, in an experiment by Kegode & Pearce (1998), winter freezing and thawing resulted in seed death and reduced *S. bicolor* var. *drummondii* seed germination by 89% (Defelice, 2006). *S. bicolor* var. *drummondii* prefers high light intensities, and is able to grow in full sunlight at latitudes of 30^{o} and at a maximum altitude of 300 m (Ecocrop, 2015f). Seeds harvested from *S. bicolor* var. *drummondii* types with tight panicles do not require light to germinate, however, light dependence increases with burial time in seeds taken from types with open panicles (Jacques et al., 1974; Defelice, 2006). Rainfall for optimal *S. bicolor* var. *drummondii* growth is reported to be between 600 and 900 mm annually. *S. bicolor* var. *drummondii* can tolerate a minimum of 500 mm and maximum of 2500 mm annual rainfall (Ecocrop, 2015f).

S. bicolor var. *drummondii* grows in well drained to dry soils only that are of varied texture and moderate to high fertility (Ecocrop, 2015f). Optimal soil depth for *S. bicolor* var. *drummondii* lies above 150 cm but soil depths of between 50 and 150 cm are tolerated (Ecocrop, 2015f). *S. bicolor* var. *drummondii* is reported to be able to tolerate pHs ranging from 5 to 8.2 and grows optimally in soils ranging from pH 6.0 to 7.0 (Ecocrop, 2015f). *S. bicolor* var. *drummondii* is able to tolerate soil salinities of between 4 and 10 dS/m (Ecocrop, 2015f).

Table 4.63: Physiological conditions tolerated by shattercane (*Sorghum bicolor* var. *drummondii*).

Parameter	Optimal	Absolute limit	References
Temperature requirement (°C)	21-33	12-38	Ecocrop (2015f)
Killing temperature during rest (°C)	-	-3	Ecocrop (2015f)
Killing temperature early growth (°C)	-	-1	Ecocrop (2015f)
Light intensity	Very bright	Very bright – clear skies	Ecocrop (2015f)
Maximum altitude (m)	-	300	Ecocrop (2015f)
Rainfall (annual - mm)	600-900	500-2500	Ecocrop (2015f)
Latitude (Degrees)	-	30	Ecocrop (2015f)
Soil pH	6-7	5-8.2	Ecocrop (2015f)
Soil depth (cm)	>150	50-150	Ecocrop (2015f)
Soil texture	Heavy, medium	Heavy, medium, light	Ecocrop (2015f)
Soil fertility	High	Moderate	Ecocrop (2015f)
Soil salinity (dS/m)	<4	>10	Ecocrop (2015f)
Soil drainage	well (dry spells)	well (dry spells)	Ecocrop (2015f)

- Recorded distribution

Native range

S. bicolor var. *drummondii* originated in southern Egypt and the Sudan (Ecocrop, 2015f) (Figure 4.51).

Cultivated range

No information on the cultivated range of *S. bicolor* var. *drummondii* could be found during the literature search.

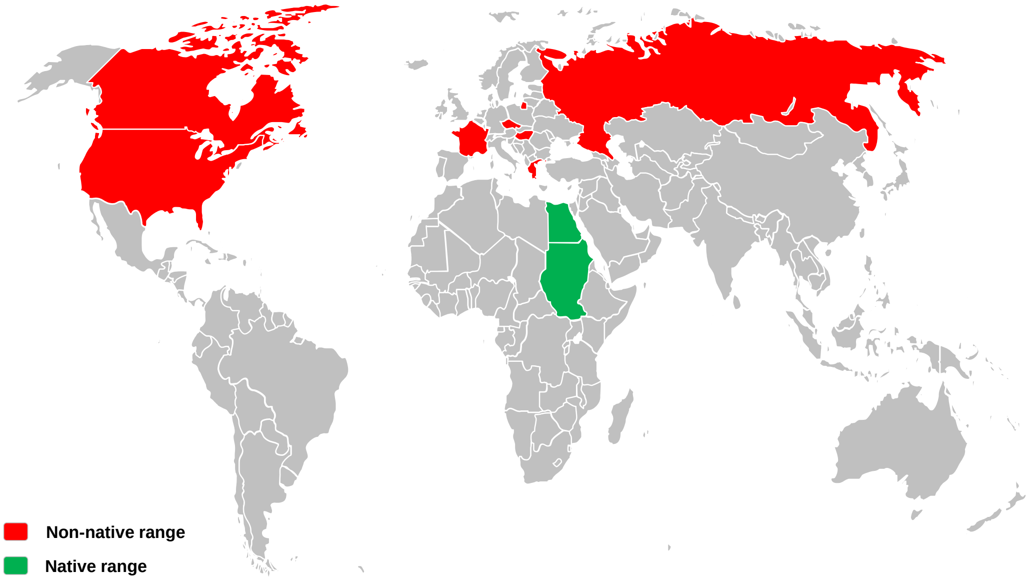

Figure 4.51: Current global recorded distribution of shattercane (*Sorghum bicolor* var. *drummondii*). Sources: DAISIE, 2015d; USDA, 2015d; Ecocrop, 2015f.

Non-native range

S. bicolor var. *drummondii* has been recorded in the Czech Republic, the European part of Russia, Hungary and Romania where it is not established. The plant has also been recorded in France and Greece where its status is unknown (DAISIE, 2015d). *S. bicolor* var. *drummondii* has been introduced to the USA and Canada (USDA, 2015d) (Figure 4.51).

Distribution in the Netherlands
According to the Nationale Databank Flora en Fauna (NDFF, 2015f), there are no current records of *S. bicolor* var. *drummondii* in the Netherlands.

Colonisation of high conservation value habitats
According to the Nationale Databank Flora en Fauna (NDFF, 2015f), there are no current records of *S. bicolor* var. *drummondii* in the Netherlands.

- Invasion process

Introduction outside cultivated land
Seed dispersal occurs primarily through seed shattering when an abscission layer forms at the base of each spikelet at the approximate time of seed maturity. Following the formation of this layer, all seeds easily separate from the plant in the presence of a light breeze. *S. bicolor* var. *drummondii* seeds may also disperse by hydrochory in irrigation and runoff water allowing long distance dispersal (Horak & Mosier, 1994; Defelice, 2006). *S. bicolor* var. *drummondii* seeds may also spread to new areas following ingestion and excretion by livestock (Fawcett, 1981; Defelice, 2006).

Establishment
No information on the establishment of *S. bicolor* var. *drummondii* outside cultivated land could be found during a search of available literature.

Spread
Seed dispersal occurs primarily through seed shattering (Defelice, 2006), but also via hydrochory in irrigation and runoff water allowing long distance dispersal (Horak & Mosier, 1994; Defelice, 2006), and following ingestion and excretion by livestock (Fawcett, 1981; Defelice, 2006).

- Environmental impacts summary

Effects on environmental targets or native species
No information on the effects of competition, parasitism, pathogens or parasites of *S. bicolor* var. *drummondii* on environmental targets or native species could be found during a search of available literature.

Interbreeding
Cultivated *S. bicolor* var. *drummondii* is closely related and is therefore able to hybridize with wild *S. bicolor* varieties with no associated reduction in reproduction

potential. Results of a study carried out by Adugna & Bekele (2013) supports the idea that hybridization between wild and cultivated sorghums may enhance fitness relative to wild plants. However, there are no native sorghum species in the Netherlands (Naturalis, 2015).

Effects on ecosystem function targets

No information on the effects of *S. bicolor* var. *drummondii* on the biotic or abiotic properties of ecosystems could be found during a search of available literature.

Effects on plant targets in cultivation systems

No information on the interbreeding effects or the effects of pathogens or parasites of *S. bicolor* var. *drummondii* on plant targets in cultivation systems could be found during a search of available literature.

Competition

S. bicolor var. *drummondii* is a widespread agricultural weed wherever grain sorghum (*Sorghum bicolor* subsp. *bicolor*) is grown today and has become a very serious weed of wheat fields in Ethiopia (Defelice, 2006). It is classified as the most troublesome weed in sorghum fields and is a major economic problem in row crops in the USA (Kegode & Pearce, 1998; Hans & Johnson, 2002; Sahoo et al., 2010).

Effects on animal health and production targets

No information on the effects of parasitism, pathogens or parasites of *S. bicolor* var. *drummondii* on animal health and production targets could be found during a search of available literature.

Human targets

No information on the effects of *S. bicolor* var. *drummondii* on human targets could be found during a search of available literature.

Effects on other targets

No information on the effects of *S. bicolor* var. *drummondii* on infrastructure could be found during a search of available literature.

- Ecological risk assessment with the ISEIA protocol

The expert team allocated *S. bicolor* var. *drummondii* a 'unlikely' ecological risk classification to the category dispersion potential or invasiveness, colonization of high value conservation habitats and adverse impacts on native species, and a ‘deficient data (DD)’ risk classification to the category alteration of ecosystem functions (Table 4.64). The total ecological risk score for the species is 4 out of a maximum of 7. Therefore, *S. bicolor* var. *drummondii* is classified in the C list of the BFIS list system. The maximum risk score takes into account the limitation on maximum risk score per category that is imposed by the ISEIA protocol if data deficiency occurs or the application of best professional judgement is required (See section 2.4.2). The maximum risk score will, therefore, vary between species. In cases where there is sufficient information, i.e. where there is no data deficiency and best professional judgement is not required, the maximum possible risk score is 12. The rationale for the allocated scores is given in the following paragraphs.

It should be noted that the risk scores for dispersion potential or invasiveness, colonization of high value conservation habitats and adverse impacts on native species are based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

Table 4.64: Consensus scores for potential risks of shattercane (*Sorghum bicolor* var. *drummondii*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	Unlikely	1
Colonization of high value conservation habitats[a]	Unlikely	1
Adverse impacts on native species	Unlikely	1
Alteration of ecosystem functions	DD	1[b]
Ecological risk score		**4**

[a] Quantitative analysis was focused on Natura 2000 areas may indicate a lower score, however, species may also occur also in other areas with high conservation value; [b] deficient data (DD) scores 1 as this is the minimum that can be awarded per risk category.

Dispersion potential or invasiveness

Classification: **Unlikely**. *S. bicolor* var. *drummondii* does extremely well in temperate, adequately watered conditions (Defelice, 2006). However, according to the Nationale Databank Flora en Fauna (NDFF, 2015f), there are no current records of *S. drummondii* in the Netherlands. Moreover, harsh Dutch winters will probably limit the dispersal potential and invasiveness of this species. *S. bicolor* var. *drummondii* is reported to tolerate minimum temperatures of -3 ^{o}C at rest and -1 ^{o}C during early growth. In an experiment by Kegode & Pearce (1998), winter freezing and thawing resulted in seed death and reduced *S. bicolor* var. *drummondii* seed germination by 89% (Defelice, 2006). *S. bicolor* var. *drummondii* has been recorded in the Czech Republic, the European part of Russia, Hungary and Romania where it is not established. The plant has also been recorded in France and Greece where its status is unknown (DAISIE, 2015d). *S. bicolor* var. *drummondii* has been introduced to the USA and Canada (USDA, 2015d). The lack of evidence pointing to the establishment of *S. bicolor* var. *drummondii* in regions climatically similar to the Netherlands together with its poor cold tolerance suggest that it is unlikely that the species will disperse and become invasive in the Netherlands despite the potential for seeds to spread via hydrochory (Horak & Mosier, 1994; Defelice, 2006) and zoochory (Fawcett, 1981; Defelice, 2006).

Colonization of high value conservation habitats

Classification: **Unlikely**. According to the Nationale Databank Flora en Fauna (NDFF, 2015f), there are no current records of *S. bicolor* var. *drummondii* in the Netherlands. This together with the lack of evidence pointing to the establishment of *S. bicolor* var. *drummondii* in regions climatically similar to the Netherlands and its poor cold tolerance suggest that it is unlikely that the species will colonise high value conservation habitats in the Netherlands.

Adverse impacts on native species

Classification: **Unlikely**. Results of a study carried out by Adugna & Bekele (2013) support the idea that hybridization between wild and cultivated sorghums may enhance fitness relative to wild plants. However, there are no native species of sorghum present in the Netherlands (Naturalis, 2015). Therefore, it is unlikely that *S. bicolor* var. *drummondii* will hybridize with native species.

Alteration of ecosystem functions

Classification: **Deficient data**. There is insufficient information to allow an assessment of the potential impact of *S. bicolor* var. *drummondii* on ecosystem functions in the Netherlands.

Risk classification according to the BFIS list system

The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.64) in combination with the current recorded distribution in the Netherlands. The species classification for *S. bicolor* var. *drummondii* is C0 (Figure 4.52). This characterises a non-native species that is absent from the area under assessment, poses a low ecological risk and is not classified in the BFIS list system.

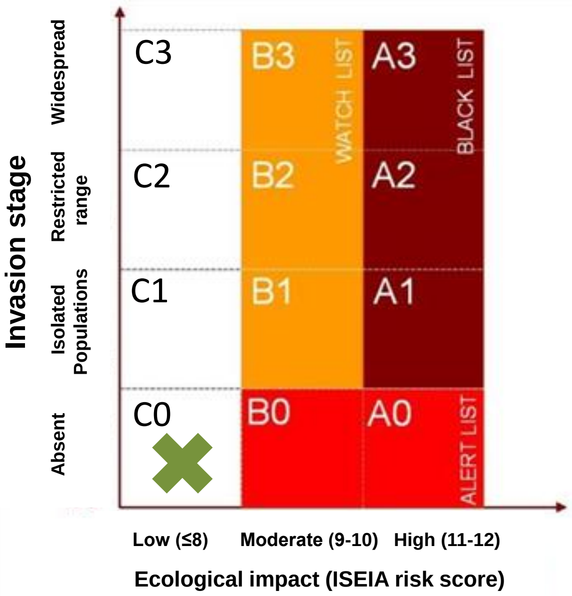

Figure 4.52: Risk classification of shattercane (*Sorghum bicolor* var. *drummondii*) according to the BFIS list system.

- Other risk assessments and classifications

S. bicolor var. *drummondii* was risk assessed for Hawaii in 2010 using a modified version of the Australian Weed Risk Assessment System (AWRAS). *S. bicolor* var. *drummondii* was categorised as a high risk species (Table 4.65).

Table 4.65: Overview of risk classifications previously performed for shattercane (*Sorghum bicolor* var. *drummondii*).

	Hawaii
Scope	Risk assessment method
Method	Modified Australian Weed Risk Assessment System (AWRAS).
Year	2010
Risk classification	**High risk (17.5)**
Source	Hear.org (2015i)

4.8.8 Giant cordgrass (*Spartina cynosuroides*)

- Species description

Giant cordgrass (*Spartina cynosuroides*) is a coarse, robust, perennial grass ranging from 2 to 4 metres tall (Figure 4.53). It may be identified by its coarsely branched inflorescence that extends well above the leaves. The flat leaf blade is 1.5 to 3 cm wide and 46 to 61 cm long with rough and sharp margins. The leaf sheath is rounded. The short membranous ligule is densely hairy. The thick, rounded stem is frequently 2 cm in diameter at the base. The 30 to 46 cm long seed head consists of 20 to 40 spikes, each approximately 7.5 cm long, and approximately 1.3 cm long spikelets growing on one side of the rachis (USDA, 2015a). The flower head is initially green, but turns a tan colour in late Autumn (October to November) when seed are produced (Silberhorn, 1992).

Figure 4.53: Giant cordgrass (*Spartina cynosuroides*) growing in a botanical garden in Munich, Germany. (Source: Diderot, 2011; Wikimedia commons).

Species taxonomy

Table 4.66: Nomenclature and taxonomical status of giant cordgrass (*Spartina cynosuroides*).

Scientific name:
Spartina cynosuroides (L.) Roth (1806)

Synonyms:
Cynodon cynosuroides (L.) Raspail
Dactylis cynosuroides L.
Limnetis cynosuroides (L.) Rich.
Limnetis polystachya (Michx.) Rich.
Paspalum cynosuroides (L.) Brot.
Poa lagopoides Steud., pro syn.
Spartina cynosuroides var. *polystachya* (Michx.) Beal
Spartina polystachya (Michx.) Willd.
Trachynotia cynosuroides (L.) Michx.
Trachynotia polystachya Michx.
Triodia cynosuroides (L.) Spreng.

Taxonomic tree (Catalogue of Life, 2015):
Kingdom: Plantae
Phylum: Tracheophyta
Class: Liliopsida
Order: Poales
Family: Poaceae
Genus: *Spartina*
Species: *Spartina cynosuroides*

Preferred Dutch name:
Not applicable

Preferred English name:
Giant cordgrass

Other Dutch names:
Not applicable

Other English names:
Big cordgrass, salt reedgrass

Life cycle

In its native southern USA, *S. cynosuroides*' major growing period occurs from late March to September or October (USDA, 2015a). The plant reaches maturity in late summer to early autumn (August to September in the USA) (Silberhorn, 1992). Seed heads form during Autumn. The base of the plant remains green throughout the winter months (USDA, 2015a).

Reproductive capacity

S. cynosuroides is able to reproduce by seed; however, it spreads vegetatively very rapidly and extensively using robust rhizomes. It can form dense monospecific stands in marshes in the USA. *S. cynosuroides'* annual productivity is very high compared to other marsh grasses and is rivalled only by smooth cordgrass (*Spartina alterniflora*). Stems can grow to an average density of 100 to 160 stems per square metre (Silberhorn, 1992).

- Habitat summary

In its native North America, *S. cynosuroides* is found in tidal sounds, bays and tidal rivers (Li & Gallagher, 1996). It usually grows above mean high water (Silberhorn, 1992). *S. cynosuroides* is adapted primarily to mineral soils in salt marshes (Table 4.67). It tolerates water levels that fluctuate from 10 cm below, to 5 cm above the soil surface and moderate salinity. Germination occurs over temperatures ranging from 25 to 35 ºC and it is recommended that, during artificial propagation, seedlings should be kept at a temperature of 27 to 30 ºC for the first two weeks and then in a greenhouse in full sun for three to four months (Center for Plant Restoration and Coastal Plant Research, 2015). In its native range, *S. cynosuroides* is closely associated with marsh-hay cordgrass (*Spartina patens*) and common reed (*Phragmites australis*) (USDA, 2015a).

Table 4.67: Physiological conditions tolerated by giant cordgrass (*Spartina cynosuroides*).

Parameter	Range	References
Temperature (germination, ºC)	25-35	Center for Plant Restoration and Coastal Plant Research (2015)
Temperature (artificial propagation, ºC)	27-30	Center for Plant Restoration and Coastal Plant Research (2015)
Water depth (cm)	10 < soil surface > 5	USDA (2015a)
Salinity	Moderate	USDA (2015a)
Substrate	Mineral soils	USDA (2015a)

- Recorded distribution

Native range
S. cynosuroides is native to the southern eastern states of the USA (USDA, 2015a).

Cultivated range
No information on the cultivated range of *S. cynosuroides* could be found during the literature search.

Invasive range
S. cynosuroides was introduced as a wetland restoration measure to China in 1979 but was not able to establish (An et al., 2007).

Distribution in the Netherlands
According to the Nationale Databank Flora en Fauna (NDFF, 2015f), there are no current records of *S. cynosuroides* in the Netherlands.

Colonisation of high conservation value habitats
According to the Nationale Databank Flora en Fauna (NDFF, 2015f), there are no current records of *S. cynosuroides* in the Netherlands.

- Invasion process

Introduction outside cultivated land
No information on the introduction of *S. cynosuroides* outside cultivated land could be found during a search of available literature.

Establishment
No information on the establishment of *S. cynosuroides* outside cultivated land could be found during a search of available literature.

Spread
No information on the spread of *S. cynosuroides* outside cultivated land could be found during a search of available literature.

- Environmental impacts summary

Effects on environmental targets or native species
No information on the effects of competition, parasitism, pathogens, parasites or interbreeding of *S. cynosuroides* on environmental targets or native species could be found during a search of available literature. However, *S. cynosuroides* is a very productive marsh grass, with an average stem density ranging from 100 to 160 stems per square metre in monospecific stands (Silberhorn, 1992).

Effects on ecosystem function targets
No information on the biotic and abiotic effects of *S. cynosuroides* on ecosystem function targets could be found during a search of available literature. However, *S. cynosuroides* is a very productive marsh grass, with an average stem density ranging from 100 to 160 stems per square metre in monospecific stands (Silberhorn, 1992).

Effects on plant targets in cultivation systems
No information on the effects of *S. cynosuroides* on plant targets in cultivation systems could be found during a search of available literature.

Effects on animal health and production targets
No information on the effects of *S. cynosuroides* on animal health and production targets could be found during a search of available literature.

Human targets
No information on the effects of *S. cynosuroides* on human targets could be found during a search of available literature.

Effects on other targets
No information on the effects of *S. cynosuroides* on infrastructure could be found during a search of available literature.

- Ecological risk assessment with the ISEIA protocol

The expert team allocated *S. cynosuroides* an 'unlikely' ecological risk classification to all categories (Table 4.68).

The total ecological risk score for the species is 4 out of a maximum of 8. Therefore, *S. cynosuroides* is classified in the C list of the BFIS list system. The maximum risk score takes into account the limitation on maximum risk score per category that is imposed by the ISEIA protocol if data deficiency occurs or the application of best professional judgement is required (See section 2.4.2). The maximum risk score will, therefore, vary between species. In cases where there is sufficient information, i.e. where there is no data deficiency and best professional judgement is not required, the maximum possible risk score is 12. The rationale for the allocated scores is given in the following paragraphs.

It should be noted that all risk scores are based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

Table 4.68: Consensus scores for potential risks of giant cordgrass (*Spartina cynosuroides*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	**Risk**	**Consensus score**
Dispersion potential or invasiveness	Unlikely	1
Colonization of high value conservation habitats	Unlikely*	1
Adverse impacts on native species	Unlikely	1
Alteration of ecosystem functions	Unlikely	1
Ecological risk score		**4**

* Quantitative analysis was focused on Natura 2000 areas may indicate a lower score; however, species may also occur in other areas with high conservation value.

Dispersion potential or invasiveness
Classification: **Unlikely**. In its native range of southeastern USA, *S. cynosuroides* is able to reproduce by seed and spreads vegetatively very rapidly and extensively using robust rhizomes forming dense monospecific stands. However, it is unlikely that *S. cynosuroides* will disperse and become invasive in the Netherlands due to the differences in climate between the Netherlands and the plants native range. An attempt was made to introduce *S. cynosuroides* to China in 1979, however, it failed to establish. No other information demonstrating the existence of a non-native range for *S. cynosuroides* could be found during the literature survey. The poor climate match

is also supported by the species temperature tolerances. Germination occurs over temperatures ranging from 25 to 35 ºC (Center for Plant Restoration and Coastal Plant Research, 2015). In conclusion, due to a poor climate match, it is unlikely that *S. cynosuroides* will disperse and become invasive in the Netherlands.

Colonization of high value conservation habitats
Classification: **Unlikely**. According to the Nationale Databank Flora en Fauna (NDFF, 2015f), there are no current records of *S. cynosuroides* in the Netherlands. Due to a poor climate match it is unlikely that *S. cynosuroides* will colonize high value conservation habitats in the Netherlands.

Adverse impacts on native species
Classification: **Unlikely**. *S. cynosuroides* is a very productive marsh grass, with an average stem density ranging from 100 to 160 stems per square metre in monospecific stands (Silberhorn, 1992). However, No information on the effects of *S. cynosuroides* on native species could be found during a search of available literature. Due to a poor climate match and the lack of evidence for impacts on native species in climatically similar regions, it is unlikely that *S. cynosuroides* would adversely affect native species in the Netherlands.

Alteration of ecosystem functions
Classification: **Unlikely**. *S. cynosuroides* is a very productive marsh grass, with an average stem density ranging from 100 to 160 stems per square metre in monospecific stands (Silberhorn, 1992). However, No information on the effects of *S. cynosuroides* on ecosystem functions could be found during a search of available literature. Due to a poor climate match it is unlikely that *S. cynosuroides* would adversely affect ecosystem functions in the Netherlands.

Risk classification according to the BFIS list system
The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.68) in combination with the current recorded distribution in the Netherlands. The species classification for *S. cynosuroides* is C0 (Figure 4.54). This characterises a non-native species that is absent from the area under assessment, poses a low ecological risk and is not classified in the BFIS list system.

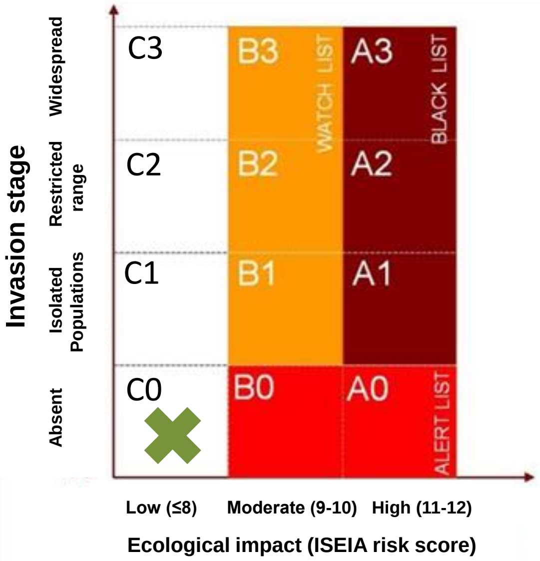

Figure 4.54: Risk classification of giant cordgrass (*Spartina cynosuroides*) according to the BFIS list system.

- Other risk assessments and classifications

No risk assessments or classifications of *S. cynosuroides* could be found during a search of available literature.

4.8.9 Prairie cordgrass (*Spartina pectinata*)

- Species description

Prairie cordgrass (*Spartina pectinata*) is a warm-season, C4 perennial grass. The wiry culms grow to 1 to 1.8 m (Figure 4.55). Each plant usually features 10 to 20, 4 to 8 cm long spikes. The root system features rhizomes that are woody, coarse and highly branching. Roots grow from the base of the clumps and the rhizomes, penetrating almost vertically to depths of between 2.4 and 3.3 m (Hitchcock et al., 1969; Weaver, 1954; Friesen et al., 2015; US Forestry Service, 2015, Missouri Botanical Garden). *Spartina pectinata* varieties *aureomarginata* (Royal Horticultural Society), savoy and red river (Google patents).

Figure 4.55: Prairie cordgrass (*Spartina pectinata*). (Source: U.S. EPA, 2006; Wikimedia Commons).

Species taxonomy

Table 4.69: Nomenclature and taxonomical status of prairie cordgrass (*Spartina pectinata*).

Scientific name:
Spartina pectinata Bosc ex Link (1820)

Synonyms:
Spartina cynosuroides var. *aureomarginata* W.Irving
Spartina cynosuroides f. *major* St.-Yves
Spartina cynosuroides var. *michauxiana* (Hitchc.) St.-Yves
Spartina michauxiana Hitchc.
Spartina michauxiana var. *suttiei* Farw.
Spartina michauxiana var. *tenuior* Farw.
Spartina pectinata var. *suttiei* (Farw.) Fernald
Spartina pectinata f. *variegata* Vict.

Taxonomic tree (Catalogue of Life, 2015):
Kingdom: Plantae
Phylum: Tracheophyta
Class: Liliopsida
Order: Poales
Family: Poaceae
Genus: *Spartina*
Species: *Spartina pectinata*

Preferred Dutch name:
Slijkgras (unofficial)

Preferred English name:
Prairie cordgrass

Other Dutch names:
Not available

Other English names:
Ripgut, cordgrass, marsh grass, slough grass, fresh water cordgrass, broadleaf

Life cycle

Compared to other grasses in its native range, *S. pectinata* renews growth rather late but grows more rapidly than any other prairie grass. By early June in Missouri (USA), *S. pectinata* has grown to 0.6-0.9 m. Flowering stalks appear after two years at the earliest (Weaver, 1958; US Forestry Service, 2015). In general, flowering occurs from June to October in its native range, and maximum floral production occurs from August to September (Hitchcock et al., 1969; US Forestry Service, 2015).

Reproductive capacity

S. pectinata produces both rhizomes and seeds (Zilverberg et al., 2014); however, most reproduction occurs vegetatively (Weaver, 1954; US Forestry Service, 2015).

Reproduction from rhizomes results in 100% coverage and almost no other plants are able to grow in dense stands (Weaver, 1960b; US Forestry Service, 2015).

- Habitat summary

S. pectinata usually found in wetlands but is occasionally found in other habitat types (Hansen et al., 1988; US Forestry Service, 2015). It grows around ponds and on the wet banks of slow flowing streams (Weaver, 1960b). The plant has also been recorded on lower, poorly drained soils and alkaline fens, floodplains and till plains (Betz, 1978; Weaver, 1960a; US Forestry Service, 2015), along prairie drainage ways and around prairie marshes (US Forestry Service, 2015). *S. pectinata* may also be found in roadside ditches, low areas along railroads, edges of fields, and poorly drained areas of vacant lots (Encyclopaedia of Life, 2015).

S. pectinata seeds germinate readily in wet soil, followed by rapid seedling development (Weaver, 1954; US Forestry Service, 2015). The seedlings are shade-intolerant and only establish on areas of bare ground (Weaver, 1954; US Forestry Service, 2015). Optimum temperatures for germination have been reported to range from 20 ^{o}C at night to 30 ^{o}C (Eddleman & Meinhardt, 1978; US Forestry Service, 2015) (Table 4.70). In greenhouse experiments seedlings tolerated moisture stress conditions with high survival for up to four weeks but with reduced growth rate (Eddleman & Meinhardt, 1978; US Forestry Service, 2015). *S. pectinata* rhizomes are tolerant of cold winter conditions. At an experimental field site in Ontario, Canada winter temperatures corresponding to 50% rhizome mortality (LT_{50}) in November and February was near -24°C and in late April -10°C for *S. pectinata* (Friesen et al., 2015). Moreover, *S. pectinata* leaves remained viable to -9°C (Friesen et al., 2015).

S. pectinata tolerates most soil textures from fine clays to silt loams and is tolerant of high groundwater levels but intolerant of prolonged flooding (Hansen et al., 1988; US Forestry Service, 2015). The plant has been recorded at elevations of 640 to 2,134 m in the USA (Dittberner & Olson, 1984; US Forestry Service, 2015).

Table 4.70: Physiological conditions tolerated by prairie cordgrass (*Spartina pectinata*).

Parameter	Data origin	Occurrence	References
Temperature (germination optimum °C)	Greenhouse	20-30	Eddleman & Meinhardt (1978); US Forest Service (2015)
Temperature (LT_{50} November and February °C)	Canada	-24	Friesen et al. (2015)
Temperature (LT_{50} April °C)	Canada	-10	Friesen et al. (2015)
Altitude (m)	USA	640-2134	Dittberner & Olson (1984); US Forest Service (2015)
Soil texture	North America	fine clays to silt loams	Hansen et al. (1988); US Forest Service (2015)

In its native range *S. pectinata* is associated with tall rushes (*Scirpus* spp.), reed grasses (*Phragmites* spp.), sedges (*Carex* spp.), Canada wildrye (*Elymus* *canadensis*) and switchgrass (*Panicum virgatum*) (Weaver, 1960b; US Forestry Service, 2015).

- Recorded distribution

Native range
S. pectinata is native to much of the USA and Canada (USDA, 2015e). The plant is also native to Mexico (US Forestry Service, 2015) (Figure 4.56).

Cultivated range
S. pectinata is cultivated in the USA (USDA-ARS, 2015).

Non-native range
According to DAISIE (2015e), *S. pectinata* is non-native to and established in Germany and Ireland, non-native but not established in Belgium, and non-native to England (status unclear). In the Netherlands *S. pectinata* distribution is limited to a few isolated records (NDFF, 2015c). According to United States Department of Agriculture Agricultural Research Service (USDA-ARS, 2015), *S. pectinata* is naturalised in Australia (Figure 4.56).

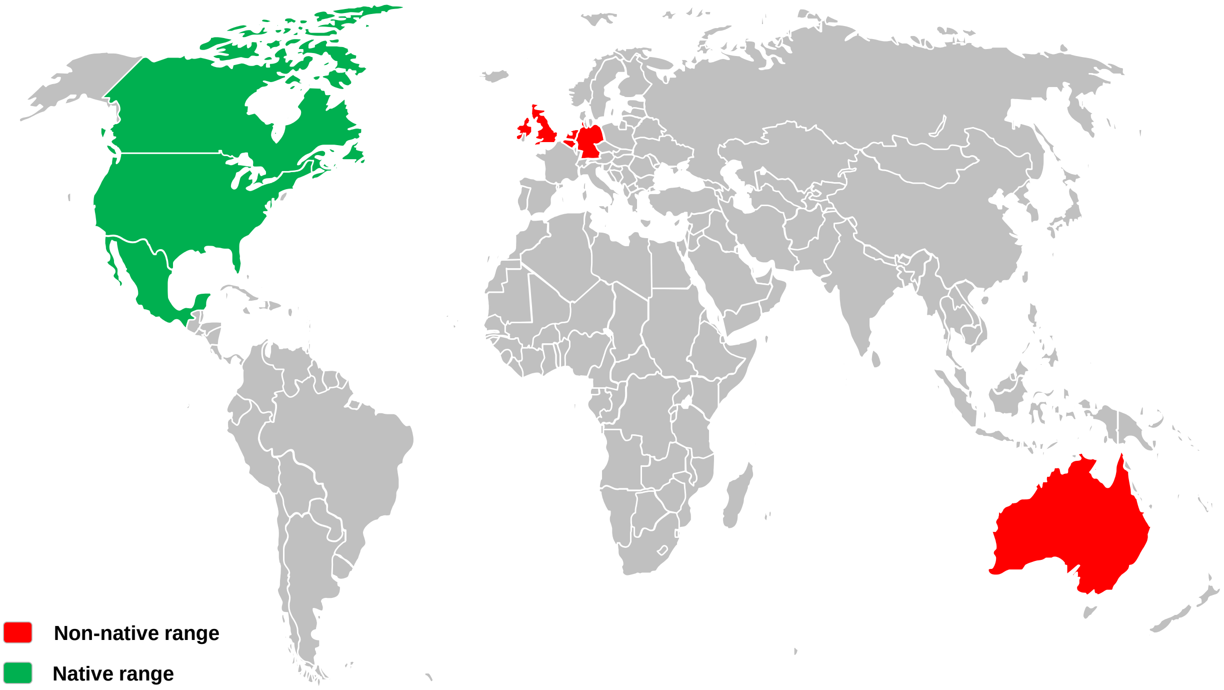

Figure 4.56: Current global recorded distribution of prairie cordgrass (*Spartina pectinata*) (Sources: USDA, 2015e; US Forest Service, 2015; DAISIE, 2015e; CABI, 2015h; NDFF, 2015c; USDA-ARS, 2015).

Distribution in the Netherlands
To date, *S. pectinata* has been recorded in 4 km squares in the Netherlands (Figure 4.57). All observations were made after 2008. However, it is present over a wide area at these locations suggesting that the species established much earlier. The species has been recorded on a golf course, in a city park, at a sand quarry and at a

roadside. The species probably arrived as a result of planting or dumping of garden waste with root remains.

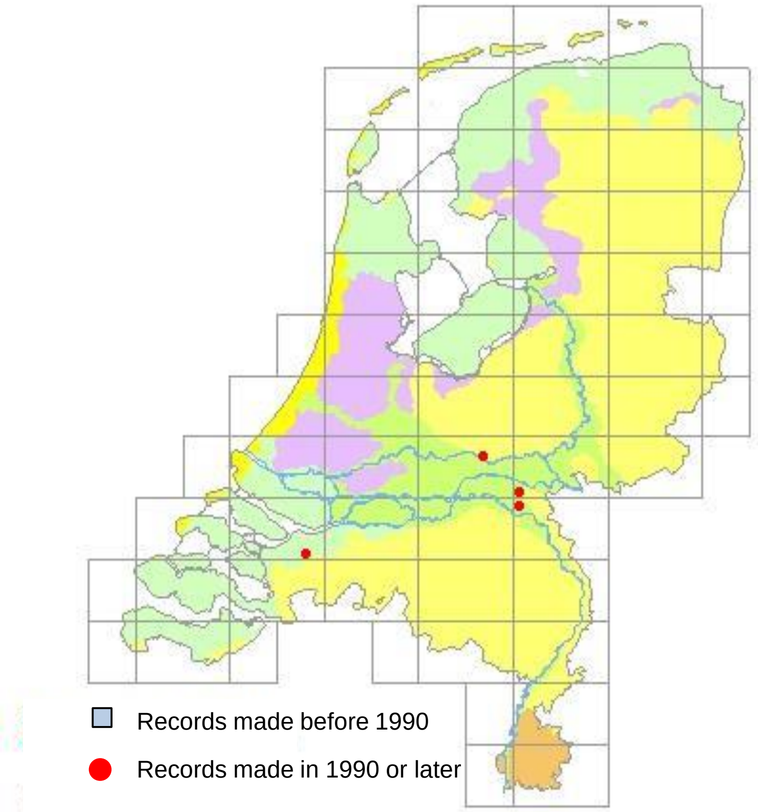

Figure 4.57: Current recorded distribution of prairie cordgrass (*Spartina pectinata*) in the Netherlands. Source: Nationale Databank Flora en Fauna (2015).

Colonisation of high conservation value habitats

No confirmed recordings of *S. pectinata* exist for Natura 2000 areas in the Netherlands.

- Invasion process

Introduction outside cultivated land

No information on the introduction of *S. pectinata* outside cultivated land could be found during a search of available literature. However, the cultivar *aureomarginata* of *S. pectinata* is present in the Dutch plant trade. This plant is planted around ponds.

Establishment

No information on the establishment of *S. pectinata* outside cultivated land could be found during a search of available literature.

Spread

S. pectinata is a highly invasive species, spreading vegetatively via its root system.

- Environmental impacts summary

According to Encyclopaedia of Life (2015), *S. pectinata* may become weedy or invasive in some regions or habitats and may displace desirable vegetation if not properly managed. It has been recorded at three locations in the UK since 1967, and a single location in the Republic of Ireland (NBN Gateway), and became established between 1980 and 2001 in Germany (Floraweb.de). However, no information on any environmental impacts occurring in these countries could be found during the literature search.

Effects on environmental targets or native species
No information on the effects of competition, parasitism, pathogens, parasites or interbreeding of *S. pectinata* on environmental targets or native species could be found during a search of available literature. However, in its native range, *S. pectinata* forms thick stands around marshes (US Forestry Service, 2015).

Effects on ecosystem function targets
No information on the biotic and abiotic effects of *S. pectinata* on ecosystem function targets could be found during a search of available literature. However, in its native range, *S. pectinata* forms thick stands around marshes (US Forestry Service, 2015).

Effects on plant targets in cultivation systems
No information on the effects of *S. pectinata* on plant targets in cultivation systems could be found during a search of available literature.

Effects on animal health and production targets
No information on the effects of *S. pectinata* on animal health and production targets could be found during a search of available literature.

Human targets
No information on the effects of *S. pectinata* on human targets could be found during a search of available literature.

Effects on other targets
No information on the effects of *S. pectinata* on infrastructure could be found during a search of available literature.

- Ecological risk assessment with the ISEIA protocol

The expert team allocated *S. pectinata* a 'medium' ecological risk classification to the category dispersion potential and invasiveness, a ‘high’ risk classification to the categories colonization of high value conservation habitats, adverse impacts on native species and alteration of ecosystem functions (Table 4.71).

Table 4.71: Consensus scores for potential risks of prairie cordgrass (*Spartina pectinata*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	**Risk**	**Consensus score**
Dispersion potential or invasiveness	Medium	2
Colonization of high value conservation habitats	High*	3
Adverse impacts on native species	High	3
Alteration of ecosystem functions	High	3
Ecological risk score		**11**

* Quantitative analysis was focused on Natura 2000 areas may indicate a lower score; however, this species may also occur in other areas with high conservation value.

The total ecological risk score for the species is 11 out of a maximum of 12. Therefore, *S. pectinata* is classified in the A list of the BFIS list system. The maximum risk score takes into account the limitation on maximum risk score per category that is imposed by the ISEIA protocol if data deficiency occurs or the application of best professional judgement is required (See section 2.4.2). The maximum risk score will, therefore, vary between species. In cases where there is sufficient information, i.e. where there is no data deficiency and best professional judgement is not required, the maximum possible risk score is 12. The rationale for the allocated scores is given in the following paragraphs.

Dispersion potential or invasiveness

Classification: **High risk**. To date, *S. pectinata* has been recorded in 4 km squares in the Netherlands. All observations were made after 2008. However, it is present over a wide area at these locations suggesting that the species established much earlier. *S. pectinata* is non-native to and established in Germany and Ireland, non-native but not established in Belgium, and non-native to England (status unclear). The suitability of the Netherlands climate for *S. pectinata* is further supported by field experiments in Ontario, Canada. Here, winter temperatures corresponding to 50% rhizome mortality (LT50) were in November and February near -24°C and in late April -10°C (Friesen et al., 2015). Moreover, *S. pectinata* leaves remained viable to -9°C (Friesen et al., 2015). The species produces both rhizomes and seeds (Zilverberg et al., 2014); however, most reproduction occurs vegetatively (Weaver, 1954; US Forestry Service, 2015). According to the Encyclopedia of Life (2015), *S. pectinata* may become weedy or invasive in some regions or habitats if not properly managed. Due to the presence of records for *S. pectinata* in the Netherlands and its established status in Germany and Ireland, temperature tolerance and capacity for vegetative reproduction, *S. pectinata* poses a high risk of dispersal and invasiveness in the Netherlands.

Colonization of high value conservation habitats

Classification: **High risk**. In its native range of North America that covers all northern states and Eastern Canada (http://plants.usda.gov/core/profile?symbol=SPPE), *S. pectinata* is usually found in wetlands and occasionally colonizes other habitat types

(Hansen et al., 1988; US Forestry Service, 2015). It grows around ponds and on the wet banks of slow flowing streams (Weaver, 1960b). The plant has also been recorded on lower, poorly drained soils and alkaline fens, floodplains and till plains (Betz, 1978; Weaver, 1960a; US Forestry Service, 2015), along prairie drainage ways and around prairie marshes (US Forestry Service, 2015). There are no confirmed records of *S. pectinata* in N2000 areas in the Netherlands. However, the fact that *S. pectinata* colonizes wetlands and the banks of rivers and streams in its native Northern United States and Canada, suggests that there is a high risk that it would colonize similar high conservation value habitats in the Netherlands.

Adverse impacts on native species

Classification: **High risk**. Reproduction from rhizomes of *S. pectinata* results in 100% ground cover and almost no other plants are able to grow in dense stands (Weaver, 1960b; US Forestry Service, 2015). Moreover, according to Encyclopedia of Life (2015), *S. pectinata* may become weedy or invasive in some regions or habitats and may displace desirable vegetation if not properly managed. There is a lack of information describing the impacts of *S. pectinata* in it's non-native European range. Due to the potential for *S. pectinata* to grow in dense stands and spread over wide areas, it is expected that *S. pectinata* will often cause local and severe (> 80%) population declines and the loss of local species richness in the Netherlands.

Alteration of ecosystem functions

Classification: **High risk**. Reproduction from rhizomes of *S. pectinata* results in 100% ground cover and almost no other plants are able to grow in dense stands (Weaver, 1960b; US Forestry Service, 2015). Moreover, according to Encyclopedia of Life (2015), *S. pectinata* may become weedy or invasive in some regions or habitats and may displace desirable vegetation if not properly managed. Due to the potential for *S. pectinata* to grow in dense stands and spread over wide areas, it is expected that *S. pectinata's* impact on ecosystems process will be strong and difficult to reverse in the Netherlands.

Risk classification according to the BFIS list system

The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.71) in combination with the current recorded distribution in the Netherlands. The species classification for *S. pectinata* is A1 (Figure 4.58). This characterises a non-native species that has limited populations in the area under assessment, poses a high ecological risk and is placed on the blacklist of the BFIS list system.

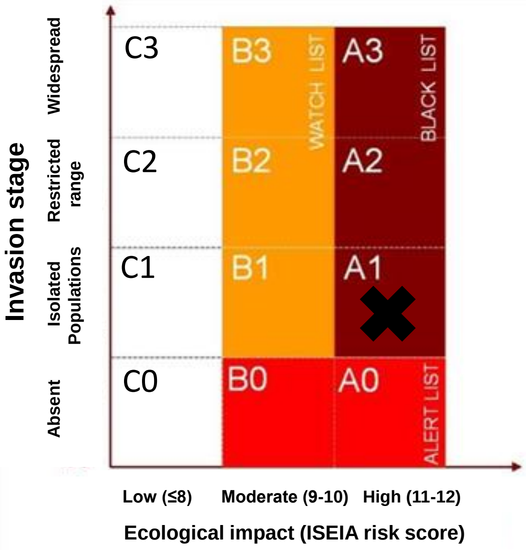

Figure 4.58: Risk classification of prairie cordgrass (*Spartina pectinata*) according to the BFIS list system.

- Other risk assessments and classifications

No risk assessments or classifications of *S. pectinata* could be found during a search of available literature.

5. Ranking of risk classifications

Tables 5.1a and 5.1b give an overview of all risk scores and risk classifications for the assessed biomass crop species. These risk assessments have been performed for the potential future situation.

Table 5.1a: Overview of risk classifications of biomass crop species for the Netherlands**.**

	Fallopia sachalinensis var. igniscum candy	*Rumex patientia x Rumex thianschanicus*	*Hibiscus cannabinus*	*Sida hermaphrodita*	*Salix schwerinii x Salix viminalis*	*Jatropha curcas*	*Asclepias syriaca*	*Symphytum x uplandicum*	*Silphium perfoliatum*	*Andropogon gerardii*	*Arundo donax*	*Miscanthus floridulus*	*Miscanthus x giganteus*
1.Dispersion potential or invasiveness	**3**	**1***	**1**	**2**	**2**	**1**	**3**	**3**	**2**	**2**	**3**	**2**	**2**
2. Colonisation of high conservation value habitats[1]	**3**	**1***	**1**	**2**	**2**	**1**	**3**	**3**	**2**	**2**	**3**	**1***	**2**
3.Direct or indirect adverse impacts on native species	**2**	**1***	**1**	**1***	**2**	**1**	**2**	**2**	**2**	**3**	**3**	**2**	**2**
3.1. Predation/herbivory	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.2. Interference or exploitation competition	2	1*	1	1*	2	1	2	2	2	3	3	2	2
3.3. Transmission of parasites and diseases	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*
3.4. Genetic effects (hybridization / introgression with natives)	NA	1*	NA	1*	2	NA	NA	2	1	1	NA	1	NA
4. Direct or indirect alteration of ecosystem functions	**2**	**1***	**1**	**1***	**2**	**1**	**2**	**2**	**2**	**2**	**3**	**2**	**2**
4.1. Modification of nutrient cycling or resource pools	2	1*	1	1*	1*	1	2	1*	1*	2	2	1*	2
4.2. Physical modifications of habitat	2	1*	1	1*	2	1	2	2	2	2	3	2	2
4.3. Modification to natural succession	2	1*	1	1*	2	1	1	2	1*	2	3	2	2
4.4. Disruption to food webs	2	1*	1	1*	2	1	1	1*	1*	2	3	2	1
ISEIA[2] risk score	**10**	**4**	**4**	**6**	**8**	**4**	**10**	**10**	**8**	**9**	**12**	**7**	**8**
Maximum possible ISEIA risk score[3]	**10**	**4**	**9**	**6**	**9**	**10**	**12**	**11**	**9**	**9**	**12**	**8**	**9**
BFIS[4] risk classification	**B0**	**Unclassified**	**C0**	**C0**	**C0**	**C0**	**B2**	**B3**	**C1**	**B0**	**A1**	**C0**	**C0**

[1] Quantitative analysis was focussed on Natura 2000 areas, however species may occur in other areas of high conservation value; [2] Risk score obtained following application of the ISEIA risk assessment protocol (Section 2.3); [3] refers to the total maximum score that may be achieved when categories that are assessed using best professional judgement and with deficient data (DD) are included (maximum score 2 and 1 respectively); [4] BFIS classification obtained by combining the recorded distribution (0: absent, 1: isolated populations, 2: restricted range, 3: widespread) with the ISEIA risk score (A: 11-12, B: 9-10, C: ≤8); * deficient data (DD) scores 1 as this is the minimum that can be awarded per risk category; NA: not applicable.

Ecological risk categorisation: 🟥 High risk; 🟧 Medium risk; 🟨 Low risk

Table 5.1b (cont.): Overview of risk classifications of biomass crop species for the Netherlands**.**

	Miscanthus sacchariflorus	***Miscanthus sinensis***	***Panicum virgatum***	***Phyllostachys bissetii***	***Phyllostachys nigra***	***Phyllostachys reticulata***	***Sorghum bicolor***	***Sorghum bicolor var. drummondii***	***Spartina cynosuroides***	***Spartina pectinata***
1.Dispersion potential or invasiveness	**2**	**1**	**3**	**2**	**2**	**2**	**1**	**1**	**1**	**2**
2. Colonisation of high conservation value habitats[1]	**2**	**1**	**2**	**1***	**1***	**1***	**1**	**1**	**1**	**3**
3.Direct or indirect adverse impacts on native species	**3**	**2**	**1**	**2**	**2**	**2**	**1**	**1**	**1**	**3**
3.1. Predation/herbivory	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.2. Interference or exploitation competition	3	2	1	2	2	2	1	1*	1	3
3.3. Transmission of parasites and diseases	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*
3.4. Genetic effects (hybridization / introgression with natives)	1	NA	1	1	1	1	1	1	1*	1*
4. Direct or indirect alteration of ecosystem functions	**2**	**2**	**2**	**2**	**2**	**2**	**1**	**1***	**1**	**3**
4.1. Modification of nutrient cycling or resource pools	1	2	2	1*	1*	1*	1	1*	1	2
4.2. Physical modifications of habitat	2	2	2	2	2	2	1	1*	1	3
4.3. Modification to natural succession	2	2	2	2	2	2	1	1*	1	2
4.4. Disruption to food webs	1*	1	2	1*	1*	1*	1	1*	1	1*
ISEIA[2] risk score	**9**	**6**	**8**	**7**	**7**	**7**	**4**	**4**	**4**	**11**
Maximum potential ISEIA risk score[3]	**11**	**10**	**10**	**7**	**8**	**8**	**11**	**7**	**8**	**12**
BFIS[4] risk classification	**B1**	**C3**	**C1**	**C0**	**C0**	**C0**	**C1**	**C0**	**C0**	**A1**

[1] Quantitative analysis was focussed on Natura 2000 areas, however species may occur in other areas of high conservation value; [2] Risk score obtained following application of the ISEIA risk assessment protocol (Section 2.3); [3] refers to the total maximum score that may be achieved when categories that are assessed using best professional judgement and with deficient data (DD) are included (maximum score 2 and 1 respectively); [4] BFIS classification obtained by combining the recorded distribution (0: absent, 1: isolated populations, 2: restricted range, 3: widespread) with the ISEIA risk score (A: 11-12, B: 9-10, C: ≤8); * deficient data (DD) scores 1 as this is the minimum that can be awarded per risk category; NA: not applicable.

Ecological risk categorisation: 🟥 High risk; 🟧 Medium risk; 🟨 Low risk

A. donax and S. pectinata received the highest risk scores for (potential) ecological risk in the Netherlands, 12 and 11 respectively. Five other species were classified as medium risk (*A. gerardii*, *A. syriaca*, *F. sachalinensis* var. *igniscum*, *M. sacchariflorus* and *S.* x *uplandicum*). 15 species were classified as low risk (*H. cannabinus*, *J. curcas*, *M. floridulus*, *M. sinensis*, *M.* x *giganteus*, *P. virgatum*, *P. bissetii*, *P. nigra*, *P. reticulata*, *S. schwerinii* x *S. viminalis*, *S. hermaphrodita*, *S. perfoliatum*, *S. bicolor*, *S. bicolor* var. *drummondii* and *S. cynosuroides*). One species remained unclassified due to complete data deficiency (*R. patientia* x *R. thianschanicus*). It should be noted that many scores relating to the risk criteria of these species were determined using best professional judgement or were subject to data deficiency that is reflected in the relatively low maximum possible risk scores for some species. Use of best professional judgement is inherently associated with high uncertainty in the total risk score of species and may have caused an underestimation of their risk classification (see section 7.4).

The highest scoring species for the categories ‘dispersion potential or invasiveness’ and ‘colonisation of high conservation value habitats’ were *A. donax*, *A. syriaca*, *F. sachalinensis* var. *igniscum*, *P. virgatum*, *S. pectinata* and *S.* x *uplandicum* (total scores of five or six out of a maximum of six for both categories combined).

The highest scoring species for the categories direct or indirect adverse impact on native species and direct or indirect alteration of ecosystem functions were *A. gerardii*, *A. donax, M. sacchariflorus* and *S. pectinata.*

6. Management options

Combating the introduction of invasive plant species involves a number of stages that should be applied in order. The first stage involves the prevention of spread of the species across international borders. In general, it is accepted that the cost of containment or eradication of an invasive species once it has become established far outweighs the costs associated with prevention of introduction (e.g., Wittenberg & Cock, 2005). However, once cultivation of biomass crops within the Netherlands begins, this management approach is effectively ruled out. The second stage involves the prevention of the release of plants to the natural environment from isolated locations such as agricultural fields, by accident or deliberately. The third stage involves the prevention of dispersal via mechanisms such as hydrochory or by human vectors such as machinery or vehicles used in nature management. If prevention measures fail then a number of options found during the literature study are available to eradicate or control biomass crop species (Table 6.1). A description of the available methods relevant to the management of biomass crops is given in the following paragraphs.

Table 6.1: Summary of potentially effective management options for biomass crop species.

Approach	Management type	Examples	References
Prevention	Regulation	Permits	Florida Department of Agriculture and Consumer Services (undated)
Eradication / control	Herbicides	Glyphosate (*Miscanthus* spp.)	Anderson et al. (2011)
	Mechanical	Weed whips, sling blades, clippers, shovels, hoes, mattocks, and weed wrenches, mowing and tillage	Barney & DiTomaso (2010b)
	Ecosystem based	Light occlusion	G. van der Velde (pers. comm.)

Prevention in the Netherlands and EU

A committee headed by Professor J. Cramer drafted sustainability criteria for biofuels in 2006. One of the criteria states: 'biomass production must not affect protected or vulnerable biodiversity and will, where possible, enhancing biodiversity' (Hamelinck et al., 2006). Under regulations of the European Union, agricultural and vegetable crops that are traded must only be propagated from recognised varieties. In the Netherlands varieties should be approved by the Board for Plant Varieties prior to cultivation. The basis for this lies in the Dutch seed and planting material law of 2006. Accepted varieties are listed in the register of varieties. For example, soybean is accepted (two varieties), jatropha and Jerusalem artichoke are also accepted, but there is no mention of Sudan grass or miscanthus (Nederlands Rassenregister).

If the acceptance of varieties on the register of varieties were to take potential invasiveness into account, then any risks could be contained at an early stage. However, enquiries to the secretary of the Council of Plant Varieties revealed that criteria for the acceptance of plant varieties in the register of varieties do not include their potential invasiveness. The Council is only responsible for the crops covered by the EC directives for admission of Vegetable and Field Crops. Biomass crops are, according to the Secretary of the Council, not covered by this directive, meaning that the Council has no influence on the occurrence of an aggressive invasion of new biomass species or varieties.

It should be noted that many species analysed in this report are also sold as ornamental plants in the Netherlands. Therefore, these species may also be introduced as a result of escape from parks and gardens or planting / sowing by the public. A search using google.nl revealed that *A. donax*, *A. syriaca*, *J. curcas*, *Miscanthus* spp., *P. virgatum, Phyllostachys* spp., *S. hermaphrodita*, *S. perfoliatum*, *S. pectinata* and *S.* x *uplandicum* are all available to the public as plant or seed from internet retailers in the Netherlands. Measures to regulate the sale of high risk species identified in this study, i.e. *A. donax* and *S. pectinata*, should be considered alongside measures to prevent escape from cultivation.

Prevention in other countries

The Florida Department of Agriculture and Consumer Services in the United States recommend that a number of administrative procedures are undertaken to control the use of biomass crops in the United States (Florida Department of Agriculture and Consumer Services, undated). Organisations intending to plant non-native species must submit the following information prior to the granting of a permit:

- A cover letter or letter of intent;
- A completed biomass permit Application form (Appendix 1);
- Evidence of site ownership/permission;
- A voucher specimen of the plant;
- A description of non-native plant to be grown and an estimated cost of removing and destroying, and the basis for calculating or determining the estimate.

After an initial review of the above information a site visit is undertaken prior to permit approval. Following permit approval the applicant must provide a surety bond certificate that is equal to 150 percent of the estimated cost of eliminating the crop. The surety bond is issued by an insurance company and ensures that sufficient budget can be made available to finance full removal of the crop once cultivation ceases.

To prevent escape from cultivation fields, monitoring should be introduced that facilitates the early identification of new biomass crop stands. Farmers should be encouraged to monitor areas surrounding cultivation fields to limit the risk of crop escape. Nature organisations may facilitate the early identification of non-native species establishing in their management area by a) identifying priority species through risk assessment, b) encouraging early recognition by training field staff, c) registering incoming notifications from third-parties, d) registering any new records in central registration databases (e.g., the 'Nationale Database Flora & Fauna'). Moreover, openly accessible databases may also be used and consulted (e.g., www.waarnemingen.nl, that feature species records made by the public and professionals).

Eradication or containment

If a biomass crop escapes cultivation an eradication or containment programme should be initiated, the choice of approach depending on the distribution of the escaped crop. Eradication measures generally work best when targeted at small, isolated populations where removal is economically feasible whereas containment measures should be applied to crops with larger distributions to prevent further spread and protect areas of high conservation value. Eradication measures should be complemented by early detection measures that identify escapes before the establishment of a viable seed bank or vegetative reproduction system (Zamora et al., 1989; Barney & DiTomaso, 2010b).

Eradication involves the complete elimination of the species, requiring multiple years and should include all regenerative plant parts i.e. rhizomes, seeds, tubers, reproductive stem fragments and root crowns. Viable eradication methods for escaped crop species are usually limited to mechanical removal or herbicide treatment. Biological control is not a desirable approach for invasive species that are also important crops due to their potentially widespread and spatially unlimited effect. Cultural control options such as prescribed burning, grazing and revegetation efforts are impractical or not effective for the eradication of small infestations (Barney & DiTomaso, 2010b).

Examples of mechanical techniques for the eradication of small infestations are manual methods e.g. weed whips, sling blades, clippers, shovels, hoes, mattocks, and weed wrenches, and mowing and tillage. While impractical and too expensive for eradicating large infestations, these mechanical methods can be successful for small populations. The method used will depend on the species in question, but in every case repeated treatments ensuring that reproductive structures are completely eliminated will be required. In the United States, chemical control is the most frequently used and cost effective technique for the eradication of invasive plant species (DiTomaso, 2000). In The USA, the most commonly used herbicides that may also be used for reclaiming abandoned production fields include (1) glyphosate, (2) the auxin-like growth regulators that selectively control broadleaf species such as dicamba and triclopyr, and (3) the imidazolinone and sulfonylurea herbicides e.g. imazapic and tribenuron-methyl, respectively. Similar to other eradication methods, chemical control requires repeat applications to completely remove reproductive structures (Barney & DiTomaso, 2010b). According to the Dutch board for the authorization of plant protection products and biocides (ctgb), glyphosate, triclopyr, dicamba and tribenuron-methyl are accepted for professional use in the Netherlands. Covering small stands with light occluding material may be an additional method of eradication. However, light occlusion will also negatively affect other plant species within the non-native plant stand.

Species specific management options

Management options for *Miscanthus* spp. include doing nothing, ceasing import and sale of the species, monitoring existing and new invasions while evaluating conditions for successful reproduction and establishment, and controlling or eradicating escaped populations. West et al. (2014), state that active monitoring of plantations, combined with maintained vegetation buffers, is pivotal to the achievable goal of containing *M.* x *giganteus*. 7.62 metre wide buffers (recommended by the USDA NRCS) combined with a rigorous monitoring program should prevent the spread of non-fertile cultivars (West et al., 2014). Any cost-benefit analysis should consider the potential difficulty of eradication. The current absence of a viable seed bank means that eradication has a good chance of success, particularly if started early in the invasion process, any manual or chemical control methods used remove or kill viable rhizomes, and accidental spread is prevented. Most herbicide trials to date have demonstrated some tolerance of *M. sinensis* and *M.* x *giganteus* crops to herbicides for weed control. *M.* x *giganteus* crop removal experiments indicate that high rates of glyphosate applied early in the growing season can achieve 50 % control (Anderson et al., 2011). Thus, complete eradication of escaped Miscanthus will likely require multiple treatments in successive years and might require subsequent habitat restoration (Hager et al., 2015).

7. Discussion

7.1 Introduction and spread

It should be noted that lag times between introduction and establishment of non-native species can be considerable, even for herbaceous species. For example, *S. pectinata* was first recorded in the Netherlands in 2008 and has only been recorded four times since. However, *S. pectinata* is known for its rapid spread potential and invasiveness, suggesting that the species may be recorded more frequently in the future following an initial lag period.

7.2 Potential risks

In the Netherlands there is relatively little attention to the potential risks of non-native crops grown for energy production. An internet search yielded little information. For example, the municipality of Aalten has played a role in assessing whether *M.* x *giganteus* should be grown for energy production. A second example can be found on a Dutch website specifically to promote *M.* x *giganteus* (http://www.cradlecrops.nl/miscanthus/) where the crop is stated as non-invasive, and, in contrast to various other perennial crops, does not pose a problem when it comes to removal of the crop. The Dutch research organisation Applied Plant Research (PPO) describes several potential energy crops, several of which are highlighted because of their invasive nature (Van der Mheen, 2011). This lack of attention possibly relates to the small acreage devoted to biomass crops and the expectation that the cultivation of biomass crops in the Netherlands will not hugely increase in the future.

In the English and German literature, more attention is devoted to the ecological risks of biomass crops. It appears that, most attention to potential risks has occurred in the USA. In Switzerland, a manual on biofuels and invasive species has been published that was intended for government, private parties and NGOs (IUCN, 2009). The Landwirtschaftskammer (agricultural office) of the German province, Nordrhein-Westfalen has warned to monitor *Igniscum* closely due to its potential invasiveness (Landwirtschaftskammer Nordrhein-Westfalen, 2015). Finally, in Flanders, the Institute for Forestry and Nature Research (INBO) (a scientific institution of the Flemish government) has written a report on the ecosystem service production of biomass crops in which the risk of invasiveness is mentioned (Van Kerckvoorde & Van Reeth, 2014).

Potential risks associated with the escape of genetically modified crop species from cultivation provides an extra challenge for risk assessors. Currently a number of micro-algal species are being assessed for potential use in biofuel production. For example, the species *Chlamydomonas reinhardtii*, that was initially considered for inclusion in the horizonscan and risk analysis but ruled out due to its native species status, has a track record of stable genetic modifications (Enzing et al., 2012), and may be used in the production of biohydrogen (Hallenbeck, 2011). According to Henley et al. (2013) any properties of genetically modified (GM) algae whose expression depends on conditions characteristic of mass culture systems and not found in natural systems (e.g., shallow, well-mixed, with high nutrient and CO_2 loading) would rapidly disappear if released to the environment. Moreover, Henley et al. (2013) state that the risk of potential harm that could be caused if GM algae thrives in nature is very low for GM traits associated with higher triacylglyceride (TAG) accumulation, important in biofuel production. However, Flynn et al. (2010) state that changes in biochemical composition associated with genetic modification may negatively affect the value of GM algae as prey for zooplankton. Surviving grazing pressure is the most important factor determining the success of alien plant species (Kimball & Schiffman, 2003; Vavra et al., 2007; Flynn et al., 2010). Therefore, avoidance of GM strains by zooplankton may increase the probability that escaped GM strains could become nuisance species. Currently, the potential for GM strains of biomass species for the production of biofuels is being researched and no potential GM biomass crops were identified for risk analysis during the course of this project. However, the potential use of GM crops for biofuel production emphasises the need for future ecological risk analyses of GM species chosen for use on an industrial scale.

7.3 Management options

Potential biomass crop species that are native to the Netherlands, e.g., reed canary grass (*Phalaris arundinacea*) should be prioritised for cultivation over potentially invasive non-native species. The potential of different *P. arundinacea* varieties has been evaluated in a number of northern European countries, demonstrating its feasibility for use as a solid energy fuel (Lewandowski et al., 2003).

The location where biomass crops are cultivated can have an impact on their dispersal potential. For example, crops that are capable of spreading long distances through the dispersal of propagules in flowing water (hydrochory) should not be planted near to streams and rivers e.g. *A. donax*. Moreover, crops should not be planted near habitats of high conservation value that are also suitable habitats for crop establishment e.g. *M. sacchariflorus* should not be cultivated near to the floodplains of rivers.

Consideration should also be made of the relative ease with which different biomass crops could be managed if they were to escape cultivation. It is possible that species with underground rhizomes that are not widespread are easy to remove manually. However, it is these types of species that spread easily in disturbed habitats e.g. *Fallopia* species in the Netherlands. Moreover, if these species were to become widespread at these locations (e.g., dike embankments and nature areas), and manual removal becomes too labour intensive, other management measures normally applied on agricultural land are not suitable. In general, rhizomatous species and species with a long-lived seed stock must be strictly managed if permitted for cultivation. Annual species without a seed stock may be cultivated under a less strict management regime, similar to the current management approach for rapeseed in the Netherlands.

7.4 Species traits and the potential invasiveness of non-native species

A draft list of 21 plant traits associated with potential invasiveness was derived from available scientific literature (Table 7.1). It should be noted that the relative influence of each individual trait on invasiveness will vary. Moreover, it is likely that certain combinations of traits in relation to spatially specific environmental factors will result in a non-native species becoming invasive e.g. dispersal in flowing water (hydrochory), growth form and environmental tolerance (Barney & DiTomaso, 2008; Hayes & Barry, 2008). The trait 'winter hard' on its own is unlikely to be significantly associated with invasiveness.

Table 7.1: Plant species traits related to invasiveness.

Category	Trait	Reference
Dispersal	Hydrochory[a]	Barney & DiTomaso (2008); Low & Booth (2007); Smith et al. (2013)
	Zoochory[b]	Barney & DiTomaso (2008); Low & Booth (2007); Smith et al. (2013)
	Anemochory[c]	Barney & DiTomaso (2008); Low & Booth (2007); Smith et al. (2013)
Morphological	Grows at high densities	Barney & DiTomaso (2008); DiTomaso et al. (2007)
	High yielding (aboveground biomass)	Barney & DiTomaso (2008); DiTomaso et al. (2010); Smith et al. (2013)
	Growth form[d]	Hayes & Barry (2008)
Physiological	Winter hard	
	C_4 photosynthesis[e]	Barney & DiTomaso (2008); DiTomaso et al. (2007); Raghu et al. (2006)
	Perennial	Barney & DiTomaso (2008); DiTomaso et al. (2007); DiTomaso et al. (2010); Raghu et al. (2006)
	Drought tolerant	Barney & DiTomaso (2008); DiTomaso et al. (2007); DiTomaso et al. (2010); Smith et al. (2013)
	High water-use efficiency	Barney & DiTomaso (2008); Raghu et al. (2006)
	Tolerates soil disturbance	Barney & DiTomaso (2008); Smith et al. (2013)
	Rapid growth /establishment rates	Parrish & Fike (2005); Barney & DiTomaso (2008); DiTomaso et al. (2007); Raghu et al. (2006); Smith et al. (2013)
	Long canopy duration	DiTomaso et al. (2007); Raghu et al. (2006)
	Tolerates low fertility soil	DiTomaso et al. (2007); DiTomaso et al. (2010); Raghu et al. (2006); Smith et al. (2013)
	Tolerates saline soil	DiTomaso et al. (2007); DiTomaso et al. (2010); Smith et al. (2013)
	Short juvenile period	Hayes & Barry (2008)
	Tolerates a wide range of climatic conditions	Smith et al. (2013)
Reproduction	Fertile seeds	
	Long seed longevity	
	High seed production	Parrish & Fike (2005); Barney & DiTomaso (2008)
	Vegetative reproduction	Parrish & Fike (2005); Barney & DiTomaso (2008); Hayes & Barry (2008); Raghu et al. (2006); Smith et al. (2013)
	Long flowering period	Hayes & Barry (2008)

[a] Dispersal of seeds, fruits, or other plant parts by water; [b] Dispersal of seeds, fruits, or other plant parts by animals; [c] Dispersal of seeds, fruits, or other plant parts by wind; [d] No definition given in original article; [e] Plants using C_4 photosynthesis have a competitive advantage over plants possessing the more common C_3 carbon fixation pathway under conditions of drought, high temperatures, and nitrogen or CO_2 limitation.

Based on available data, a preliminary trait analysis was undertaken for the 23 risk assessed biomass crop species (Appendix 2). The literature used to inform the risk analyses was re-reviewed to identify if the species possessed any of the traits identified in table 7.1. However, conclusions could not be drawn from this analysis due to (1) Differences between species relating to the availability of information on traits and the high level of information deficiency in general, (2) the binary nature of the data, i.e. quantitative data in relation to particular traits were not analyzed, (3) the analysis lacked context i.e. the way that a particular trait exerts influence over an individual is dependent on local conditions, particularly for sessile species.

7.5 Uncertainty

Best professional judgement

A lack of information in the literature on the (potential) impacts of a number of biomass crop species in the Netherlands has resulted in a reliance on expert knowledge and field observations to judge the level of certain impacts (best professional judgement). In qualitative assessments of risk, lack of data is a frequently occurring problem. For example, of the more than 10,000 European alien species registered in the DAISIE database, ecological impacts are only documented for 1094 species (11%) and economic impacts for only 1347 species (13%) (Vilà et al., 2010; Hulme, 2012). This may well be due to a lack of observations rather than a lack of impact in species with No information. Moreover, the step between introduction and establishment is a critically important filter in biological invasions and one for which we have little information (Puth & Post, 2005; Hulme, 2012). Incomplete data input often results in a heavy reliance on expert judgement (Maguire, 2004; Strubbe et al., 2011; Verbrugge et al., 2012). Expert knowledge may not always be objective, accurate, consistent or reproducible (Hulme, 2012). Experts may interpret the same information differently depending on how the information is presented. The use of value laden words such as ‘invasive’ or ‘aggressive’ may influence the objective judgement of some assessors (Hulme, 2012). Species factsheets often include the most dramatic impacts and experts may focus on such information allowing an initially formed opinion to influence further judgement, even in the presence of contradictory information (Hastie & Dawes, 2010; Hulme, 2012). Moreover, experts may look for evidence that confirms their initial preconceptions about a species (confirmation bias) (Hulme, 2012).

Underestimation of risk scores due to protocol

According to the ISEIA-protocol, the risks of species lacking information were classified as likely or unlikely, resulting in risk scores 1 and 2, respectively, for one or more risk sections. The BFIS list-A or list-B classification of species is theoretically impossible if best professional judgement is applied for two or four risk sections, respectively (maximum total risk score is then 10 or 8 out of 12, with risk levels of 11-12 and 9-10 for black list and watch list, respectively). Therefore, best professional judgement may have caused an underestimation of risk scores and risk classifications of species. Limited data availability has inherently led to a high level of uncertainty in the risk scores for the assessment criteria ‘dispersion potential or invasiveness’ of *A. gerardii*, *P. bissetii*, *P. reticulata*, *R. patientia* x *R. thianschanicus*, *S. schwerinii* x *S. viminalis*, *S. hermaphrodita*, *S. bicolor* var. *drummondii*, *S. cynosuroides* and for ecological effect criteria of *H. cannabinus*, *J. curcas*, *M. floridulus*, *M. sinensis*, *M.* x *giganteus*, *P. bissetii*, *P. nigra, R. patientia* x *R. thianschanicus*, *S. hermaphrodita*, *S. perfoliatum*, *S. bicolor* var. *drummondii* and *S. cynosuroides*. Data on the potential transmission of diseases and parasites are lacking or scarce for all species. Therefore, periodical reviews of new literature data of these species and updates of their risk scores are recommended.

Species can only be compared for characteristics such as habitat requirements and intensity of impact if sufficient information is available. Risk criteria in the ISEIA protocol were sometimes restrictive, as there was an absence of quantitative data that allowed the criteria to be assessed (e.g., for assessing the 1 km per year dispersal criterion for the ‘dispersion or invasiveness’ section). The broadness of the categories used in the ISEIA protocol to define the current recorded distribution of non-native species may in some instances be misleading. For example, the term widespread may be applied to distributions with very different characteristics. A species may be widespread with a high density of records covering the entire country or widespread with a low density of records that are spread across the entire country. Secondary vectors are not addressed in the ISEIA protocol and therefore are not incorporated in the assessment of ecological risk undertaken. However, secondary vectors are important factors that determine the distribution and spread of the species assessed. For example, the transport and accidental spillage of seeds has been implicated in the potential introduction of *P. virgatum* in the USA (Barney et al., 2008). Moreover, the relative economic importance of biomass crops will influence the risk of future introductions. For example *M.* x *giganteus* is already cultivated in the Netherlands and the Dutch government is actively encouraging industries that could make potential use of this biomass crop.

Identification of species and variations within species

Difficulties in correctly identifying *Miscanthus* and *Phyllostachys* species due to species similarity, and the correct identification of *Salix* species and *S.* x *uplandicum* due to the high number of related hybrids, increases the uncertainty of recorded distributions within these genera in the Netherlands. Additionally, there was a lack of information in the literature concerning variations in the potential invasiveness of different genotypes of the crop species assessed. Therefore, assessments were based on information for particular species and differences between genotypes of the same species were not considered. A second assumption made was that all species/genotypes were considered fertile, unless explicitly stated otherwise. In fact, for most species (natural) sterile hybrids are available. For example, *Miscanthus sinensis* has been assessed as a fertile species, but the variety Goliath is in fact a sterile triploid hybrid of *Miscanthus sinensis*. Population origin may also influence potential invasiveness. For example, the functional traits shoot ratio, leaf area ratio and net CO_2 assimilation were significantly different in invasive populations of the Chinese tallowtree (*Sapium sebiferum*) in the USA and native Chinese populations, possibly resulting in different growth strategies for native versus invasive populations (Zou et al., 2007).

8. Conclusions and recommendations

New and potential non-native biomass crops

- A preliminary list of 52 new and potential non-native biomass crops for the Netherlands were identified.
- 32 species were removed after screening with four exclusion criteria leaving an initial shortlist of 20 species. Of the 32 species removed, three were excluded because they are not primarily used as biomass crops for the production of biodiesel, oil, ethanol and methane; or for direct combustion / energy production (criteria 2); 26 were excluded because they are native to or non-native and established in the Netherlands (criteria 3); and three were excluded because they have not been recently introduced or probably will not be introduced as a biomass crop to the Netherlands (criteria 4).
- Three species, miscanthus (*Miscanthus* x *giganteus*), jatropha (*Jatropha curcas*) and kenaf (*Hibiscus cannabinus*) were re-added to the list due to interest within the Netherlands Food and Consumer Product Authority (NVWA, Nederlandse Voedsel- en Warenautoriteit) pertaining to these species. The definitive list of potential biomass crops for the Netherlands contains 23 species.

Risk analyses of non-native biomass crops

- *A. donax and S. pectinata* received the highest risk scores, 12 and 11 respectively for (potential) ecological risk in the Netherlands. Five other species were classified as medium risk (*A. gerardii*, *A. syriaca*, *F. sachalinensis* var. *igniscum*, *M. sacchariflorus* and *S.* x *uplandicum*). 15 species were classified as low risk (*H. cannabinus*, *J. curcas*, *M. floridulus*, *M. sinensis*, *M.* x *giganteus*,*P. virgatum*, *P. bissetii*, *P. nigra*, *P. reticulata*, *S. schwerinii* x *S. viminalis*, *S. hermaphrodita*, *S. perfoliatum*, *S. bicolor*, *S. bicolor* var. *drummondii* and *S. cynosuroides*). One species remained unclassified due to complete data deficiency (*R. patientia* x *R. thianschanicus*).
- The highest scoring species for the categories ‘dispersion potential or invasiveness’ and ‘colonisation of high conservation value habitats’ were *A. donax*, *A. syriaca*, *F. sachalinensis* var. *igniscum*, *P. virgatum*, *S. pectinata* and *S.* x *uplandicum* (total scores of five or six out of a maximum of six for both categories combined).
- The highest scoring species for the categories direct or indirect adverse impact on native species and direct or indirect alteration of ecosystem functions were *A. gerardii*, *A. donax, M. sacchariflorus* and *S. pectinata.*
- Species included in the risk analyses and already present in Dutch nature are *A. donax*, *A. syriaca*, *Miscanthus* spp., *P. virgatum*, *S. bicolor*, *S. pectinata*, *S. perfoliatum* and *S.* x *uplandicum*.
- Many criteria were either assessed using best professional judgement or not assessed due to data limitations i.e., *A. gerardii*, *F. sachalinensis* var. *igniscum*, *H. cannabinus*, *J. curcas*, *M. floridulus*, *M. sacchariflorus*, *M. sinensis*, *M.* x

giganteus, *P. virgatum*, *P. bissetii*, *P. nigra*, *P. reticulata*, *R. patientia* x *R. thianschanicus*, *S. schwerinii* x *S. viminalis*, *S. hermaphrodita*, *S. perfoliatum*, *S. bicolor* var. sweet, *S. bicolor* var. *drummondii*, *S. cynosuroides* and *S.* x *uplandicum*. This approach is inherently associated with high uncertainty in the total risk score of species and may have caused an underestimation of their risk classification.

- There was a lack of information in the literature concerning variations in the potential invasiveness of different genotypes of the crops assessed, i.e. *A. gerardii*, *A. donax*, *Miscanthus* spp., *P. virgatum*, *Phyllostachys* spp., *S. bicolor*, *S. pectinata* and *S.* x *uplandicum*. Characteristics that may influence invasiveness frequently vary between genotypes.

Management options

- Currently, in the Netherlands, relatively little attention has been focussed on the potential ecological risks of non-native biomass crops to biodiversity and ecosystems. This lack of attention possibly relates to the small acreage devoted to biomass crops grown for energy production, and the expectation that the cultivation of biomass crops in the Netherlands will not hugely increase in the future.
- In general, it is accepted that the cost of control and eradication of an invasive species once it has become established far outweighs the costs associated with prevention of introduction.
- Currently, in the Netherlands, non-native biomass crop species fall outside the scope of regulations that promote the mandatory screening of plant species prior to their cultivation. Moreover, potential invasiveness, and impacts on biodiversity and ecosystems are not considered as part of the screening process that assesses the suitability of varieties for cultivation in the Netherlands.
- In Florida, USA, organisations intending to plant non-native species must submit the following information prior to the granting of a permit: a cover letter or letter of intent, a completed biomass permit application form (Appendix 1), evidence of site ownership/permission, a voucher specimen of the plant, a description of the non-native plant to be grown including an estimated cost of removal and destruction, together with the basis for calculating or determining the estimate.
- Monitoring should be introduced that facilitates the early identification of new biomass crop stands. Farmers should be encouraged to monitor areas surrounding cultivation fields to limit the risk of crop escape. Nature organisations may facilitate the early identification of non-native species establishing in their management area by a) identifying priority species through risk assessment, b) encouraging early recognition by training field staff, c) registering incoming notifications from third-parties, d) registering any new records in central registration databases.
- Other options for the management and control of small populations of invasive non-native biomass species include: herbicides (e.g. glyphosate for the

management of *Miscanthus* spp., the auxin-like growth regulators and the imidazolinone and sulfonylurea herbicides all of which may also be used for reclaiming abandoned production fields), and mechanical methods such as weed whips, sling blades, clippers, shovels, hoes, mattocks, and weed wrenches, and mowing and tillage.

- Biological techniques are inappropriate for the management of escaped populations of plants that are economically important crop species. Cultural techniques such as prescribed burning, grazing and revegetation efforts are impractical or not effective for the eradication of small infestations of invasive plant species.
- It is possible that species with underground rhizomes that are not widespread are easy to remove manually. However, it is these types of species that spread easily in disturbed habitats e.g., *Fallopia* species in the Netherlands. Moreover, if these species were to become widespread at these locations (e.g. dike embankments and nature areas), and manual removal becomes too labour intensive, other management measures, normally applied on agricultural land are not suitable. Rhizomatous species and species with a long-lived seed stock must be strictly managed if permitted for cultivation. Annual species without a seed stock may be cultivated under a less strict management regime, similar to the current management approach for rapeseed in the Netherlands.
- A search using google.nl revealed that *A. donax*, *A. syriaca*, *J. curcas*, *Miscanthus* spp., *P. virgatum, Phyllostachys* spp., *S. hermaphrodita*, *S. perfoliatum*, *S. pectinata* and *S.* x *uplandicum* are all available to the public as plant or seed from internet retailers in the Netherlands.

Recommendations

- It is recommended that potential biomass crop species that are native to the Netherlands, e.g., reed canary grass (*Phalaris arundinacea*) should be prioritised for cultivation over potentially invasive non-native species.
- It is recommended that the suitability of non-native biomass crop varieties for introduction should be assessed and approved by a responsible body in the Netherlands (e.g., the Board for Plant Varieties).
- Due to difficulties in identification, the current recorded distributions of *Miscanthus* spp. in the Netherlands are treated with a high degree of scepticism. Therefore, risk assessors have been unable to apply the distribution of *Miscanthus* spp. during the risk analyses. It is recommended, that Dutch identification keys for *Miscanthus* spp. are developed and that descriptions and photo material differentiating between *Miscanthus* spp. should be added to QBank, the online resource containing databases on quarantine plant pests and diseases.
- It is recommended that more research is undertaken that will facilitate the better identification of bamboo species and varieties cultivated and sold as ornamental plants in the Netherlands, as this will reduce the uncertainty surrounding the recorded distributions of species within this plant group.

- In cases where there is either data deficiency or best professional judgement is applied during risk analyses of species, periodical reviews of new literature and updates of risk scores are recommended.
- Measures designed to regulate the sale of high risk species identified in this study to the public, i.e. *A. donax* and *S. pectinata*, should be considered alongside measures to prevent escape from cultivation.
- It is recommended that populations of *A. syriaca* present in the dunes at southern Kennemerland in the Netherlands should be removed to prevent further spread of this species within this Natura 2000 designated habitat.
- Differences in invasiveness potential between genotypes of the same species can be very large and thus should be investigated before final conclusions can be made on their invasiveness potential.
- Potential risks associated with the escape of genetically modified crop species from cultivation provide an extra challenge for risk assessors. The potential use of genetically modified (GM) crops for biofuel production emphasises the need for future ecological risk analyses of GM species chosen for use on an industrial scale.

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Glossary

Term	Description
Achenes	A small, dry one-seeded fruit that does not open to release the seed
Acuminate	Tip of the leaf gradually tapering to a sharp point
Adventitious	Plant part developing in an abnormal position, as a root that grows from a stem
Allelochemicals	Chemicals produced by a living organism that exerts a detrimental physiological effect on individuals of another species when released into the environment
Allelopathic	Secreting chemicals which suppress competitors
Allopolyploid	Hybrids that have a chromosome number double that off their parents. Some of these are created via selective breeding to produce new varieties of plants from previously sterile species
Anemochory	Seed dispersal by wind
Annual	Completing its life-cycle within twelve months from germination
Anther	Part of the stamen containing the pollen grains
Apical	Relating to the apex or tip of a pyramidal or pointed structure
Autochory	Active seed dispersal by the plant itself
Axillary	Arising in the axil of a leaf or bract
Axil	(of a leaf) angle between its upperside and the stem on which it is borne; normal position of lateral buds for lateral buds
Backcross	Cross (a hybrid) with one of its parents or an organism with the same genetic characteristics as one of the parents
Bifid	(of a part of a plant or animal) divided by a deep cleft or notch into two parts
Bio-based economy	All economic activity derived from scientific and research activity focused on biotechnology
Biomass crop	Crops grown specifically for use as fuel and offer high output per hectare with low inputs
Biofuel	A fuel derived immediately from living matter
Blade	The expanded part of a leaf or petal. Especially a leaf of grass or the broad portion of a leaf as distinct from the petiole
Bract	Small leaf with relatively undeveloped blade, in axil of which arises a flower
Cardenolides	Any of numerous organic compounds with a characteristic ring structure many of which are found in plants (as some milkweeds), have an effect on the vertebrate heart like that of digitalis, and cause vomiting
C3 photosynthesis	The major of the three metabolic pathways for carbon fixation by plants. This process uses the enzyme RuBisCO in relatively inefficient conditions, to fix CO_2 from the air and obtain the 3-carbon organic intermediate molecule 3-phosphoglycerate
C4 photosynthesis	C4 carbon fixation is one of three biochemical mechanisms, along with C3 and CAM photosynthesis, used in carbon fixation. It is named for the 4-carbon molecule present in the first product of carbon fixation in the small subset of plants known as C4 plants, in contrast to the 3-carbon molecule products in C3 plants
Calyx	The sepals of a flower, typically forming a whorl that encloses the petals and forms a protective layer around a flower in bud
Campanulate	(of a flower) bell-shaped, like a campanula
Caryopsis	A dry one-seeded fruit in which the ovary wall is united with the seed coat, typical of grasses and cereals.
Ciliolate	Covered with minute hairs
Clone	An organism or cell, or group of organisms or cells, produced asexually from one ancestor or stock, to which they are genetically identical
Coppice	An area of woodland in which the trees or shrubs are periodically cut back to ground level to stimulate growth and provide firewood or timber
Coppice stool	A coppiced woodland will have trees with multiple stems growing out of the stool, which arise from dormant buds on the stool
Cordate	Heart-shaped
Corolla	The petals as a whole
Cultivar	A plant variety that has been produced in cultivation by selective breeding. Cultivars are usually designated in the style *Taxus baccata* ‘Variegata’
Culm	The hollow stem of a grass or cereal plant, especially that bearing the flower
Cyme	A flower cluster with a central stem bearing a single terminal flower that develops first, the other flowers in the cluster developing as terminal buds of lateral stems
Cymose	Of, relating to, being, or bearing a cyme

Deciduous	(of a tree or shrub) shedding its leaves annually
Diploid	(of a cell or nucleus) containing two complete sets of chromosomes, one from each parent
Disilicate	A silicate compound that has two silicon atoms in the molecule
Ecotype	A distinct form or race of a plant or animal species occupying a particular habitat
Endosperm	The part of a seed which acts as a food store for the developing plant embryo, usually containing starch with protein and other nutrients.
Established species	Species with one or more breeding populations
Exocarp	The outer layer of the pericarp of a fruit
Fecund	Producing or capable of producing an abundance of offspring or new growth; highly fertile
Filliform	Thread-like
Floret	One of the small flowers making up a composite flower head
Gamete	A mature haploid male or female germ cell which is able to unite with another of the opposite sex in sexual reproduction to form a zygote.
Genotype	The genetic constitution of an individual organism
Glabrous	Without hairs
Glandular	Furnished with glands
Glumes	Each of two membranous bracts surrounding the spikelet of a grass (forming the husk of a cereal grain) or one surrounding the florets of a sedge
Heptaploid	Having seven times the monoploid number of chromosomes
Herbaceous	Denoting or relating to herbs
Hermaphrodite	A person or animal having both male and female sex organs or other sexual characteristics, either abnormally or (in the case of some organisms) as the natural condition.
Humic	Relating to or consisting of humus
Hybridization	A cross between parents, that are genetically unlike
Hydrochory	Dispersal by water
Hydromorphic	(of a soil) developed in the presence of an excess of moisture which tends to suppress aerobic factors in soil-building
Hydrophyte	A plant which grows only in or on water
Indurate	Hardened
Inflorescence	The complete flower head of a plant including stems, stalks, bracts, and flowers
Intergrade	Pass into another form by a series of intervening forms
Internode	A part of a plant stem between two of the nodes from which leaves emerge
Introgression	Infiltration of genes of one species into genotype of another
Invasive species	Non-native species which spread quickly and are dominating in newly colonized areas
Involute	Curled spirally
Keel	A longitudinal ridge
Lanceolate	Shaped like a lance head; of a narrow oval shape tapering to a point at each end
Lemma	A part of the spikelet of grasses (Poaceae). It is the lowermost of two chaff-like bracts enclosing the grass floret.
Ligulate	Strap-shaped, as in the ray florets of plants of the daisy family
Ligule	A narrow strap-shaped part of a plant, especially a membranous scale on the inner side of the leaf sheath at its junction with the blade in most grasses and sedges
Lobes	A roundish and flattish projecting or hanging part of something, typically one of two or more such parts divided by a fissure
Locular	Having, formed of, or divided into small cavities or compartments
Lanceolate	Shaped like the head of a lance, tapering from a rounded base towards the apex
Leaf area index	Leaf area index (LAI) is a dimensionless quantity that characterizes plant canopies. It is defined as the one-sided green leaf area per unit ground surface area (LAI = leaf area / ground area, m^2 / m^2) in broadleaf canopies
Mesic	(of an environment or habitat) containing a moderate amount of moisture
Mesothermal	Refers to certain forms of climate found typically in the Earth's Temperate Zones. It has a moderate amount of heat, with winters not cold enough to sustain snow cover
Monoculture	The cultivation of a single crop in a given area
Monoecious	(of a plant or invertebrate animal) having both the male and female reproductive organs in the same individual; hermaphrodite
Mycorrhiza	The symbiotic association of the mycelium of a fungus with the roots of plants
Naturalized	Plants established as a part of the flora of a locale other than their place of origin
Node	A point on a stem where a leaf is attached or has been attached
Non-native	Species not native, originating from elsewhere

Opalescent	Showing many small points of shifting colour against a pale or dark ground
Orbicular	Rounded, with length and breadth about the same
Orbiculate	Circular or nearly circular in outline
Ovate	Egg-shaped
Palea	The upper bract of the floret of a grass
Pallid	Lacking vigour or intensity; insipid
Palmate	(of a leaf) having five or more lobes whose midribs all radiate from one point
Panicles	A loose branching cluster of flowers, as in oats
Pedicel	Stalk of a single flower
Pendulous	Hanging downwards
Perennial	Living for more than two years and usually flowering each year
Pericarp	The part of a fruit formed from the wall of the ripened ovary
Petiole	Stalk of a leaf
Phenotype	The set of observable characteristics of an individual resulting from the interaction of its genotype with the environment.
Pilose	Covered with long soft hairs
Pioneer species	Hardy species which are the first to colonize previously disrupted or damaged ecosystems
Ploidy	The number of sets of chromosomes in a cell, or in the cells of an organism
Polycarpic	Fruiting many times or year after year
Propagation	The reproduction or spreading of something
Propagule	A vegetative structure that can become detached from a plant and give rise to a new plant, e.g. a bud, sucker, or spore
Quadrangular	Having four sides
Raceme	Unbranched racemose inflorescence in which the flowers are borne on pedicels
Ramet	An independent member of a clone
Reticulate	Being or involving evolutionary change dependent on genetic recombination involving diverse interbreeding populations
Rachis	A stem of a plant, especially a grass, bearing flower stalks at short intervals
Rhachilla	A branch of inflorescence; the zigzag axis on which the florets are arranged in the spikelets of grasses
Rhizomes	A continuously growing horizontal underground stem which puts out lateral shoots and adventitious roots at intervals
Rhomboid	Having or resembling the shape of a rhombus
Rachilla	A small or secondary rachis; specifically : the axis of a spikelet of a grass or sedge
Riparian	Relating to wetlands adjacent to rivers and streams
Rotation	The growing of different crops in succession on a piece of land to avoid exhausting the soil and to control weeds, pests, and diseases
Ruderal	Plant living in waste places near habitations
Sagittate	Shaped like an arrowhead
Senescence	The condition or process of deterioration with age
Schizocarp	A dry fruit that splits into single-seeded parts when ripe
Seed bank	The natural storage of seeds, often dormant, within the soil of most ecosystems
Sepals	A number of outer series of perianth leaves, especially when green and leaf-like
Sessile	Without a stalk
Serrate	Toothed like a saw
Silicaceous	Of, relating to, or containing silica or a silicate
Sodic	Sodic soil or soil sodicity may refer to: (Sodic) saline soil, a soil with excess salts where sodium chloride (NaCl) predominates
Species evenness	Refers to how close in numbers each species in an environment are
Spikelets	The basic unit of a grass flower, consisting of two glumes or outer bracts at the base and one or more florets above
Stamens	The male fertilizing organ of a flower, typically consisting of a pollen-containing anther and a filament
Staminate	(of a plant or flower) having stamens but no pistils
Steppe	A large area of flat unforested grassland in SE Europe or Siberia
Stipules	A small leaf-like appendage to a leaf, typically borne in pairs at the base of the leaf stalk
Stoloniferous	Producing or bearing stolons
Stolons	A horizontal branch from the base of a plant that produces new plants from buds at its tip or nodes
Sustainability	Meeting the needs of today's population without compromising the needs of future generations
Symbiotic	Relationships or interactions between people or organisms which are mutually beneficial to both

Temperate	Relating to or denoting a region or climate characterized by mild temperatures
Testa	The protective outer covering of a seed; the seed coat
Triploid	(of a cell or nucleus) containing three homologous sets of chromosomes
Tuberous	Bearing tubers
Understory	A tangle of shrubs, young trees, palms and woody plants that grow in the shade of the taller trees
Variegated	(of a plant or foliage) having or consisting of leaves that are edged or patterned in a second colour, especially white as well as green
Variety	A taxonomic rank below subspecies
Vector	An organism that does not cause disease itself but which spreads infection by conveying pathogens from one host to another
Venation	The arrangement of veins in a leaf
Vegetative	A type of asexual reproduction employed by plants wherein new independent individuals emerge from the vegetative parts of plants, such as specialized stems, leaves, roots, and not from seeds or spores
Zoochory	Seed dispersal by animals

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Appendix 1

ADAM H. PUTNAM
COMMISSIONER

Florida Department of Agriculture and Consumer Services
Division of Plant Industry

BIOMASS/BIOFUEL PLANTING PERMIT APPLICATION

Section 581.083, F.S./Rule 5B-57.011, F.A.C.

1911 SW 34 Street/P.O. Box 147100, Gainesville, FL 32614
Phone: (352) 395-4700 / Fax: (352) 395-4624

Name of Applicant/Company

Mailing Address **City, State, Zip Code**

If the applicant is a Corporation, Partnership, or other business entity, the applicant must also provide the name and address of each officer, partner, or management agent. The applicant shall notify the department within 10 business days of any change or address or change in the principle place of business. (Use additional pages if necessary)

Owner of Site **Address of Owner**

Street Address of Intended Planting Site

Size of Planting (In Acres) **Parcel Numbers/s of Site**

Common Name of Plant **Scientific Name**

Botanical Description:

Methods of Containment (How will inadvertent spread from the site be controlled?):

(Use additional pages if needed)

Provide a detailed statement of estimated cost of removing and destroying the plant species that is the subject of this special permit.

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_________________________	______________________
Applicant Signature	**Date**

All Applications Must Be Submitted With The Following:

- **$50.00 Application Fee**
- **Proof of Proposed Site Ownership**
- **Voucher Specimen of the Plant**

☐ **Approved (See Below)**

☐ **Disapproved For The Following Reasons:**____________________________________

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___________________________	______________________
Division Director	**Date**

If approved, the Biomass/Biofuel Permit (FDACS-08382) including the permit conditions will be sent to the applicant upon signature of Compliance Agreement (FDACS-08383) and proof of bond or certificate of deposit (FDACS-08439 or FDACS-08440).

Appendix 2

Category	Species trait	*Spartina pectinata*	*Miscanthus sacchariflorus*	*Andropogon gerardii*	*Arundo donax*	*Miscanthus sinensis*	*Fallopia sachalinensis* var. *Igniscumcandy*	*Asclepias syriaca*	*Symphytum x uplandicum*	*Hibiscus cannabinus*	*Jatropha curcas*	*Miscanthus x giganteus*	*Panicum virgatum*	*Phyllostachys bissetii*	*Phyllostachys nigra*	*Phyllostachys reticulata*	*Rumex patientia L. x Rumex tianschanicus*	*Salix schwerinii x Salix viminalis*	*Sida hermaphrodita*	*Sorghum bicolor var. sweet*	*Sorghum bicolor spp drummondii*	*Spartina cynosuroides*	*Miscanthus floridulus*
		A1	A1/B1	B0	B0	B3	B0/C0	B1/C1	B0/C0	C0	C0	C0	C1	C0	C0	C0	NA	C0	C0	C1	C0	C0	C0
Dispersal	Hydrochory	DD	1^{d}	0^{d}	$1^{a,b}$	1^{d}	DD	DD	1^{d}	DD	1^{d}	1^{d}	DD	DD	DD	DD	DD	DD	DD	DD	1^{d}	DD	DD
	Zoochory	DD	DD	0^{d}	DD	DD	DD	DD	DD	DD	1^{d}	DD	DD	DD	DD	DD	DD	DD	DD	DD	1^{d}	DD	DD
	Anemochory	DD	DD	0^{d}	DD	1^{d}	DD	1^{d}	DD	DD	DD	1^{d}	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	1^{d}
Morphological	Grows at high densities	1^{d}	1^{d}	1^{d}	1^{a}	1^{a}	DD	1^{d}	DD	1^{d}	DD	1^{d}	1^{d}	DD	1^{d}	1^{d}	DD	DD	DD	DD	DD	1^{d}	1^{d}
	High yielding (above-ground biomass)	DD	1^{d}	1^{d}	$1^{a,b}$	1^{a}	1^{d}	DD	DD	1^{d}	DD	1^{d}	1^{d}	1^{d}	1^{d}	1^{d}	DD	1^{d}	DD	DD	DD	1^{d}	1^{d}
Physiological	Rapid growth / establishment rate	1^{d}	DD	DD	$1^{a,b,c}$	$1^{a,c,d}$	DD	DD	DD	DD	DD	1^{d}	1^{d}	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD
	C4 photosynthesis	1^{d}	DD	1^{d}	0^{a}	1^{a}	DD	DD	DD	0^{d}	DD	1^{d}	1^{d}	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD
	Perennial	1^{d}	1^{d}	1^{d}	1^{a}	1^{a}	DD	1^{d}	DD	DD	1^{d}	DD	1^{d}	1^{d}	1^{d}	DD	DD	1^{d}	1^{d}	1^{d}	DD	DD	DD
	Drought tolerant	0^{d}	DD	1^{d}	1^{a}	1^{a}	DD	DD	DD	DD	1^{d}	DD	1^{d}	DD	DD	DD	DD	DD	DD	1^{d}	DD	DD	DD
	High water use efficiency	DD	DD	DD	0^{a}	1^{d}	DD	DD	DD	DD	DD	1^{d}	1^{d}	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD
	Tolerates soil disturbance	DD	DD	1^{d}	$1^{a,b,c}$	$1^{a,d}$	DD	1^{d}	1^{d}	DD	1^{d}	DD	1^{d}	DD	DD	DD	DD	1^{d}	1^{d}	1^{d}	DD	DD	DD
	Long canopy duration	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD
	Tolerates low fertility soil	DD	DD	1^{d}	1^{c}	1^{d}	1^{d}	1^{d}	DD	0^{d}	1^{d}	1^{d}	1^{d}	DD	1^{d}	DD	DD	DD	DD	1^{d}	0^{d}	DD	1^{d}
	Tolerates saline soil	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	1^{d}	1^{d}	DD	1^{d}
	Short juvenile period	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD
	Tolerates a wide range of climatic conditions	1^{d}	1^{d}	DD	1^{d}	1^{c}	DD	1^{d}	DD	1^{d}	1^{d}	1^{d}	1^{d}	DD	DD	DD	DD	DD	DD	DD	DD	DD	1^{d}
	Winterhard in the Netherlands	1^{d}	1^{d}	1^{d}	1^{d}	1^{d}	DD	1^{d}	1^{d}	0^{d}	1^{d}	1^{d}	1^{d}	1^{d}	1^{d}	1^{d}	DD	1^{d}	DD	0^{d}	0^{d}	0^{d}	1^{d}
Reproduction	Vegetative propagation	DD	1^{d}	1^{d}	$1^{a,c}$	$1^{a,c}$	1^{d}	1^{d}	1^{d}	DD	DD	1^{d}	1^{d}	1^{d}	1^{d}	DD	DD	DD	1^{d}	1^{d}	DD	1^{d}	1^{d}
	Fertile seeds	1^{d}	1^{d}	1^{d}	0^{d}	1^{d}	0^{d}	1^{d}	1^{d}	DD	1^{d}	0^{d}	1^{d}	1^{d}	1^{d}	DD	DD	DD	1^{d}	1^{d}/ 0^{d*}	1^{d}	1^{d}	1^{d}
	High seed longevity	DD	DD	DD	DD	DD	DD	0^{d}	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	0^{d}
	High seed production	DD	0^{d}	0^{d}	0^{b}	1^{d}	DD	1^{d}	DD	DD	DD	1^{d}	1^{d}	DD	DD	DD	DD	DD	1^{d}	DD	DD	DD	1^{d}
	Long flowering period	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD	DD

1: trait reported as characteristic of the species; 2: trait reported as not characteristic of species; DD: data deficiency; [a]Barney & Ditomaso (2008); [b]Low & Booth (2007); [c]Smith et al. (2013); [d]Matthews et al. (2015); *Depends on the fertility of the variety assessed