8-2022

Environmental weed risk assessment protocol for growing non-indigenous plants in the Western Australian rangelands

Geoff A. Moore Mr
DPIRD, Department of Primary Industries and Regional Development

Christine Munday Ms
Formerly DBCA, Department of Biodiversity, Conservation and Attractions

Papori Barua Dr
DPIRD, Department of Primary Industries and Regional Development

Recommended Citation

Moore G, Munday C, Barua P (2022) 'Environmental weed risk assessment protocol for growing non-indigenous plants in the Western Australian rangelands', Department of Primary Industries and Regional Development, Bulletin no. 4924, Perth.

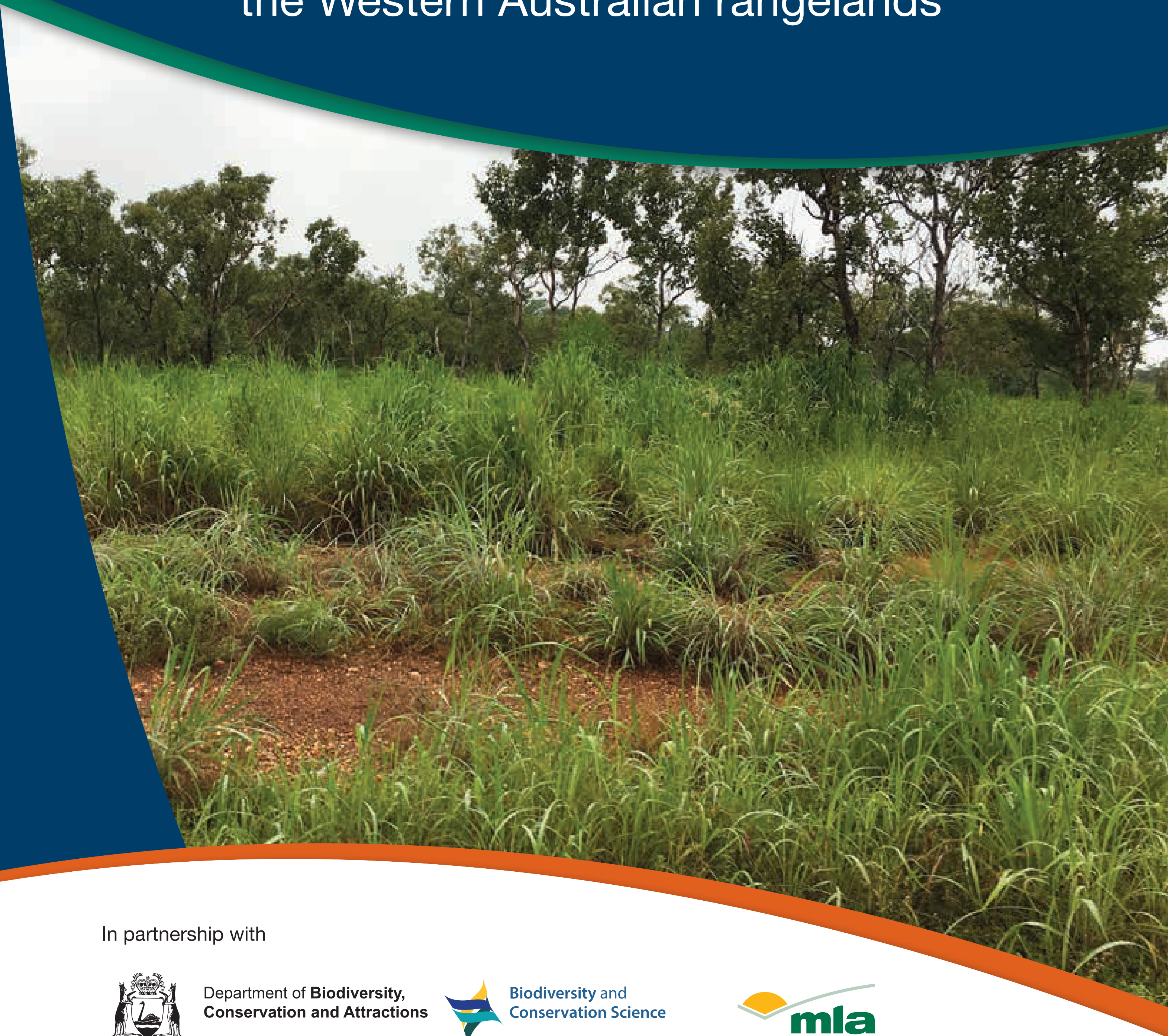
Department of
Primary Industries and
Regional Development

GOVERNMENT OF
WESTERN AUSTRALIA

Bulletin 4924

Environmental weed risk assessment protocol

for growing non-indigenous plants in the Western Australian rangelands



In partnership with

GOVERNMENT OF
WESTERN AUSTRALIA

Department of **Biodiversity, Conservation and Attractions**

Biodiversity and Conservation Science

mla
MEAT & LIVESTOCK AUSTRALIA

Cover: Gamba grass (*Andropogon gayanus*) – a serious weed in the Northern Territory and a declared pest in Western Australia

Recommended reference

Moore G, Munday C, Barua P (2022) 'Environmental weed risk assessment protocol for growing non-indigenous plants in the Western Australian rangelands', Department of Primary Industries and Regional Development, *Bulletin no. 4924*, Perth.

Disclaimer

Copies of this document are available in alternative formats upon request.

Department of Primary Industries and Regional Development
3 Baron-Hay Court, South Perth WA 6151

Telephone: +61 (0)8 9368 3333

Email: enquiries@dpird.wa.gov.au

Website: dpird.wa.gov.au

Bulletin 4924
ISSN 1833-7236
August 2022

Environmental weed risk assessment protocol

for growing non-indigenous plants in the Western Australian rangelands

Compiled by

Geoff Moore[1], Christine Munday[2] and Papori Barua[1]

[1] Department of Primary Industries and Regional Development

[2] Formerly Department of Biodiversity, Conservation and Attractions

Based on the Future Farm Industries CRC 'Environmental Weed Risk Assessment Protocol' by L Stone, C Munday and K Bettink (2012)

Contents

Introduction

The rangelands of Western Australia (WA) occupy 2.26 million square kilometres (about 85% of WA). They extend from the Murchison and Goldfields in the south to the Kimberley region in the north. They are flanked by the Indian Ocean to the west and by the South Australian and Northern Territory borders to the east.

They experience extreme climatic conditions and contain multiple unique ecosystems with high environmental, economic, social and cultural values. Rich with endemic flora and fauna, the rangelands include two World Heritage sites and many national parks. However, they are also the source of great mineral wealth and contain large areas under pastoral production, together with associated infrastructure (roads, rail and ports). Some regions have a long history (more than 100 years) of grazing by domestic and feral animals. As a result, the rangelands vary widely from pristine environments that support native vegetation to highly denuded and disturbed areas that suffer from overgrazing and soil erosion. The social environment includes urban settlements, Indigenous communities, pastoral stations, mining camps and tourist facilities.

Traditionally, agriculture in the rangelands has predominantly relied on stock grazing on native vegetation supplemented by irrigation precincts around Carnarvon and on the Ord River near Kununurra. In recent years, considerable interest has been shown in irrigated mosaic agriculture using groundwater or surface water resources in the west Kimberley and from mine dewatering in the Pilbara. There is also a potential role for improved dryland pastures or the oversowing of legumes in medium to high rainfall areas of the Kimberley.

The introduction of non-indigenous species may improve the viability and sustainability of agricultural systems, including pastoral enterprises. For example, non-indigenous species have been used to successfully rehabilitate unstable, eroded and disturbed sites in the northern Australian rangelands

(Payne et al. 2004). However, there is clear evidence that throughout Australia some introduced species have become established in non-target areas and some have become environmental weeds (Lonsdale 1994; Low 1997; Virtue et al. 2004). Introduced plants can change hydrological conditions, increase the frequency and intensity of fire regimes, provide cover and nutrition for feral animals making control more difficult, and reduce the diversity of the native flora and fauna. Many of the characteristics that make a species useful as a pasture species, such as vigorous growth, persistence and the ability to spread, may also increase the risk that it will become a weed capable of invading natural environments (Cook and Dias 2006). This can result in conflict or contentious species that are both commercially valuable but also invasive in some natural ecosystems (Friedel et al. 2010).

A weed risk assessment (WRA) can provide information for species selection and management to help achieve a balance between agricultural productivity and risk to natural environments.

Where rangelands are under pastoral lease tenure, pastoralists are required to apply for a diversification permit from the Pastoral Lands Board (PLB) to grow any permitted non-indigenous plants. The PLB through the Department of Lands, Planning and Heritage (DPLH) then seeks advice from State Government agencies including the Department of Primary Industries and Regional Development (DPIRD) and the Department of Biodiversity, Conservation and Attractions (DBCA). This environmental WRA system is the methodology used for providing weed risk advice to DPLH on the use of permitted non-indigenous species and their introduction to novel environments in the rangelands. The protocol is designed to add to the transparency, scientific rigour and consistency of information available to decision-makers. It is also recommended that pastoralists use this information when considering the use of non-indigenous species.

There is increasing recognition of duty of care and the requirement to work within a risk management framework for the benefit of those currently using the land and for preserving the status of the environment. This is recognised in environmental legislation including the *Environmental Protection Act 1986*, the *Biosecurity and Agriculture Management Act 2007* and the *Biodiversity Conservation Act 2016* (replacing the *Wildlife Conservation Act 1950*), and regional strategies such as that developed for the Kimberley (Kimberley Science and Conservation Strategy 2011). The Australian Government's *Environmental Protection and Biodiversity Conservation Act 2000* is also relevant to matters of national environmental significance such as threatened ecological communities and RAMSAR wetlands.

RIGHT: There is increasing interest in mosaic agriculture in northern WA – a maize crop under irrigation in the east Pilbara

Background

This WRA protocol was jointly developed by DPIRD and DBCA and is based on the Environmental Weed Risk Assessment Protocol developed for the Future Farm Industries Co-operative Research Centre (FFI CRC). In turn, the FFI CRC methodology was developed to assess the risk of perennial and woody species for agricultural systems across southern Australia becoming weeds of the natural environment (Stone et al. 2012). The FFI CRC weed risk assessment protocol was designed using the principles of the National Post-Border Weed Risk Management Protocol (Standards Australia 2006) and the South Australian Weed Risk Management Guide (Virtue 2004).

This environmental WRA protocol for growing non-indigenous plants in the WA rangelands is based on the FFI CRC system but with some changes to reflect the different environment and objectives (Munday et al. 2016, 2018). The sections on (i) Invasiveness and (ii) Impacts have only minor changes from the FFI CRC protocols, except for some rephrasing to reflect the different environment and context. The potential distribution section is essentially the same although there is greater flexibility with the methodology, and the target region is, of course, different. The five weed risk levels in the FFI CRC system have been simplified to four weed risk categories (Munday et al. 2018).

In common with all risk assessment systems, it is important that the aim, scope, methodology and limitations of the process are well understood.

This WRA protocol has been developed specifically as a post-border assessment of non-indigenous species that may have agricultural value in the WA rangelands and the risk that they may become environmental weeds. In this context, non-indigenous plants refer to species non-native to WA. Weeds can occur in many land-use systems including agriculture, horticulture and forestry; however, the focus of this protocol is on the risk that non-indigenous agricultural plants may become environmental weeds.

Weed risk assessment is a dynamic process and reflects the information known and accessed at the time. The process may also indicate where further research is required, and the assessment should be revised when additional information becomes available.

*Gamba grass (*Andropogon gayanus*) was introduced into the Northern Territory (NT) as a pasture grass but has subsequently become a serious weed that can greatly increase the intensity of wildfires. It is a declared pest (prohibited) in WA.*

Assessment process

The environmental weed risk of a species is assessed for three regions in the pastoral zone of WA using a three-step process (Figure 1).

Step 1: Species prerequisites for WRA

Non-indigenous species or specific varieties may undergo post-border weed risk assessment after checking that each of the proposed species is:

- permitted entry into Australia
- not a Weed of National Significance (WoNS)
- not listed as a WA prohibited organism (s12) or a declared pest (s22) on Western Australian Organism List (WAOL) categorised under the *Biosecurity and Agriculture Management Act 2007* (BAM Act).
- either listed as a permitted organism (s11), or a permit has been granted for its import (r73) on WAOL.

If a proposed species is not listed as a prohibited organism, declared pest or permitted organism on WAOL, the applicant/importer can lodge an 'Application for Import Permit' with DPIRD.

Step 2: A filter

The **second step** is a 'filter' to identify species that are:

a) recorded as environmental weeds in similar environments in Australia or overseas, and

b) likely to persist in the given environment without management.

Species with a 'negative' response to both filters represent a negligible to low environmental weed risk in the pastoral zone. The justification for these decisions can be referenced using available weed lists – for example, the Weeds of Australia database; Randall (2017); Keighery (1991); Keighery and Longman (2004) and Hussey et al. (2007), while the soil and climate requirements for many species are readily available – for example, Cook et al. (2008) and Moore et al. (2006, 2021).

Step 3: Full environmental weed risk assessment

The **third step** applies to all other species. For these plants, a full environmental WRA is undertaken using the methodology described in this bulletin.

LEFT: In terms of the WA rangelands, most horticultural species have a 'negative' response to both 'filter questions' and are assessed accordingly.

*The tropical pasture legume, siratro (*Macroptilium atropurpureum*) growing on the roadside where it is ungrazed.*

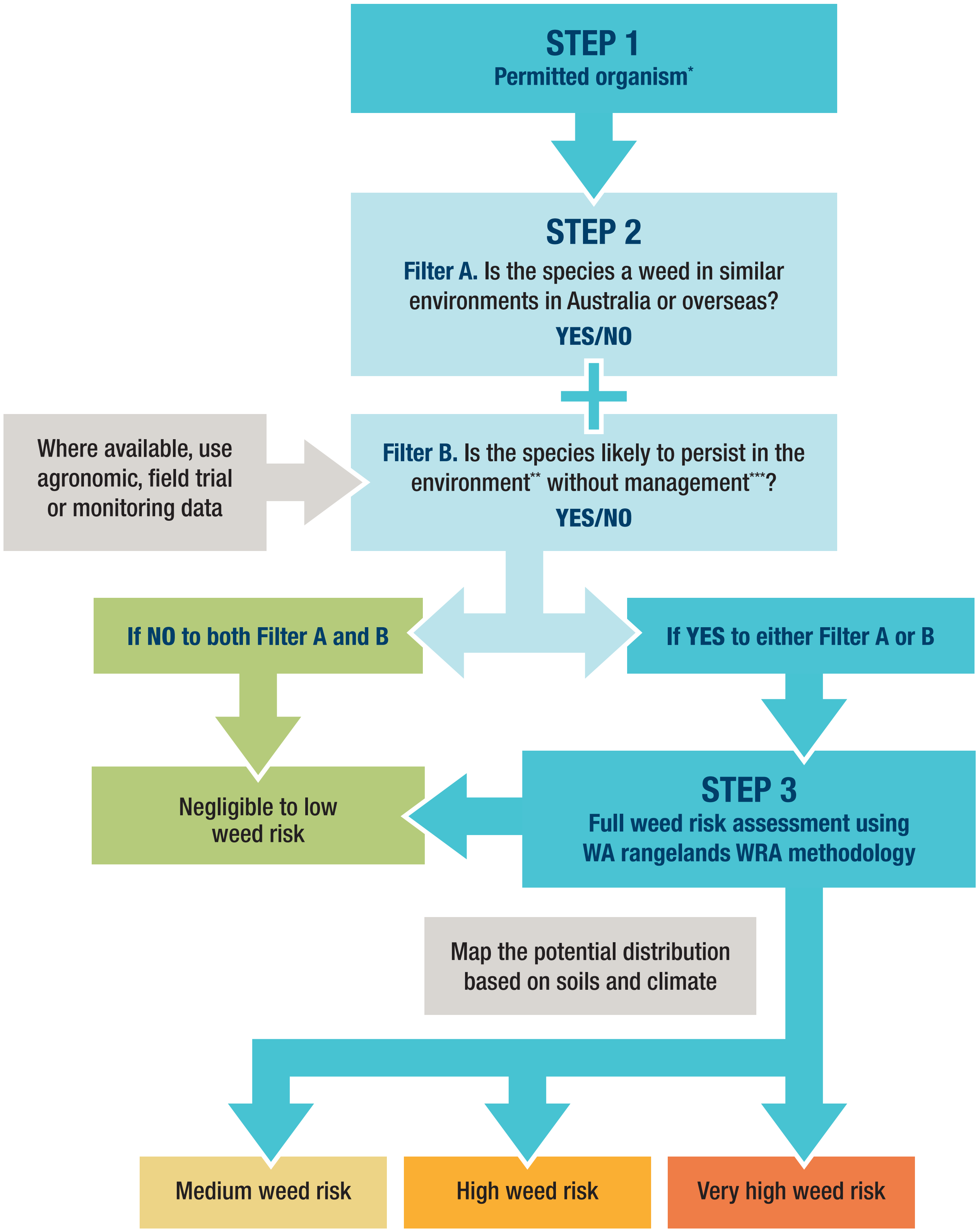


Figure 1. Flow diagram showing the three-step assessment process

Notes: *For all organisms listed on WAOL under s11 of the *Biosecurity and Agriculture Management Act 2007* or r73 of the *Biosecurity and Agriculture Management Regulations 2013*.

**The 'environment' may be considered in the context of the WA rangelands and the three regions (Kimberley, Pilbara and Gascoyne–Goldfields regions), or for a specific application within a single region.

*** 'Without management' means without any fertiliser, rhizobia, irrigation, grazing management or control of competition from other species.

The WRA protocol is subdivided into three sections where:

1. **invasiveness** – assesses the ability of a species to spread beyond agricultural systems or grazed native vegetation into intact native vegetation
2. **impacts** – assesses the potential detrimental impacts a species may have on intact natural ecosystems
3. **potential distribution** – assesses how widely adapted is the species to the novel environment based on the climate and soils of the target area.

Weed risk score calculation

The first two sections of the protocol contain a series of questions that will generate a score depending on the response given. The scores for each question are then summed and standardised (maximum score of 10 for each section).

To adjust the score for invasiveness to a number between 0 and 10, divide the raw score by 28 and multiply by 10. Round off to one decimal place.

To adjust the score for impacts to number between 0 and 10, divide the raw score by 20 and multiply by 10. Round off to one decimal place.

The adjusted scores for each section are then multiplied by the potential distribution score (the area of suitable climate and soils – Table 2) to arrive at the overall weed risk score (equation 1).

The weed risk category is then determined from the weed risk score (Table 1).

Example: For species X with an invasiveness score of 6.2, an impacts score of 3.2 and a potential distribution score of 4.4, the risk score equals 6.2 x 3.2 x 4.4 = 87.3, which equates to a medium risk rating.

If species with a High or Very high risk rating are approved, the Pastoral Lands Board may include additional conditions. These conditions have regard to advice or conditions drafted by the DBCA and DPIRD, which may include, but are not limited to:

- a biosecurity plan to be developed, implemented and reported
- monitoring zones to be established (appropriate to the weed risk of the plant)
- a requirement for regular monitoring and review of, and reporting to, the PLB on the permit area, monitoring zones, and the biosecurity plan above and beyond what might be required under the standard conditions.

(Source: Pastoral Lands Board Policy November 2021 – Cultivation of Non-Indigenous Plant Species on a Pastoral Lease. PLB Policy – Cultivation of non-indigenous plants)

Equation 1:

Weed risk score = Invasiveness (0–10) x Impacts (0–10) x Potential distribution (0–10)

Table 1. Weed risk scores and corresponding risk rating

Weed risk score	Risk rating	Possible conditions on a diversification permit
≥236	Very high	Unlikely to be approved (consider alternative species). If approved, it is recommended the Pastoral Lands Board (PLB) include additional conditions.
112–235	High	If approved, the PLB may include additional conditions
50–111	Medium	Standard conditions
0–49	Negligible to low	Standard conditions

Source: Future Farm Industries (FFI) CRC, Stone et al. (2012)

Guidelines for completing an assessment

The weed risk assessment should be undertaken by a suitably qualified and experienced person.

Species summary

Begin with a short summary of the species describing the plant's nomenclature (taxon, synonyms, common name), morphology, origin, use in agriculture, weed history in Australia and overseas, and the production systems where it is envisaged the species will fit.

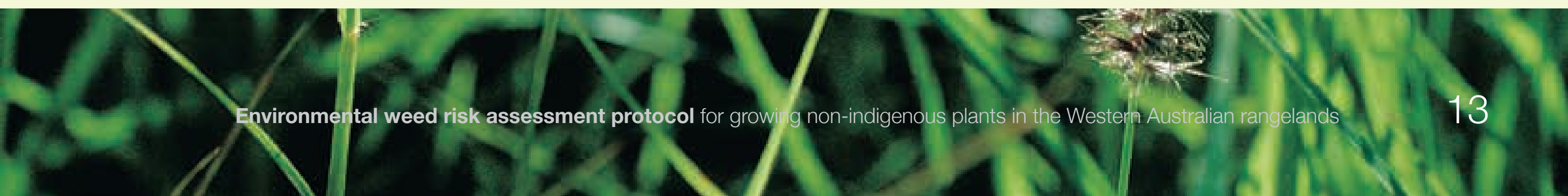
Questions

The answer to each question requires a search of the scientific literature or expert knowledge of the species. References to support your answers should be provided where possible. For each question, there should be a clear explanation of how your answer was selected and, wherever possible, references and attributions provided. Explanatory notes accompany many questions and technical terms are defined in footnotes or provided in the glossary.

Many of the questions are phrased so that personal communication from experts, observations from field trials and unpublished information can be included. This allows the most up-to-date and comprehensive data to be included in the assessment (refer to Appendix 1 for useful sources of information). Where there is a lack of reliable information on which to base an answer, the precautionary principle (caution) must prevail. As such, the 'Don't know' response attracts a comparatively high score.

The WRA process is a dynamic process that uses the best information available at the time. For some species, further research and evaluation under controlled conditions with appropriate precautions may provide additional information. Additional information should be added to the WRA as it becomes available and could, in some cases, change the risk score. In addition, the breeding of new varieties or the natural adaptation of non-indigenous species to a new environment in the medium term may alter the characteristics of the plant and could alter the risk it may pose to that environment (Driscoll et al. 2014).

The completed WRA should be reviewed by a technical review panel comprising agricultural and weed specialists with knowledge of the species under assessment. The assessment is complete after appropriate revision.



Weed risk assessment protocol

Section 1: Invasiveness

This section assesses the ability of a species to spread beyond agricultural systems or grazed native vegetation into intact native vegetation. Characteristics such as how well the species can establish, reproduce and disperse are assessed.

Note that an ‘environmental weed’ refers to plant species that have a significant adverse impact on intact natural ecosystems. The distinction should be made between environmental weeds and naturalised[G] plants (the superscript G = see glossary for a description). Naturalised plants may not be invasive[G] and may not have an adverse impact on intact natural environments. However, evidence that naturalised plants have been specifically targeted for control measures to protect natural ecosystems may provide important information in the determination of invasiveness.

1. Does the species have a documented environmental weed history?

The most reliable indicator of weed potential is a history of weediness elsewhere. Species with close relatives that are known weeds also have a higher weed risk.

Where possible, provide information about the history of the weed species in northern Australia or in semi-arid and arid regions of Australia or in regions of the world with similar climates.

a) Is it an environmental weed in Australia?

b) Is it an environmental weed overseas?

c) Is the species not known to be an environmental weed, but environmental weed species are known to fall within the genus?

d) Does the genus have no known environmental weeds?

2. What is the ability of the species to successfully establish and compete with other plants, especially among intact native vegetation?

Species that can establish well in competition with other plants and with limited impacts from invertebrates and diseases have greater potential to become weeds in natural ecosystems. Seedling vigour should be considered as a component of this.

Kapok bush (Aerva javanica) *was deliberately introduced as a fodder plant for drier regions, and for the revegetation of degraded rangeland pastures. It is spread by wind and animals and is now relatively widespread across northern Australia*

a) High – species can establish and displace intact native vegetation in good condition

b) Moderate – species can establish among intact native vegetation but may not displace the native vegetation

c) Low – species can only establish where there is little or no competition or in areas where the native vegetation is in poor condition or has been disturbed

d) Very low – species can only successfully establish in vegetation that has been highly disturbed (for example, roadsides, degraded or cleared areas)

e) Don't know

A plant is considered 'established' if it is an annual that has been able to reproduce by the end of the first growing season (for example, at the end of wet season in the Kimberley) or a perennial that has persisted through its first dry season. In your answers, include susceptibility to disease and predation by insects such as grasshoppers and caterpillars.

There is grazing by cattle over most of the WA Rangelands

3. Grazing tolerance and palatability

In the rangelands, many domestic, feral and native grazers roam freely. Grazing tolerance is influenced by the desirability of the species, its growth stage, the inherent plant structure and growth habit, and the grazing pressure. For example, the palatability of plants during the wet season (when there is often a surplus of feed) and during the 'dry' season (when there is usually a shortage of palatable feed), combined with the innate tolerance of the species to grazing, will affect its ability to persist over time when 'unmanaged'.

Consider whether the species:

a) is unpalatable (or toxic) and rarely grazed (such as undesirable species like three-awn grasses (*Aristida* spp.))

b) will persist under heavy continuous grazing (examples are rhizomatous grasses like couch grass (*Cynodon dactylon*); or shrubs and trees where, once well established, some or most of the foliage is out-of-reach of herbivores or has limited palatability)

c) is tolerant of grazing (in general, only young growth (annuals) or young regrowth (perennials) are grazed – for example, after a fire or early in the wet season, or when plants are only occasionally browsed)

d) is readily grazed during the wet season with some preferential grazing while during the dry season some plants are grazed while others are left ungrazed (this includes species like barley Mitchell grass (*Astrebla pectinata*))

e) is preferentially grazed at all growth stages or has a low tolerance to grazing and plants are easily killed. Plant numbers decline over successive years

f) Don't know

4. What is the plant's ability to persist as a long-term sward or stand without management?

This refers to the plant's ability to persist over time without management intervention – for example, when there is no control of grazing or weed competition and no fertiliser is applied. Some species may establish well in the first year but persist poorly in subsequent years. Those that have good persistence may become problematic weeds in natural ecosystems.

a) Plant numbers increase substantially with successive reproductive cycles to form a near monoculture over a significant area

b) Plant numbers remain at a steady level, persisting as a significant component of a mixed sward/stand

c) Plant numbers decline slowly over successive years so that it becomes a minor component of the vegetation

d) Plant numbers decline rapidly over successive years so that only occasional plants can be found

e) Don't know

Questions 5 to 9 refer to the rate of dispersal, establishment and reproduction of the species. Species that have efficient primary dispersal mechanisms that enable rapid spread from the initial area of establishment pose a high risk of spread to neighbouring areas. Provide evidence of the mechanism and dispersal distance, where possible.

When answering these questions, include any vegetative propagules, including broken fragments of roots or stems, bulbils, corms and seeds that can develop self-sustaining root systems. For example, some propagules may still be attached to the parent plant but are able to survive if that attachment is severed. Search the literature and document any evidence of rapid colonisation.

5. Is the plant likely to rapidly spread and or colonise a site?

Extreme climatic events in the rangelands may result in episodic rather than incremental movement of plants. Some plants can rapidly spread or colonise an area after events like cyclones and in high rainfall years.

a) High risk – plants with a history of spreading rapidly, with many plants successfully establishing under favourable conditions (>200m from the sown area within two years for herbaceous perennials or five years for woody perennials)

b) Medium risk – some plants will spread outside the planted area and successfully establish under favourable conditions, >100m from the sown area within five years for herbaceous perennials or 10 years for woody perennials

c) Low – no or minimal spread of sown species. Outside the planted area, a few plants will spread and successfully establish within 100m of the planted area under favourable conditions within five years for herbaceous perennials or 10 years for woody perennials

d) No spread of sown species more than 10m outside the planted area within five years for herbaceous perennials or 10 years for woody perennials

e) Don't know

6. Will the species establish and reproduce in low-nutrient soils?

This question deals with the ability of the species to establish in a novel environment without the addition of fertiliser or rhizobia. Many of the soils in the rangelands are low in multiple nutrients including phosphorus, nitrogen, sulphur, calcium, potassium and trace elements. Species that can grow or even thrive in these low-nutrient soils pose a higher weed risk than those that require good fertility for successful establishment, growth and seed production.

Also consider that many non-indigenous legumes have specific rhizobia requirements that may or may not be met by rhizobia present in the soils. If the specific rhizobia are absent, establishment, growth and reproduction may be affected, and this should be reflected in your choice of answer.

a) Establishment, growth and reproduction uninhibited in low-nutrient soils
b) Establishment, growth and reproduction reduced in low-nutrient soils
c) Establishment, growth and reproduction severely diminished in low-nutrient soils
d) Establishment, growth and reproduction unlikely in low-nutrient soils without soil additives
e) Don't know

Question 7 has four parts which cover the main means of non-human dispersal of a species. Species with several means of dispersal tend to spread faster than those with only one. Consider if the propagules are adapted for long-distance dispersal and how regularly these means of dispersal might occur. Expert opinion and evidence from the literature can be used when determining your response.

7.1 How likely is long-distance dispersal (>100m) by flying animals?

Consider features of weeds that favour long-distance dispersal by birds and bats, which include fruits that are eaten whole with seeds that are defecated or regurgitated (for example, lantana, neem, wild passionfruit) or propagules that attach to feathers or skin.

a) Common
b) Occasional
c) Unlikely
d) Don't know

Red deep sands like Pindan, Cockatoo sands are common in northern WA, where most of the soils are inherently very low in the macronutrients (nitrogen, phosphorus, potassium) – (Smolinski 2021)

7.2 How likely is long-distance dispersal (>100m) by stock, native or feral animals?

In the WA rangelands, there is limited fencing and thus minimal restriction of animal movement whether stock (cattle, sheep), native (kangaroos, emus) or feral animals (donkeys, horses, camels, goats). Consider whether propagules have hooks, barbs or sticky substances that attach to hair or skin (Noogoora burr and the like), very small seeds that can lodge within feathers, hair or feet (nutgrass), or seeds that may pass through the gut, remain viable and are defecated (mesquite). Domesticated animals may carry seed in the gut or externally when grazing rangelands.

a) Common
b) Occasional
c) Unlikely
d) Don't know

7.3 How likely is long-distance dispersal (>100m) by water?

Consider the amount of seed produced, whether propagules will readily float (for example, leguminous pods that do not shatter), whether they remain viable after immersion and where the species grows in relation to the water catchment and the likelihood of overland flow (for example, mimosa, parkinsonia, rubber bush).

a) Common
b) Occasional
c) Unlikely
d) Don't know

7.4 How likely is long-distance dispersal (>100m) by wind?

Consider the quantity of seed produced, whether long-distance dispersal by wind may be aided by parachutes, wings or plumes attached to the seed, whether the seed is very small and could be spread in dust storms (for example, lesser mission grass, rubber vine) or whether plants that break off whole or in parts can be blown across the soil surface (for example, windmill grass).

a) Common
b) Occasional
c) Unlikely
d) Don't know

Question 8 has two parts and relates to the likelihood of dispersal by human-influenced means. Species considered agriculturally useful, such as pasture plants, may be introduced or dispersed intentionally but these questions focus on accidental spread. When answering these questions, consider how often new populations could start at least 100 metres from the original planting.

8.1 How likely is long-distance dispersal (>100m) accidentally by people and vehicles?

Consider features that favour accidental human-influenced spread including: species that are dragged by farm machinery or road-working machinery (for example, root fragments of couch grass); propagules that have hooks, barbs or sticky substances to attach to vehicles, people or objects (for example, Mossman River grass (*Cenchrus echinatus*) (see below), khaki weed (*Alternanthera pungens*)); species with small bulbils, corms or tubers (for example, coral creeper (*Antigonon leptopus*)); and species with very small seeds that are released from pods upon contact to lodge in footwear, clothing or machinery.

a) Common
b) Occasional
c) Unlikely
d) Don't know

8.2 How likely is long-distance dispersal (>100m) accidentally through the movement of produce or materials for infrastructure?

Plant propagules can be present as contaminants in produce such as crop seed, pasture seed, hay, soil, gravel, fertilisers, manures and mulch. For example, fodder produced under irrigation is often moved to a new destination to feed stock – when mustering, in feedlots, in holding paddocks and on transport. Unwanted species commonly spread this way include Gambia pea (*Crotalaria goreensis*) in hay and parkinsonia (*Parkinsonia aculeata*) in soil but may also include agriculturally useful species unintentionally dispersed.

a) Common
b) Occasional
c) Unlikely
d) Don't know

*TOP: Mossman River grass (*Cenchrus echinatus*) has seed-heads that produce spiny 'burrs' that readily attach to fur and clothing.*

*BELOW: Purpletop Rhodes grass (*Chloris inflata*) is an annual to short-lived perennial grass weed which spreads by wind. It has a similar appearance to the cultivated Rhodes grass (*Chloris gayana*) but is less palatable and considered unproductive.*

Question 9 looks at the reproductive ability and persistence of the species. This is assessed from a combination of factors, namely the minimum regeneration time, the average seedset in a favourable season and the persistence of viable seed in the soil seedbank. Compared to a single high factor, the combination of these factors can substantially increase or decrease the weed risk.

9.1 What is the minimum generation time of the species?

The minimum generation time of a species is the time from germination to production of viable propagules. The shorter the generation time, the more likely a species will become a weed.

a) <1 year
b) 2 to 3 years
c) >3 years/never
d) Don't know

9.2 What is the average seedset of the species in a favourable season?

This is usually measured as annual seed fall immediately below plants and applies to the typical plant density within one square metre (this can number from one to many individual plants). Any information about seed production should be included in the text.

a) High (>1000 seeds per square metre per year for woody species; >5000 seeds per square metre per year for herbaceous species)
b) Low
c) None
d) Don't know

Seed which can survive ingestion by cattle, like hard-seeded legumes is spread in the dung

9.3 What is the seed persistence of the species in the soil seedbank?

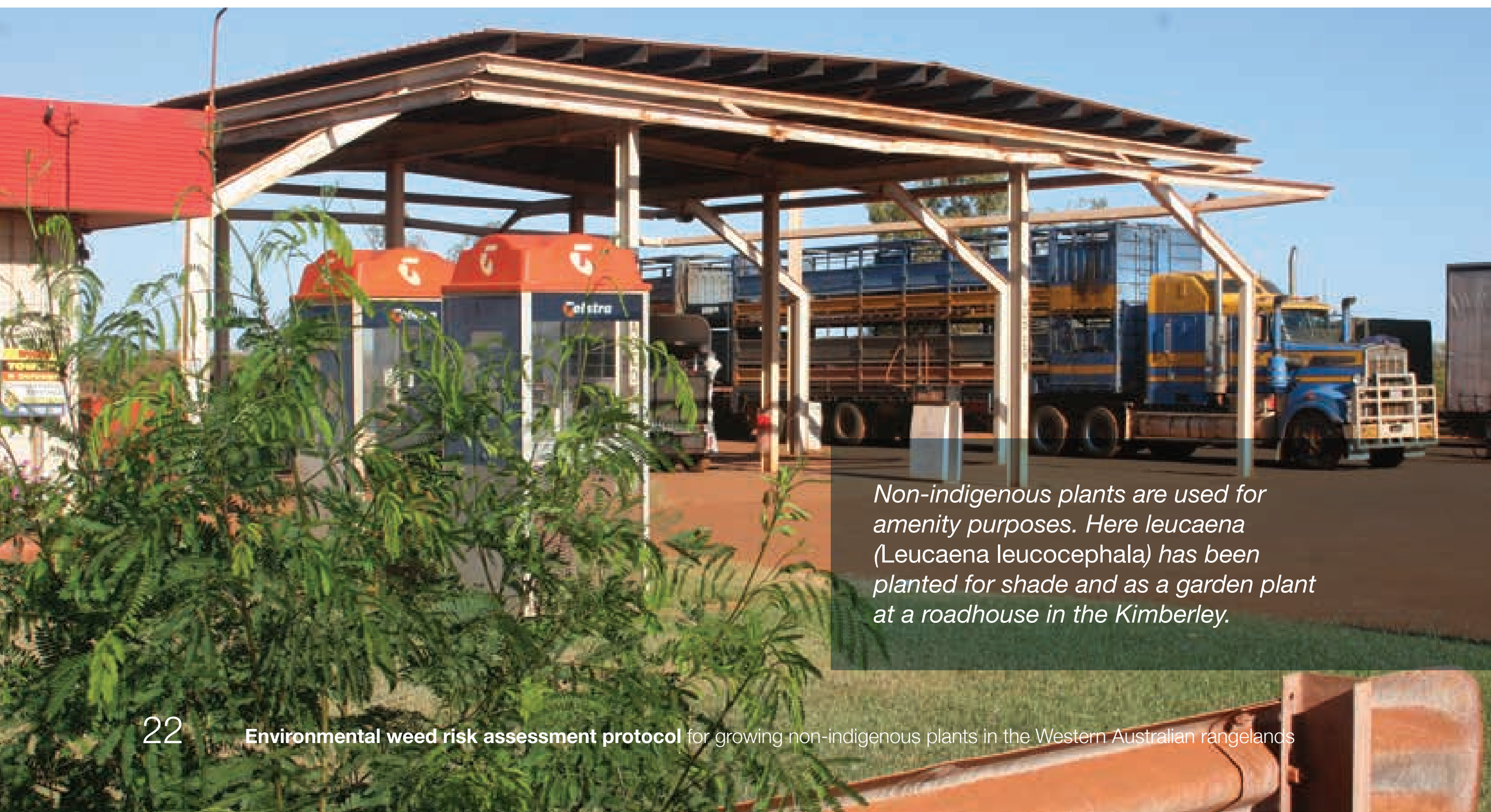
Seed of some species, particularly hard-seeded legumes can remain viable in the soil for long periods and then germinate under favorable conditions. If more than 1% of the seed is viable after one year, it is considered to have persisted. If available, provide information about the percentage of seed that remains viable over time.

a) >5 years
b) 2 to 5 years
c) <2 years
d) Don’t know

9.4 Can the species reproduce vegetatively?

Vegetative means of reproduction include bulbs, bulbils, corms, tubers, rhizomes, stolons, root suckers, root fragments and shoot fragments from which new plants can arise with self-supporting root systems (even if still attached to the parent plant). Note: some species may reproduce vegetatively only after fire or other disturbance. Species that reproduce via vegetative means include spreading grasses like couch grass and kikuyu.

a) Yes – rapid vegetative
b) Yes – slow vegetative (for example, reproduction by stolons or rhizomes)
c) No
d) Don’t know



*Non-indigenous plants are used for amenity purposes. Here leucaena (*Leucaena leucocephala*) has been planted for shade and as a garden plant at a roadhouse in the Kimberley.*

Section 2: Impacts

This section provides an assessment of the potential detrimental impacts a species may have on intact natural ecosystems including national parks, conservation reserves and nature reserves.

Estimating the potential impact of a species may be difficult without conducting specific experiments across many ecological systems and conditions and over a long time. However, a literature search can provide evidence of high or low impacts in other natural ecosystems in similar environments and this is one of the most reliable indicators of species behaviour when assessing weed risk.

The questions in this section require a comprehensive literature search, but there is also room for responses directly from experts.

Each response should be as comprehensive as possible. The assumptions about the density that the assessed species may reach in native vegetation should be described and an answer selected based on this. Particular types of established vegetation may invade at high density, and others not at all, so please consider the information available on as many types of native vegetation as possible when you answer. Some species have specific soil and/or fertility requirements, which means their impact will be linked to the soil type.

*ABOVE: Stinking passionflower (*Passiflora foetida*) invading Millstream Chichester National Park (Photo: Bruce Webber WABSI)*

1. Could the species reduce the biodiversity value of a natural ecosystem, either by reducing the amount of biodiversity present (diversity and abundance of native species) or by degrading the visual appearance?

Consider the ecosystem habitat and species richness of plants, animals and insects. This will impact on the value of the vegetation for plant and animal conservation, cultural heritage significance and nature-based tourism.

a) The species could significantly reduce biodiversity such that areas infested become low priorities for nature conservation or nature-based tourism, or both

b) The species could have some effect on biodiversity and reduce its value for conservation or tourism, or both

c) The species would have marginal effects on biodiversity but is visually obvious and could degrade the natural appearance of the landscape

d) The species would not affect or would have little effect on the biodiversity or the appearance of natural ecosystems

e) Don't know

2. Does the species have a history of or potential to reduce the establishment of other plant species?

Many high impact weed species can prevent or reduce the germination and establishment of other plant species through shading, competition for resources or release of allelopathic[G] substances. For example, a tall dense shrub may shade out groundcovers and herbs, or a dense tussock-forming grass may prevent the establishment of herbs and seedling trees or shrubs.

a) The species can significantly inhibit the establishment of other plants (for example, regenerating native vegetation) by preventing germination or out-competing seedlings or both, or by the species forming a monoculture over a large area
b) The species can inhibit the establishment of other plants and may become dominant
c) The species can cause some minor displacement by inhibiting establishment but will not become dominant
d) The species does not inhibit the establishment of other plants
e) Don't know

3. Could the species alter the structure of a native ecosystem at risk of invasion from this species by adding a new strata level?

The number and type of strata vary according to the vegetation association. In the savanna woodlands that cover much of the Kimberley, the vegetation strata include an open tree layer (>10–20m), a sub-canopy stratum of non-eucalypt species (5–10m), scattered shrubs (1–3m), and an understorey and largely continuous cover of C4 annual and perennial tussock grasses.

In the Pindan soil–vegetation association in the west Kimberley, the strata include an open tree layer (stunted bloodwoods Bauhinia spp., ironwood and paperbarks), a prominent tall shrub layer of *Acacia* species, and an understorey of annual and perennial tussock grasses. In lower rainfall environments or shallow soils, the common strata include scattered trees and shrubs (>3m in height), shrubs (from 1–3m), low shrubs (<1m), hummock grasses and perennial tussock grasses.

Invasive species that add a new strata level (or life-form) to an ecosystem often dramatically alter the function of the ecosystem if they are present at high density. Some transformer[G] species fall into this category.

To determine whether the species could create a new strata level, answer with respect to the type of ecosystems that are most likely to be invaded by this species. Examples include shrubby *Acacia* species invading grassy woodlands and *Mimosa* species invading wetlands.

a) Will add a new strata level, and could reach medium to high density
b) Will add a new strata level, but at a low density
c) Will not add a new strata level
d) Don't know

4. Could or does the species restrict the physical movement of people, animals or water?

Species that can restrict physical movement may be prickly (for example, mesquite (*Prosopis* spp.) or *Opuntia* spp.), form dense monocultures that are impenetrable (e.g. suckering stands of *Acacia*), form tangled mats or blankets over vegetation (e.g. *Merremia aegyptia*, *M. dissecta*), or form thickets that divert water from main watercourses (e.g. olive hymenachne, *Hymenachne amplexicaulis*).

a) Species infestations could become impenetrable throughout the year, preventing the physical movement of people, animals or water
b) Species infestations could significantly slow the physical movement of people, animals and/or water throughout the year
c) Species infestations could slow the physical movement of people, animals or water at certain times of the year or provide a minor obstruction throughout the year
d) Species infestations have no effect on physical movement
e) Don't know

5. Does the species have or show the potential to modify the existing fire behaviour and alter the fire regime?

This question refers to changes to the normal frequency or intensity of fires. More frequent and hotter fires are detrimental to the environment and to the level of biodiversity, and can increase the cost of fire management. For example, highly productive bunch grasses invading shrubby native woodland can increase fire frequency and intensity by increased biomass or distribution within the ecosystem. Consider what vegetation may already be present, and if the species could dramatically change the current fire regime.

a) High – major effect on frequency or fire intensity. May greatly increase the dry season fuel load (for example, Gamba grass in the Northern Territory)
b) Moderate effect on frequency or fire intensity
c) Minor or no effect
d) Don't know

RIGHT: In the Northern Territory, Gamba grass-fuelled fires can greatly increase the intensity of fires compared with equivalent fires in non-invaded native pasture and savannah

Question 6 is concerned with the presence and impact of the species on the flora and fauna in natural environments.

6.1 Is the species toxic to animals? Does it have spines or burrs, or host other pests or diseases that could impact on native fauna and flora?

a) Yes – plant poisonous or other adverse factors present

b) No – plant is not poisonous, does not produce burrs or spines or harbour pests or diseases

6.2 Could the species provide food or shelter for pest animals?

Only answer yes if the plant species is likely to encourage the population growth of the pest, for example, blackberry that harbours rabbits.

a) Yes – could provide more shelter or greater nutritional value than the native vegetation

b) No – could provide similar or less shelter or nutritional value than the native vegetation

c) Don't know

Question 7 is concerned with the presence and impact of the species on the matrix of natural environment.

7.1 Does the species have (or show the potential to have) a major effect on nutrient levels in intact native vegetation?

Consider, for example, that leguminous species may increase soil nitrogen and make native vegetation more prone to invasion by species not usually present. Similarly, highly vigorous bunch grasses may deplete the soil of nutrients and alter the biodiversity.

a) Will significantly increase soil nutrient levels

b) Will significantly decrease soil nutrient levels

c) Will have minimal effect on soil nutrient levels

d) Don't know

*LEFT: Rubber bush or calotropis (*Calotropis procera*) a declared pest in WA is toxic to stock*

7.2 Could the species reduce water quality or cause silting of waterways?

Could the species have a physical effect on water flow or quality? For example, para grass (Urochloa mutica) can form pure stands, replacing native wetland plants and interfering with aquatic ecosystems. Para grass is a significant issue in the Kakadu National Park where it dominates areas of tropical floodplain and impacts native birdlife, while in north Queensland it blocks irrigation ditches and increases sedimentation in creeks (Hannan-Jones and Csurhes 2012).

a) Could significantly reduce water quality or cause silting or alteration of flow of waterways
b) May have some effect on water quality or silting of waterways in some ecosystems
c) Minor or no effect on water quality
d) Don't know

7.3 Does the species have (or show the potential to have) a major effect on the watertable below intact native vegetation?

This question refers to the ability of the species to significantly lower the watertable compared to other plants present in a natural ecosystem. Compare the potential to what already occurs in the native vegetation. For many species, the overall effect on the watertable will not be dissimilar to that which naturally occurs in native vegetation. An example of a species that can significantly lower the watertable is giant reed (*Arundo donax*), which uses substantial amounts of groundwater in arid environs in California and is also an invasive weed in Queensland.

a) Yes – can significantly lower the watertable or reduce groundwater recharge to the watertable, or both
b) No – will have little or no impact on hydrology
c) Don't know

*Aquatic plants can clog waterways, here native bullrush (*Typhus domingensis*) is growing in a creek in the Pilbara*

Section 3: Potential distribution

The third section of the protocol is to determine potential distribution. This is a prediction of how widely adapted the species is to the novel environment (that is, the climate and soils of the target area[G]) without management, which means without cultivation, weed control, addition of fertiliser, irrigation or (for legumes) inoculation with specific rhizobia requirements.

The potential distribution is an estimate of the area of suitable soils and climate on a regional basis. For the pastoral zone of WA, the three regions assessed are the Kimberley, Pilbara and Gascoyne–Goldfields (Gascoyne, Murchison and Goldfields) regions plus the agricultural area (Figure 2).

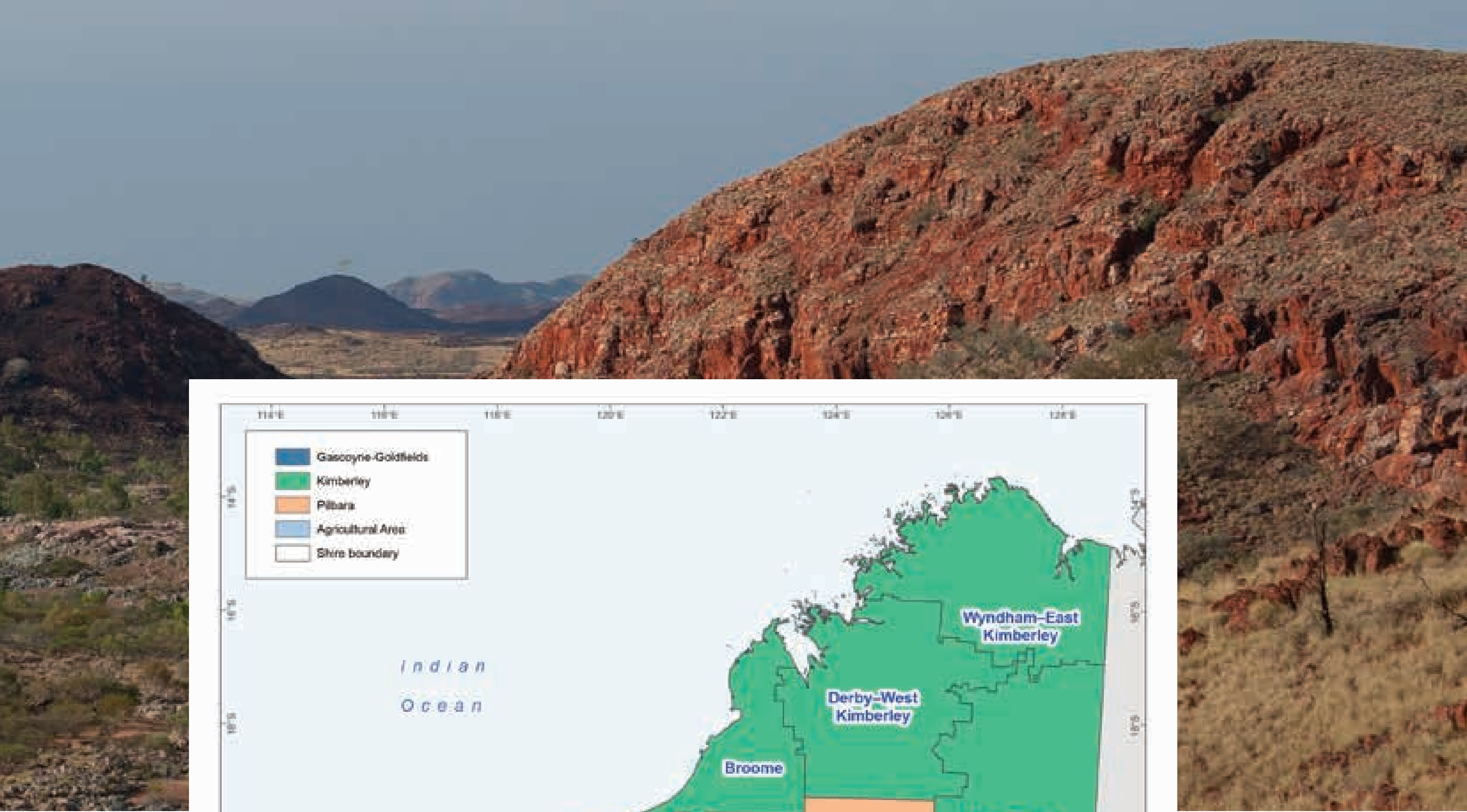
As an environmental weed risk assessment, it specifically refers to the area of native vegetation with suitable soils and climate. However, in the pastoral zone, native vegetation is assumed to be ubiquitous as the area cleared of native vegetation is negligible (<1%).

The potential distribution is determined by digitally overlaying areas of suitable climate and soils to determine the area (ha) where the species has the potential to grow. The output is a broad indicator only and the maps should not be used to identify specific areas where a species can or cannot grow. The area (ha) of suitable soils and climate in a region is then converted to a potential distribution score (0.5 to 10) using Table 2.

Table 2. Determining the potential distribution score (0–10) from the area (ha) of suitable soils and climate

Area (million ha)	Potential distribution score
>50	10
20 to 50	9
10 to 20	8
5 to 10	7
3 to 5	6
2 to 3	5
1 to 2	4
0.5 to 1	3
0.25 to 0.5	2
<0.25	1
0	0.5

Source: Stone et al. 2012



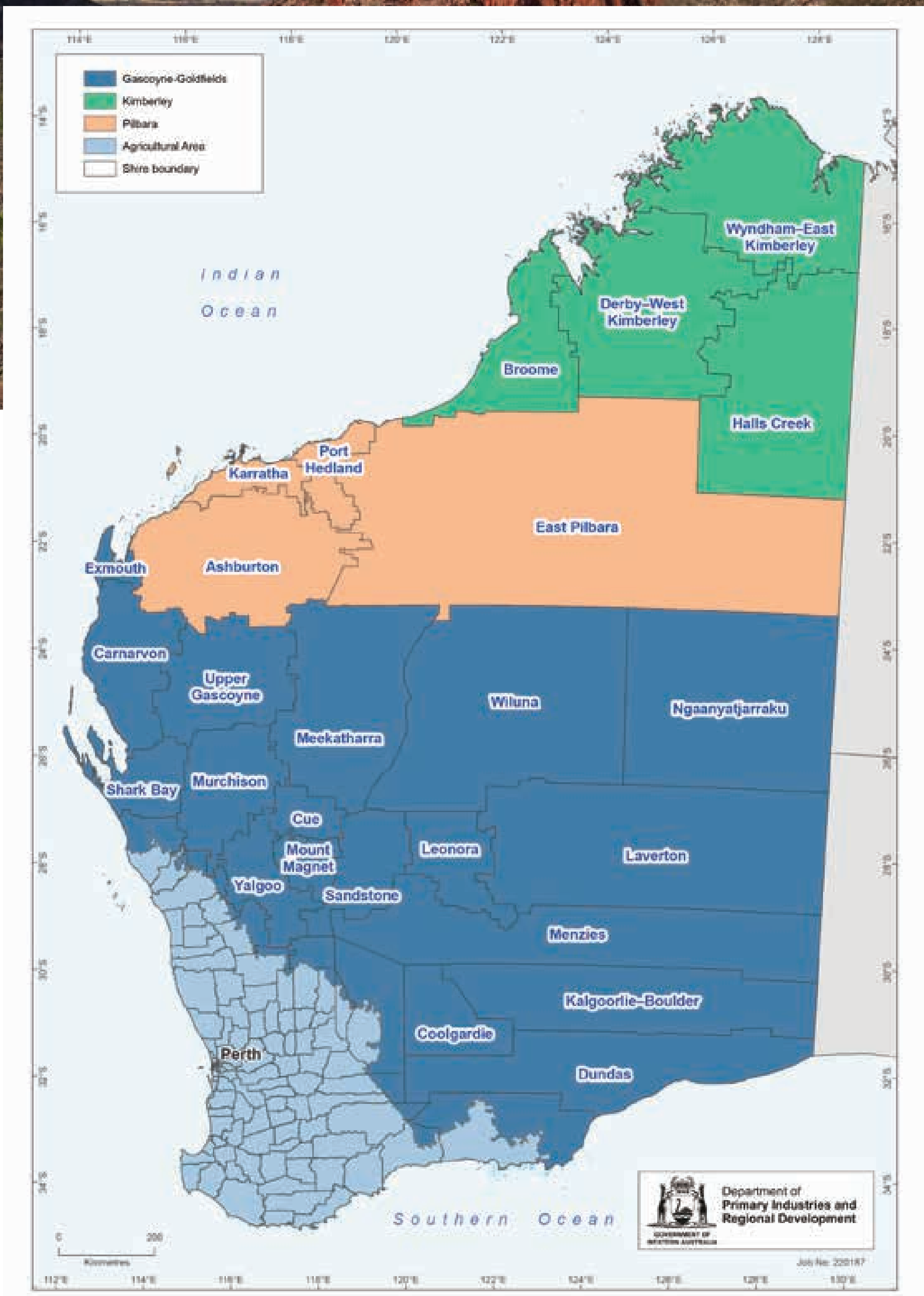


Figure 2. The three regions of the WA pastoral zone (Kimberley, Pilbara, Gascoyne–Goldfields) plus the agricultural area

Methods for assessing the potential distribution

There are several methods for assessing the potential distribution of a species, as the information available about the current distribution and the understanding of soil and climate requirements can vary widely. Always use the most detailed and reliable information available.

Where there is good information available on the specific soil and climate requirements of a species, this can be used to produce potential distribution maps based on climate (rainfall, temperature, length of dry season), soils and topography. For an example, refer to Figure 3 which shows the potential distribution of lucerne for the Pilbara and Kimberley regions.

Where there is little or no information available or the species is new to WA, potential distribution can be predicted from the international distribution of the species using a climate matching model (for example, Climatch 2020), together with a digital overlay of soils.

Climate analysis is done using Climatch 2020, a software package designed specifically for risk assessment of insects and weeds. This program uses global distribution data or source location[G] (that is, collection information, particularly GPS locations). Only areas where there is a match to ≥80% of the mean climate variables are used. The size of each output square is approximately 250,000ha. Therefore, the smallest match for any species, other than no match, is 250,000ha.

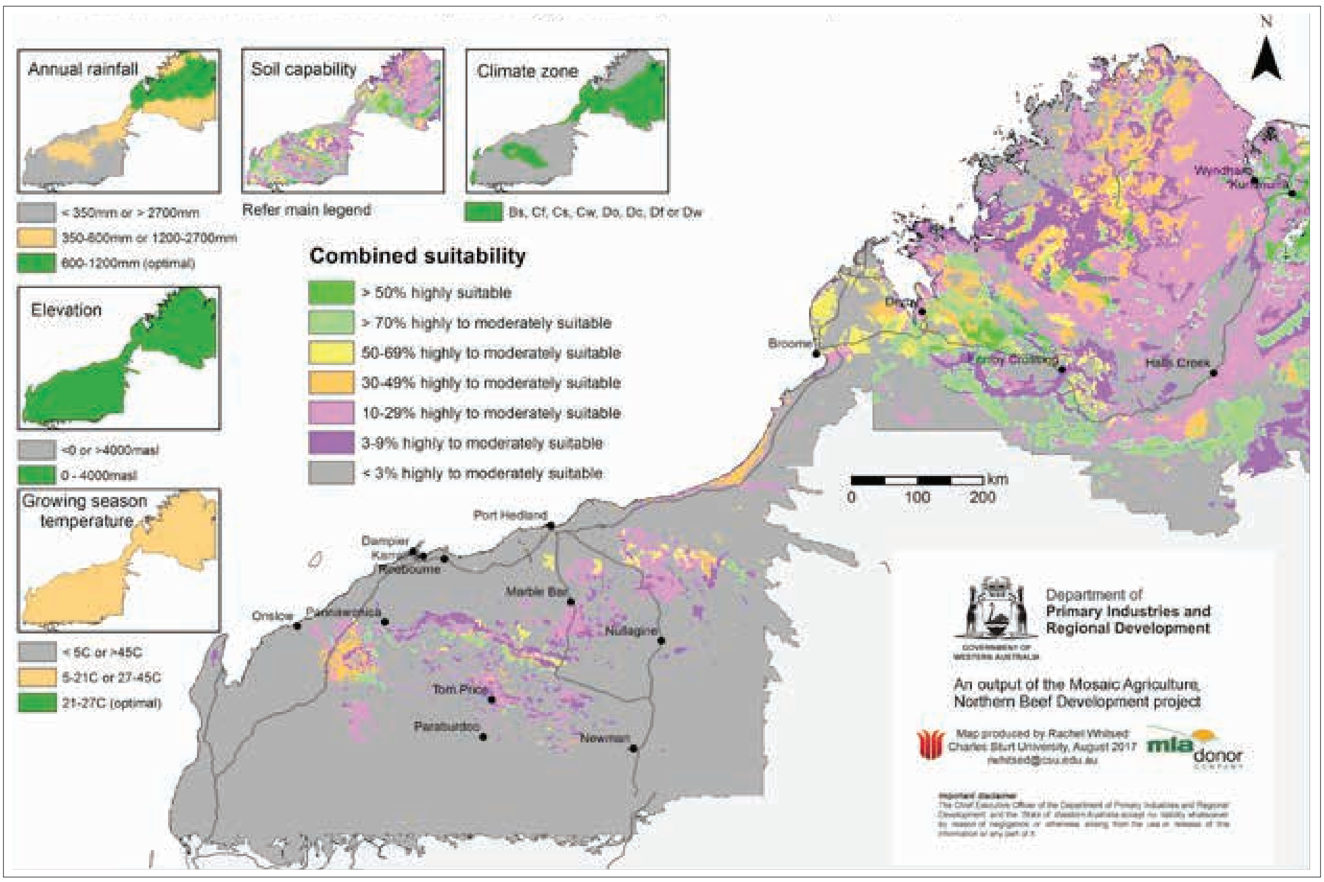


Figure 3. An example of a potential distribution map for lucerne (*Medicago sativa*) for the Kimberley and Pilbara regions based on the specific soil and climate requirements

Soils information

Soils sharing similar qualities that can be managed together under similar land use are assigned to a soil generic group. In WA, where these are referred to as WA Soil Groups, they provide a simple, standardised and easy-to-understand way to recognise the most common soils (Schoknecht and Pathan 2013). For broadscale mapping, the 'Soil Supergroups' are the appropriate level in the hierarchy to use for a regional-scale assessment. The 13 Soil Supergroups for WA are summarised in Table 3.

The best soils information available for most of the WA rangelands is based on 'land system mapping' at a scale of 1:250,000 (Payne and Schoknecht 2011). A land system is defined as 'an area or group of areas through which there is a recurring pattern of topography, soils and vegetation' (Christian and Stewart 1953). The map units or polygons contain a range of soils, and the description includes the proportion of the main soils. As a result, only part of a map unit may have suitable soils for a species to grow.

For each of the Soil Supergroups, a species is assessed as to whether it will grow or not (Yes/No). Alternatively, a land capability assessment can be used. This describes how well adapted a plant is to an environment rather than simply whether it will grow or not. The four land capability categories are described in Table 4. For a regional-scale soil map to overlay with climate when determining the potential distribution, land capability classes I to III are assigned as suitable, while classes IV and V are unsuitable.

Table 3. A summary of the WA Soil Supergroups

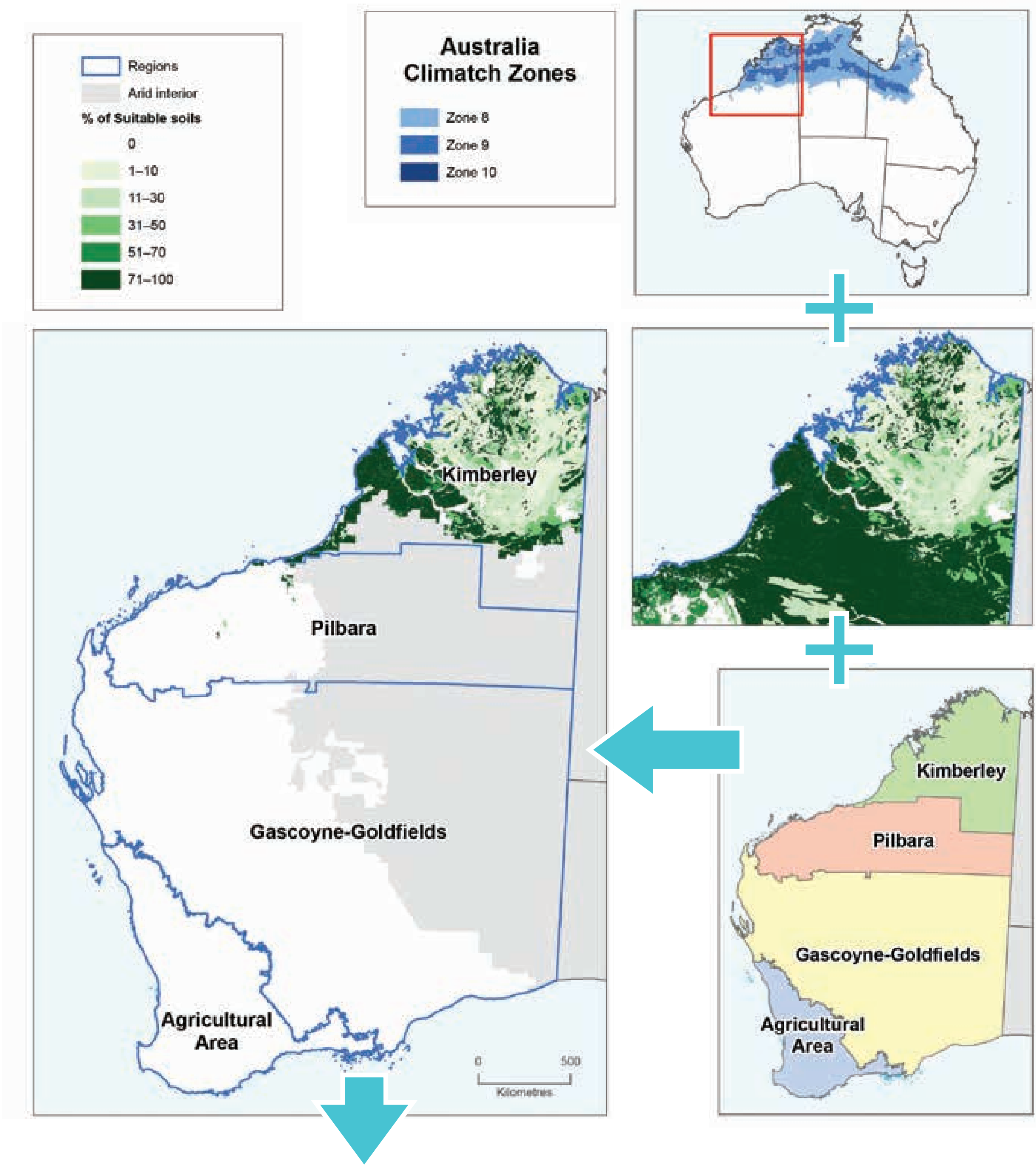
Soil Supergroup	Definition
Wet or waterlogged soils	Soils seasonally wet within 80cm of the surface for a major part of the year.
Rocky or stony soils	Soils, generally shallow, with >50% of coarse fragments >20mm in size (coarse gravels, cobbles, stones or boulders) throughout the profile. Include areas of rock outcrop (all lithologies).
Ironstone gravelly soils	Soils that have an ironstone gravel layer (>20% and >20cm thick) or ferricrete/cemented gravels within the top 15cm, and ironstone gravels a dominant feature of the profile.
Sandy duplexes	Soils with a sandy surface and a texture contrast or a permeability contrast (reticulite) at 3 to 80cm.
Sandy earths	Soils with a sandy surface and grading to loam by 80cm. May be clayey at depth.
Shallow sands	Sands ≤80cm over rock, hardpan or other cemented layer.
Deep sands	Sands >80cm deep.
Loamy duplexes	Soils with a loamy surface and a texture contrast at 3 to 80cm.
Loamy earths	Soils with a loamy surface and either loamy throughout or grading to clay by 80cm.
Shallow loams	Loams ≤80cm over rock, hardpan or other cemented layer.
Cracking clays	Soils that have a clayey surface at least 30cm thick and crack strongly when dry.
Non-cracking clays	Soils that have a clayey surface at least 30cm thick and do not crack strongly when dry.
Miscellaneous soils	Other soils.

Table 4. A description of the land capability* categories

Adaptation to the climate and soils	Definition	Land capability class
High to very high	Plants are well suited to the climate and/or the soils in the assessment area on a broadscale.	I to II
Moderate	Plants are marginally suited to the climate and/or the soils in the assessment area but may grow well in niche environments. Plants will struggle to persist in the medium term on a broad scale or will persist but at a low density due to soil constraints. However, they may persist in niche environments with more favourable conditions.	III
Low	Plants are poorly suited to the climate and/or the soils in the assessment area resulting in a greatly reduced ability for the species to persist in the medium term. They may persist but not thrive in niche environments with more favourable conditions.	IV
Very low	Plants are very poorly suited to the climate and/or the soils in the assessment area.	V

* Adapted from FAO (1976) and van Gool et al. (2005) for a rangelands context

The potential distribution map in Figure 3 shows that the area of suitable soils and climate for lucerne in the Pilbara is 0.79 million hectares (Mha), which translates to a potential distribution score of 3 (using Table 2), while in the Kimberley the suitable area is 7.2Mha which equates to a potential distribution score of 7. The potential distribution scores are then used in equation 1 to calculate the overall weed risk score. An example of a potential distribution map based on Climatch (2020) modelling and suitable soils is shown in Figure 4.



Region	Area suitable soils Climate Zone 8 (Mha)	Area suitable soils Climate Zone 9 (Mha)	Area suitable soils Climate Zone 10 (Mha)	Total (Mha)
Kimberley	6.26	6.07	0.21	12.53
Pilbara	1.63	0.00	0.00	1.63
Gascoyne-Goldfields	0.00	0.00	0.00	0.00
Agricultural area	0.00	0.00	0.00	0.00
TOTAL (Mha)	7.89	6.07	0.21	14.16

Figure 4. An example of a potential distribution map for the four regions in WA based on Climatch modelling and suitable soils

Management of introduced species

Setting up a fixed transect on an irrigation development for monitoring purposes. The aim is to collect reliable, robust data on whether there has or has not been spread of sown (permitted) species off-site.

Whenever the introduction of a non-indigenous species into a novel environment is proposed, a management plan should be prepared. For species with significant agricultural potential but a higher weed risk the first option is to consider lower risk species. However, where there are no lower risk alternatives, specific management guidelines should be developed and implemented to minimise the overall risk. This may include regular monitoring to detect any spread of the permitted species outside the permit area or a biosecurity plan, or both.

The guidelines should reflect the level of weed risk, the biology and agronomy of the species, and management techniques to minimise the weed risk. Control procedures should be included if the sown species does spread offsite or if the agricultural system ceases.

Monitoring

Regular monitoring using fixed monitoring transects is recommended for species with a medium or higher weed risk rating.

As a guide, at least three 'monitoring transects' should be established for a single centre pivot irrigator or small cluster of pivots. Position the monitoring transects in areas of the highest risk, such as run-off areas. Larger developments will require more transects. As a guide, we recommend three transects per 100 to 150ha of irrigation development.

An initial base survey should be conducted after the wet season to establish permanent transects and collect the base data. The survey should be conducted by people who have received appropriate training in plant identification and survey methods.

Subsequent surveys should be conducted annually after the wet season, except as listed below:

- After five years of monitoring, if no permitted species have been detected outside the permit area, then the frequency of monitoring can decrease to every two years.
- After 10 years of monitoring, if no permitted species have been detected outside the permit area, then the frequency of monitoring can decrease to every five years.

Biosecurity plan

The Pastoral Lands Board provides guidelines for developing a biosecurity plan for weed risk management using a risk matrix approach. Refer to: PLB Guidelines for developing Biosecurity plans

Acknowledgements

This WRA protocol was jointly developed by the Department of Primary Industries and Regional Development (DPIRD) and the Department of Biodiversity, Conservation and Attractions (DBCA) as part of the Mosaic Agriculture sub-project within the Northern Beef Development Project, a WA Government-funded project.

The assessment protocol is based on the WRA developed for the Future Farm Industries Co-operative Research Centre (FFI CRC). The FFI CRC 'Environmental weed risk assessment protocol' was developed by Lynley Stone and revised by Christine Munday and Karen Bettink (Stone et al. 2012). The authors acknowledge project funding from Royalties for Regions through the Northern Beef Development Project and from the MLA Donor Company (MDC).

The authors would like to thank Kerry Coyle for editing the manuscript; Greg Keighery and Dr Chris Schelfhout for reviewing the draft manuscript; Phil Goulding (DPIRD–GIS Products Group) for Figures 2 and 4; and Dr Rachel Whitsed (Charles Sturt University) for Figure 3. A special thanks to Megan Hele (MeganHeleDesign) the graphic designer for the excellent layout.

Glossary

Allelopathy: A biological phenomenon by which an organism produces and releases into the environment one or more biochemicals that influence the growth, survival and reproduction of other organisms. This may result in the suppression of neighbouring plants.

Assessment area/region: Geographical region for WRA and for which the potential distribution of weeds may be calculated.

Contentious or conflict species: Plant species that are (or potentially are) commercially valuable that may be invasive and may be introduced to areas outside their native range (adapted from Friedel et al. 2010).

Environmental weed: Plant species, outside their native range, that are naturalised in (that is, establish self-propagating populations) and have an adverse impact on terrestrial or aquatic natural ecosystems. They may alter the natural environment leading to a change in the native community flora and fauna. (Note: Native species introduced outside their native range may become damaging environmental weeds and the potential for hybridisation with native species is likely to be increased. This can be detrimental to the integrity of the natural environment of the location.)

Habitat: The biophysical medium or media occupied (continuously, periodically or occasionally) by an organism or group of organisms (or once occupied and into which organisms of that kind have the potential to be reintroduced).

Invasive species: A species outside its native range that can reproduce without intervention resulting in the establishment of a population that spreads and threatens ecosystems, habitats or other species with economic or environmental harm. This can include weeds in agricultural systems. Not all non-indigenous species are invasive. There may be natural or imposed checks and controls on their spread or competitiveness.

Naturalised: A species, outside its native range, which establishes a self-sustaining population with successful recruitment (without ongoing human input).

Non-indigenous: A species found or introduced outside its native range. In this context, it refers to a plant species that is not native to Western Australia.

Novel environment: Refers to an environment which is new and different from where the species has previously grown.

Source location: Location where the species is found growing, often reported as herbarium data. This may include the native distribution and where the species has been introduced deliberately, accidentally or become naturalised.

Transformer species: Invasive species that change the character, condition, form or nature of ecosystems over substantial areas relative to the extent of that ecosystem (Richardson et al. 2000).

Target area: Area proposed for introduction.

Weed: Any plant that is unwanted in a particular situation. Weeds may threaten agricultural productivity, have detrimental effects on natural environments and the native species they support or impact on human health, cultural, social, economic, scientific or aesthetic assets or values. Any plant can be a weed if it is in a place where it is not wanted.

Appendix 1

Resource list

Websites – Specific floras

Australia

- The Australasian Virtual Herbarium (also good for Australian distribution of a species): https://avh.chah.org.au
- South Australia: http://www.flora.sa.gov.au
- Western Australia: http://florabase.dpaw.wa.gov.au
- New South Wales: PlantNET – NSW Flora Online http://plantnet.rbgsyd.nsw.gov.au

International

- eFLORAS.org – links to online floras from around the world: http://www.efloras.org
- Jepsons Online Interchange (plants in California): https://ucjeps.berkeley.edu/interchange/
- Flora Europaea: https://eunis.eea.europa.eu/references/1780/species
- International Environmental Weed Foundation: http://www.iewf.org/

General database resources

- Germplasm Resources Information Network (GRIN): http://www.ars-grin.gov/
- International Legume Database and Information Service (ILDIS): http://www.ildis.org/
- International Plant Name Index (IPNI): http://www.ipni.org
- TROPICOS – a large database of plant nomenclatural information from around the world (can map world distribution of species): http://www.tropicos.org/
- electronic Plant Information Centre (ePIC) – Royal Botanic Gardens, Kew: https://www.ipl.org/electronic-plant-information-centre-epic
- Global Biodiversity Information Facility (GBIF): http://www.gbif.org/
- United States Department of Agriculture – Plants database: https://plants.sc.egov.usda.gov/java/
- GrassBase – The Online World Grass Flora: http://www.kew.org/data/grassbase/

Weed sites

- Weeds of Australia – Biosecurity Queensland Edition, Queensland Government: https://keyserver.lucidcentral.org/weeds/data/media/Html/index.htm
- Weeds Australia: https://weeds.org.au/
- Noxious weeds in Australian States and Territories: https://weeds.org.au/weeds-profiles/
- Pacific Island Ecosystems at Risk (PIER) has information on a range of temperate and tropical weeds: http://www.hear.org/pier
- The Nature Conservancy has information on temperate weeds: http://tncinvasives.ucdavis.edu/
- United States Department Agriculture (USDA) introduced, invasive and noxious plants: http://plants.usda.gov/topics.html/
- Weeds of National Significance (WoNS) Australia: https://weeds.org.au/weeds-profiles/

Appendix 2

Scoring system

Section 1. Invasiveness		
Question	Answer	Score
1	A	3
	B	2
	C	1
	D	0
2	A	3
	B	2
	C	1
	D	0
	E	2
3	A	4
	B	3
	C	2
	D	1
	E	0
	F	2
4	A	3
	B	2
	C	1
	D	0
	E	2
5	A	3
	B	2
	C	1
	D	0
	E	2
6	A	3
	B	2
	C	1
	D	0
	E	2
7.1 to 7.3	A	2
	B	1
	C	0
	D	1
8.1 to 8.2	A	2
	B	1
	C	0
	D	1
9.1 to 9.4	A	2
	B	1
	C	0
	D	1

Section 2. Impacts		
Question	Answer	Score
1	A	3
	B	2
	C	1
	D	0
	E	2
2	A	3
	B	2
	C	1
	D	0
	E	2
3	A	3
	B	2
	C	0
	D	2
4	A	3
	B	2
	C	1
	D	0
	E	2
5	A	3
	B	2
	C	0
	D	2
6.1	A	2
	B	0
6.2	A	2
	B	0
	C	2
7.1 to 7.2	A	2
	B	1
	C	0
	D	1
7.3	A	1
	B	0
	C	1

Key for questions with multiple parts

Section 1. Invasiveness		
Question	**Answer**	**Score**
7.1 to 7.3	7 or 8	3
	4, 5 or 6	2
	2 or 3	1
	0 or 1	0
8.1 to 8.2	3 or 4	3
	2	2
	1	1
	0	0
9.1 to 9.4	7 or 8	3
	4, 5 or 6	2
	2 or 3	1
	0 or 1	0
Section 2. Impacts		
6.1 to 6.2	4	2
	2	1
	0	0
7.1 to 7.3	5	3
	3 or 4	2
	1 or 2	1
	0	0

Computing the standardised scores and overall weed risk score

Invasiveness	Impacts	Potential distribution	Weed risk category
{(raw score/28)*10}	{(raw score/20)*10}	4	Refer to Table 1
Example: {(16/28)*10} = 5.7	{(9/20)*10} = 4.5	5.7 x 4.5 x 4 = 102.8	Medium

References

Christian CS, Stewart GA (1953) General report on survey of the Katherine-Darwin region, 1946. Land Research Series No. 1, CSIRO Australia.

Climatch (2020) Australian Government Department of Agriculture and Water Resources, https://climatch.cp1.agriculture.gov.au/, accessed December 2020.

Cook BG, Pengelly BC, Brown SD, Donnelly JL, Eagles DA, Franco MA, Hanson J, Mullen BF, Partridge IJ, Peters M and Schultze-Kraft R (2005) Tropical forages an interactive selection tool, CSIRO, Department of Primary Industries and Fisheries (Qld), Centro Internacional de Agricultura Tropical (CIAT) and International Livestock Research Institute (ILRI) Brisbane, Australia. https://www.tropicalforages.info/text/intro/index.html

Cook GD, Dias L (2006) Turner Review No. 12 'It was no accident: deliberate plant introductions by Australian Government Agencies during the 20th century', Australian *Journal of Botany* 54:601–625.

Driscoll DA, Catford JA, Barney JN, Hulme PE, Inderjit, Martin TG, Pauchard A, Pyšek P, Richardson DM, Riley S, Visser V, Richardson DM, Riley S, Visser V (2014) New pasture plants intensify invasive species risk. In Proceedings of the National Academy of Sciences, 111(46), 16622–16627. http://www.pnas.org/content/early/2014/10/29/1409347111, accessed May 2017

FAO (1976) *A framework for land evaluation*, Food and Agriculture Organisation of the United Nations, Rome, Soils Bulletin 32.

Friedel MH, Grice AC, Clarkson JR, Ferdinands K, Setterfield SA (2010) How well are we currently dealing with contentious plants. In Proceedings of the 17th Australasian Weeds Conference, Zydenbos SM (ed) pp. 470–473.

Hannan-Jones M, Csurhes S (2012) Invasive species risk assessment: para grass (*Urochloa mutica*), Biosecurity Queensland, Queensland Department of Agriculture, Fisheries and Forestry.

Hussey BMJ, Keighery GJ, Dodd J, Lloyd SG, Cousens RD (2007) 'Western weeds. A guide to the weeds of Western Australia', 2nd edn, The Weeds Society of Western Australia Inc.

Keighery GJ (1991) 'Environmental weeds of Western Australia'. *Kowari* 2:180–188.

Keighery G, Longman V (2004) The naturalised vascular plants of Western Australia 1: Checklist, environmental weeds and distribution in IBRA regions, *Plant Protection Quarterly* 19(1):12–32.

Kimberley Science and Conservation Strategy (2011) https://www.dpaw.wa.gov.au/management/kimberley-strategy, accessed April 2016.

Lonsdale MW (1994) 'Inviting trouble – introduced pasture species in northern Australia', *Australian Journal of Ecology*, 19:345–354.

Low T (1997) 'Tropical pasture plants as weeds', *Tropical Grasslands*, 31:337–343.

Moore GA, Sanford P, Wiley T (2006) 'Perennial pastures for Western Australia'. Department of Agriculture and Food, Western Australia, Perth. Bulletin 4690.

Moore G, Revell C, Schelfhout C, Ham C and Crouch S (2021) 'Mosaic agriculture: a guide to irrigated crop and forage production in northern WA', Department of Primary Industries and Regional Development, Perth. Bulletin 4915.

Munday C, Byrne M, Moore G, Revell C (2016) 'Introducing non-indigenous plants to the Western Australian rangelands: what can weed risk assessment contribute? In 20th Australasian Weeds Conference, Perth, Western Australia, 11–15 September 2016, The Weeds Society of Western Australia, p. 210.

Munday CJ, Moore G, Whitsed R, Byrne M, Revell C (2018) 'Refining the environmental weed risk assessment for non-indigenous plants which may have agricultural potential', *In* 21st Australasian Weeds Conference, 'Weed Biosecurity – Protecting our Future', Sydney, New South Wales, Australia, 9–13 September 2018, The Weed Society of New South Wales Inc., pp. 72–76.

Payne AL, Schoknecht, NR (2011) Land systems of the Kimberley region, Western Australia, Department of Agriculture and Food, Technical Bulletin 98.

Payne AL, Watson IW, Novelly PE (2004) Spectacular recovery in the Ord River catchment, Department of Agriculture, Perth. Miscellaneous Publication 17/2004.

Randall RP (2017) Global compendium of weeds, 3rd edn, Perth, Western Australia.

Richardson DM, Pyšek P, Rejmanek M, Barbour MG, Panetta FD, West CJ (2000) 'Naturalization and invasion of alien plants: concepts and definitions', *Diversity and Distributions* 6(2):93–107.

Schoknecht NR, Pathan S (2013) Soil groups of Western Australia: a simple guide to the main soils of Western Australia, 4th edn, Department of Primary Industries and Regional Development, Western Australia, Perth. Resource Management Technical Report 380.

Smolinski H (2021) Chapter 1.5 Understanding the soils of the Kimberley and Pilbara. In 'Mosaic agriculture: a guide to irrigated crop and forage production in northern WA', Department of Primary Industries and Regional Development, Perth. Bulletin 4915.

Standards Australia (2006) HB 294:2006 National Post-Border Weed Risk Management Protocol, CRC Australian Weed Management, Adelaide, and Standards Australia International Ltd, Sydney.

Stone L, Munday C, Bettink K (2012) 'Environmental weed risk assessment protocol', Future Farm Industries CRC Weed Risk Assessment.

van Gool D, Tille PJ, Moore GA (2005) 'Land evaluation standards for land resource mapping: assessing land qualities and determining land capability in south-western Australia', Department of Agriculture and Food, Western Australia, Perth. Resource Management Technical Report 298.

Virtue J (2004) South Australia weed risk management guide, Animal and Plant Control Commission, South Australia.

Virtue JG, Bennett SJ, Randall RP (2004) 'Plant introductions in Australia: how can we resolve 'weedy' conflicts of interest?' *In* 14th Australian weeds conference papers and proceedings, Wagga Wagga, pp. 42–48.

Weeds of Australia – Biosecurity Queensland Edition, Queensland Government https://keyserver.lucidcentral.org/weeds/data/media/Html/index.htm

PR003-22