Refining the environmental weed risk assessment for non-indigenous plants which may have agricultural potential

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Summary Traditionally, in the rangelands of Western Australia (WA), the pastoral industry has relied on grazing of native vegetation. However, in recent years there has been considerable interest in mosaic agriculture based on irrigated forages. There is also a potential role for improved dryland pastures in medium to high rainfall areas of the Kimberley.

Under these conditions there is increased interest in the introduction of non-indigenous species which may improve the productivity and sustainability of agricultural systems. However, there is also clear evidence that a number of introduced non-indigenous plant species have become established in non-target areas and some have become environmental weeds.

An Environmental Risk Framework and weed risk assessment (WRA) protocol to assess species with agricultural potential in southern Australia was developed for the Future Farm Industries Co-operative Research Centre (FFI CRC) (Stone *et al.* 2012). This protocol has been adapted for use in the rangelands of northern Western Australia. The refined methodology introduces the concept of 'Inherent weed risk'. The potential distribution or land capability is considered as a separate, but integral step in the process to provide a flexible system which can assess the risk at the regional scale and also take account of the operational context.

This environmental WRA system is designed to improve the access, transparency, rigour and consistency of information available to policy makers and those considering the use of non-indigenous species and their introduction to novel environments in the WA rangelands.

Keywords Non-indigenous plants, rangelands, environmental weeds.

INTRODUCTION

Western Australia's (WA) rangelands experience a variety of extreme climatic conditions and contain multiple unique ecosystems with high environmental, economic, social and cultural values. It is an area with a rich endemic flora and fauna recognised with two World Heritage listed sites and many National Parks. However, the WA rangelands are also the source of great mining wealth and contain large areas under pastoral production, together with associated infrastructure (roads, rail, and ports). In some regions there has been a long history (>100 years) of grazing by domestic and feral animals. As a result, the condition of the native vegetation varies widely from pristine to highly denuded and disturbed areas due to overgrazing and soil erosion.

Traditionally agriculture in the WA rangelands has predominantly relied on the grazing of stock on native vegetation, with the development of irrigation precincts around Carnarvon and on the Ord River near Kununurra. However, in recent years there has been considerable interest in mosaic agriculture based on irrigated forages 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 in medium to high rainfall areas of the Kimberley.

The introduction of non-indigenous species may improve the productivity and sustainability of agricultural systems, including pastoral enterprises, and they 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 throughout Australia that some non-indigenous species introduced for forage have become established in non-target areas and some have become environmental weeds (Lonsdale 1994, Cook and Dias 2006). For example, Virtue *et al.* (2004) reported that 23% of species introduced into Australia as potential forage species were weeds of natural ecosystems. 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 may also increase the risk that it will become a weed capable of invading natural environments. A weed risk assessment (WRA) can provide information for species selection and management to help achieve a balance between the risk to the natural environment and potential agricultural productivity.

POST-BORDER WEED RISK ASSESSMENT

Post-border WRA in Australia has predominantly focused on prioritising species identified as weeds for management/control). The Future Farm Industries Co-operative Research Centre (FFI CRC) environmental WRA system was designed to assess the weed risk of forage and agro-forestry species to natural ecosystems across southern Australia (Stone *et al.* 2008, 2012) using the principles of the National Post-Border Weed Risk Management Protocol (Anon. 2006) and the South Australian Weed Risk Management Guide (Virtue 2004).

Both current commercial and prospective species were assessed and species assessed as having a 'very high' weed risk were not evaluated or promoted by the FFI CRC. The key characteristics of the FFI CRC Environmental WRA protocol were that:

- three criteria were used to assess weed risk: invasiveness, impact and potential distribution;
- the WRA were undertaken by pasture agronomists and weed scientists who had a good understanding of the species;
- the WRA were fully documented including references and sources for unpublished data;
- the WRA were critically reviewed by independent subject experts prior to being published on-line;
- the potential distribution maps were based on the combination of three factors: areas of native vegetation with a strong climate match (CLIMATE match top 20%) and suitable soils; and
- the WRA was part of an environmental weed risk strategy which included a 'not recommended' category. (Stone *et al.* 2008, 2012).

Interest in the introduction of non-indigenous into the WA rangelands suggested the need for a WRA for the region which could be based on the established and peer reviewed FFI CRC Environmental WRA system, but with some changes to reflect the different environment and objectives.

The WA Rangelands WRA protocol retains the three sections outlined in the FFI CRC Environmental WRA protocol, together with the key characteristics as outlined above. The main change in the WA Rangelands WRA protocol is the relationship with, and methodology for the potential distribution component.

The information explored for the Invasiveness and Impacts sections is essentially the same, however some questions have been rephrased as they were previously aligned with the FFI CRC forage improvement program and examples provided are from a rangelands context. The five weed risk levels in the FFI CRC system have been reduced to 4 inherent weed risk categories reflecting four recommendations or management guidelines to minimise weed risk to the natural environment.

The key refinement is the introduction of the term, 'Inherent weed risk' which is determined from the Invasiveness score multiplied by the Impacts score (Equation 1). In essence this reflects the relevant inherent characteristics of a plant species and applies irrespective of where it is grown or whether it is well suited, or poorly suited to a particular environment.

$$\text{Invasiveness score } (0\text{–}10) \times \text{Impacts score } (0\text{–}10) = \text{Inherent weed risk } (0\text{–}100) \qquad (\textit{Equation 1})$$

The Inherent weed risk scores fall along a continuum, but these scores have been divided into categories, so that appropriate management guidelines can be developed. The four categories of Inherent weed risk and the class categories were computed from the calibrated scores used in the FFI CRC Environmental WRA system (Stone *et al.* 2012).

Inherent weed risk category	Weed risk score*
1	>38.4*
2	23–38.4
3	13.7–22.9
4	≤13.6

*Weed risk values computed from Stone *et al.* (2012).

Example: A species has a weighted Invasiveness score of 4.2 out of 10 and an Impacts score of 5.2 out of 10, which when multiplied gives an inherent weed risk score of 21.8. This equates to Inherent weed risk Category 3 and applies irrespective of whether it is broadly suited, a niche species, or poorly suited to a particular environment.

The Land capability – potential distribution assessment is the final step – how well suited is the species to the assessment area? The assessment area could be a region, sub-region or 'site specific'. It is important to consider both the proposed site and surrounding land systems plus the broader region. In addition, the proximity to high value environmental assets should also be considered.

POTENTIAL DISTRIBUTION

Stone and Byrne (2011) compared five post-border WRA systems and reported that there was considerable variation in the determination of species distribution and that it significantly impacts on the final outcome of the WRA. Likewise, within the FFI CRC Environmental WRA, the potential distribution maps were often the main point of debate within the reviewing Technical Committee.

The Department of Primary Industries and Regional Development (DPIRD) in WA have been producing potential distribution maps for species based on climate for the rangelands of Western Australia. This has involved an overall Australian climatic profile developed using CLIMATCH (Anon. 2008) based on each species' overseas distribution and a final climate outcome score determined for the Kimberly and Pilbara regions. The CLIMATCH analysis is undertaken using data from a global distribution map from the Global Biodiversity Information Facility (GBIF 2014).

Similar methods have been used elsewhere (Brown *et al.* 2006), however some maps appear to: (a) either over- or under-estimate the potential distribution for species for which the soil and climate requirements are well understood, or which are naturalised in the Kimberley and Pilbara; or (b) the potential distribution for Australia has a weak correlation with the naturalised current distribution from the Atlas of Living Australia (ALA 2018) for species with a long history under cultivation.

These issues suggest that there is scope to consider new ways to determine potential distribution. A series of new potential distribution maps were produced through Charles Sturt University for 30 species considered to have potential for dryland or irrigated agriculture in the Kimberley and Pilbara regions.

The methodology to produce the potential distribution maps based on soils (no fertiliser) and climate was adapted from that used for the Tropical Forages Database potential distribution maps (Cook *et al.* 2005). The maps were produced using a GIS system to combine four climate layers together with soils information (Table 1). For each species the climate information was classified using the FAO UN Ecocrop database for annual rainfall, growing season temperature, elevation and climate zone (Anon 2013).

The soils information was taken from the DPIRD Soils database which for the Kimberley and Pilbara uses the proportion of WA Soil Super-groups (Schoknecht and Pathan 2013) within each map unit which are based on land system mapping @1:250,000. For each species the land capability class was assessed for the WA Soil Super-groups (no fertiliser) using a standard five class capability system adapted from FAO UN (1976) and van Gool *et al.* (2005) for a rangelands context.

The five layers of digital information were classified (e.g. optimal, absolute, or neither for both annual rainfall and growing season temperature) and then combined using consistent rules to determine the final percentage in each capability class. The maps display the percentage of an area which is suitable, or suitable to marginally suitable.

A matrix table of the Inherent weed risk and the land capability–potential distribution determines the four categories of management guidelines. Species assessed as Category 4 have a negligible to low risk of becoming environmental weeds and as a consequence it is not essential to determine their potential distribution.

Table 1. A summary of the input data sets for the potential distribution maps for the Pilbara-Kimberley regions.

Input data	Source
Annual rainfall	Bureau of Meteorology (BoM) 1961–1990 averages, resolution 0.025 degrees (approx. 2.7 km)
Average minimum growing season temperature	BoM 1961–1990 minimum average minimum temperature Dec-Mar, resolution 0.025 degrees (approx. 2.7 km)
Elevation	Shuttle Radar Topographic Mission (SRTM) digital surface model resolution 0.000833 degrees, resampled to 0.025 degrees
Climate zone	Trewartha climate zones, calculated from monthly rainfall and temperature long term averages (1961–1990)
Soils	Land System map units with % of Soil Super-groups for Kimberley and Pilbara (shapefile)
Species requirements	FAO Ecocrop data sheets plus Tropical species X WA soil groups (land capability)

DISCUSSION

The WA Rangelands WRA protocol has been specifically developed as a post-border assessment of the risk of non-indigenous species which may have agricultural value in the WA rangelands becoming environmental weeds.

With the FFI CRC Environmental WRA system if there are no areas with a good climate match, suitable soils and native vegetation, the potential distribution is attributed a score of 0.5 (Stone *et al.* 2012). The context for the FFI CRC was dryland or rainfed perennial pastures and agro-forestry species. In low rainfall rangelands (e.g. Pilbara) most pastures and fodders require irrigation to persist, so the potential distribution score would be 0.5. In this scenario any species could potentially be grown under irrigation as the maximum potential score would be 50 (i.e. 10 × 10 × 0.5) and in practice likely to be less than 32 which equates to a low weed risk (Stone *et al.* 2012).

In the WA Rangelands most of the agricultural development is based on irrigation, but there is the risk of propagule movement over long distances through stock or vehicle movement (Randall 2014). The introduction of 'Inherent weed risk' overcomes this issue as it identifies higher risk species. For example, species with an inherent weed risk score in category 1 (i.e. >38.4) require special management conditions even when grown in areas where they would not persist without irrigation.

This is illustrated by two hypothetical species – species A has an FFI CRC weed risk score (Invasiveness score x Impacts score x Potential distribution) of 4 × 4 × 10 = 160 (high), while species B also has a FFI CRC weed risk score of 160 (8 × 8 × 2.5 = 160). However, the inherent weed risk scores are 16 (Category 3) and 64 (Category 1), respectively, for species A and B, which better reflects the risk to the environment.

To date, 10 species have been assessed using the refined Rangelands WRA protocol and reviewed by independent assessors with technical knowledge of the species. Examples of the Inherent weed risk score results versus FFI CRC weed risk scores are presented (Table 2).

This environmental WRA system is designed to add to the transparency, scientific rigour and consistency of information available to those considering the selection or use of non-indigenous species and their introduction to novel environments in the WA rangelands. For example, pastoralists could use this information when considering the selection of non-indigenous species. In addition a high proportion of the WA rangelands are currently under pastoral lease, and under this tenure pastoralists are required to apply for a diversification permit from the Pastoral Lands Board (PLB) to grow non-indigenous plants. The PLB through the Department of Lands 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). These WRAs provide information to aid the decision making process. The new methodology is under final stages of development and is yet to be adopted across all agencies.

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Table 2. A comparison of Inherent weed risk versus the Invasiveness × Impacts × Potential Distribution WRA scores for key species in the Pilbara and Kimberley of Western Australia.

Species	Common name	Inherent weed risk category	Pilbara Inv × Imp × PD	Kimberley Inv × Imp × PD
Cenchrus setiger Vahl	birdwood grass	2	3	2
Cenchrus ciliaris L.	buffel grass	1	2	1
Leucaena leucocephala (Lam.) de Wit	leucaena	1	3	2
Megathyrsus maximus (Jacq.) B.K.Simon & S.W.L.Jacobs	panic grass	3	4	4
Cenchrus amercianus (L.) Morrone	pearl millet	4	4	4
Chloris gayana Kunth	Rhodes grass	3	4	4
Stylosanthes hamata L. (Taub)	Caribbean stylo	3	4	2

REFERENCES

ALA (2018). Atlas of Living Australia. http://www.ala.org.au/australias-species/ (accessed 14 August 2018).

Anon. (2006). HB 294:2006. National post-border weed risk management protocol. (CRC Australian Weed Management, Adelaide and Standards Australia, Sydney and Standards New Zealand, Wellington).

Anon. (2008). CLIMATCH. Department of Agriculture, Fisheries and Forestry, Bureau of Rural Sciences. http://data.daff.gov.au:8080/Climatch/climatch.jsp (accessed 14 August 2018).

Anon. (2013). Ecocrop database. FAO Rome, Italy http://ecocrop.fao.org/ecocrop/srv/en/home (accessed 14 August 2018).

Brown, L., Barry, S., Cunningham, D. and Bomford, M. (2006). Current practice in applying CLIMATE for weed risk assessment in Australia. Proceedings of the 15th Australian Weeds Conference, eds C. Preston, J.H. Watts and N.D. Crossman, pp. 703-6. (Weed Society of South Australia.

Cook, B.G., Pengelly, B.C., Brown, S.D., Donnelly, J.L., Eagles, D.A., Franco, M.A., Hanson, J., Mullen, B.F., Partridge, I.J., Peters, M. and Schultze-Kraft, R. (2005). Tropical Forages: An interactive selection tool, CSIRO, DPI and F (Queensland), CIAT and ILRI, Brisbane, Australia.) http://www.tropicalforages.info/ (accessed 14 August 2018).

Cook, G.D. and Dias, L. (2005). Turner Review No. 12 It was no accident: deliberate plant introductions by Australian Government Agencies during the 20th century. Australian *Journal of Botany* 54, 601-25.

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

GBIF (2014). Global Biodiversity Information Facility. http://www.gbif.org/ (accessed 14 August 2018).

Lonsdale, M.W. (1994). Inviting trouble – introduced pasture species in northern Australia. *Australian Journal of Ecology* 19, 345-54.

Payne, A.L., Watson, I.W., and Novelly, P.E. (2004). Spectacular recovery in the Ord River catchment. Miscellaneous Publication No. 17/2004. Department of Agriculture and Food, Western Australia Perth.

Randall, R. (2014). Weed threats to the Kimberley Region, Pathways and the risk of incursion. Department of Agriculture and Food, Western Australia.

Schoknecht, N.R., and Pathan, S. (2013). Soil groups of Western Australia: A simple guide to the main soils of Western Australia (4th Edition). Resource Management Technical Report 380. Department of Agriculture and Food, Western Australia, Perth.

Stone, L.M. and Byrne, M. (2011). Comparing the outputs of five weed risk assessment models implemented in Australia: are there consistencies across models? *Plant Protection Quarterly* 26, 29-35.

Stone, L.M., Byrne, M., and Virtue, J.G. (2008). An environmental weed risk assessment model for Australian forage improvement programs. *Australian Journal of Experimental Agriculture*, 48, 568-74.

Stone, L., Munday, C. and Bettink, K. (2012). Future Farm Industries CRC Weed Risk Assessment.

Thorpe, J.R. and Lynch, R. (2000). The determination of Weeds of National Significance. National Weeds Strategy Executive Committee, Launceston.

van Gool, D., Tille, P.J. and Moore, G.A. (2005). Land evaluation standards for land resource mapping: Assessing land qualities and determining land capability in south-western Australia. Report 298. Department of Agriculture and Food, Western Australia, Perth.

Virtue, J. (2004). SA Weed Risk Management Guide. Animal and Plant Control Commission, South Australia.

Virtue, J.G., Bennett, S.J. and Randall, R.P. (2004), Plant introductions in Australia: how can we resolve 'weedy' conflicts of interest? Proceedings of the 14th Australian Weeds Conference, eds B.M. Sindel and S.B. Johnson pp. 42-8. (Weed Society of New South Wales, Wagga Wagga).