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LEADING THE SEARCH FOR WEED SOLUTIONS

# Best Practice for Making Strategic Decisions About Invasive Plants of Commercial Value

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# Best Practice for Making Strategic Decisions About Invasive Plants of Commercial Value

by Tony Grice, Margaret Friedel, Samantha Setterfield, Keith Ferdinands, John Clarkson, John Rolfe, Neil MacLeod

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*Best Practice for Making Strategic Decisions About Invasive Plants of Commercial Value*
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# Foreword

A number of plant species introduced into Australia are important for their commercial value but also can become invaders. Divergent perspectives on these commercially valued invasive species have led to contention among interested parties, and a concerted effort is urgently needed to resolve these conflicts.

A central step towards resolution is the development and application of assessment and policy frameworks that incorporate an understanding of the ecological, economic and social factors involved.

The intention of this research was to provide a foundation for objective, comprehensive and coherent approaches to resolving controversial weed problems. The project was therefore designed to identify approaches to a more thorough analysis of economic, environmental and social costs and benefits and to explore policy, regulatory and management options for dealing with species that are both weedy and beneficial.

This research outlines better processes for making decisions about contentious invasive plants of commercial value. It therefore proposes that weed risk management (WRM) systems have a clear framework backed by guiding principles and a time frame.

This project was funded in Phase 1 of the National Weeds and Productivity Research Program, which was managed by the Australian Government Department of Agriculture, Fisheries and Forestry (DAFF) from 2008 to 2010. The Rural Industries Research and Development Corporation (RIRDC) is now publishing the final reports of these projects.

Phase 2 of the Program, which is funded to 30 June 2012 by the Australian Government, is being managed by RIRDC with the goal of reducing the impact of invasive weeds on farm and forestry productivity as well as on biodiversity. RIRDC is commissioning some 50 projects that both extends on the research undertaken in Phase 1 and moves into new areas. These reports will be published in the second half of 2012.

This report is an addition to RIRDC's diverse range of over 2200 research publications which can be viewed and freely downloaded from our website www.rirdc.gov.au. Information on the Weeds Program is available online at www.rirdc.gov.au/weeds

Most of RIRDC's publications are available for viewing, free downloading or purchasing online at www.rirdc.gov.au. Purchases can also be made by phoning 1300 634 313.

**Craig Burns**
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# Executive Summary

## What the report is about

This project critically examines current approaches to weed risk management at the national and state and territory levels and, in particular, their relevance for dealing with contentious commercially valued plants.

Building on the deliberations of a working group and a smaller writing workshop, this research identifies some of the impediments to improved management of contentious plants and develops a possible framework for aiding decision making and management responses in connection with invasive species.

It builds on the currently available frameworks and tools in order to put forward a combination of improved use of existing methods and the incorporation of some additional decision-support tools.

The research acknowledges that invasive but commercially valued species are often inadequately managed; it looks at why, and offers a number of options that might reduce adverse effects while still enabling commercial uses. It also discusses containment of contentious commercially useful plants, describes the challenges associated with this, and suggests ways these might be overcome.

Finally, it outlines research proposals designed to respond to impediments or knowledge gaps that limit our ability to strategically manage contentious plants.

## Aims/objectives

This research had two aims:

- to identify approaches to a more thorough analysis of economic, environmental and social costs and benefits; and
- to explore effective policy, regulatory and management options for dealing with species that are both invasive and beneficial.

The intention was to provide a foundation for objective, comprehensive and coherent approaches to resolving controversial weed problems.

## Methods used

A working group of resource economists, weed ecologists, social scientists and policy experts considered the following:

- frameworks for analysing and assessing economic, environmental and social factors associated with the production, impacts and control of these weeds
- policy options for supporting strategic decisions relating to commercial use of contentious plant species
- containment protocols that might help avoid or minimise costs while supporting benefits in cases where it is decided to permit the commercial exploitation of a species that also presents a risk as a weed
- knowledge gaps and research needs.

## Results/key findings

This project concludes that the systems for managing the potential introduction of new species are robust but that the legacy of earlier introductions remains a serious problem. It suggests that existing legislation could be improved or more effectively applied, that there are a number of tools that could support better decision making, and that there are gaps in knowledge that currently impede progress.

### *Implications are relevant for stakeholders in:*

- *industry*
- *communities*
- *policy makers*
- *others where relevant*

## Recommendations

This research outlines better processes for making decisions about contentious invasive plants of commercial value. It therefore proposes that WRM systems have a clear framework backed by guiding principles and a time frame.

# Introduction

A number of introduced plant species in Australia are, or have the potential to be, commercially valuable as well as highly invasive, among them pasture grasses, tree crops and prospective biofuel plants. Despite innovative research into a number of these species in northern Australia—for example, buffel grass (Friedel et al. 2009), olive hymenachne (Miles 2009) and gamba grass (Setterfield 2009)—there remain knowledge gaps in relation to best practice for managing the species strategically. There are, for instance, limits to the application of cost-avoided economic models where the main impacts are those to which it is difficult to assign an economic cost, such as biodiversity loss and cultural use. Improved management calls for better tools for analysing all costs and benefits associated with these species, incorporation of the results of these assessments in relevant policies, and implementation of effective containment strategies in cases where commercial use of invasive species is allowed to proceed.

Our intention was to provide a foundation for objective, comprehensive and coherent approaches to resolving controversial weed problems. The project was therefore designed to identify approaches to a more thorough analysis of economic, environmental and social costs and benefits and to explore policy, regulatory and management options for dealing with species that are both weedy and beneficial.

## Research approach and methods

We wanted to review the current situation in relation to introduced plant species that are commercially valuable yet invasive or potentially so and then propose a consistent approach for resolving problems associated with use of these species. We established a working group of resource economists, weed ecologists, social scientists and policy experts to examine the following elements of the project:

- frameworks for analysing and assessing economic, environmental and social factors associated with the production, impacts and control of these weeds
- policy options for supporting strategic decisions relating to commercial use of contentious plant species
- containment protocols that might help avoid or minimise costs while supporting benefits in cases where it is decided to permit the commercial exploitation of a species that also presents a risk as a weed
- knowledge gaps and research needs.

An initial workshop reviewed existing approaches and considered ways in which they might be improved. At a subsequent writing workshop the material developed was drafted into publishable form as the basis for this report and the development of journal publications and presentations at the 17th Australasian Weeds Conference in September 2010.

# Outputs and outcomes

## Project workshop, 22–24 April 2009

A working group of 15 people with expertise in resource economics, policy, social science and ecology was convened to identify approaches to a more thorough analysis of the economic, environmental and social costs and benefits of commercially valued invasive species and to investigate more effective policy, regulatory and management options. Appendix A lists the workshop participants.

## Writing workshop, 20–24 October 2009

The structure and content of this report were devised by the five people who participated in the writing workshop. Two papers—presented here in the following two sections—were the main products of this workshop. They discuss the four elements of the project (as just listed). A proposal for a symposium at the 2010 Australian Weeds Conference was also developed and was subsequently accepted by the conference organisers.

## Communications plan

We developed a communications plan with three aims in mind:

- to ensure that all interested parties are aware of and understand the project results
- to build links with Land and Water Australia initiatives arising from recent Defeating the Weed Menace projects (dealing with the delivery of policy advice to governments) through communication with the personnel involved. The project builds in part on DWM projects led by our three participating institutions
- to secure long-term benefits as a result of this project by strengthening collaborative links between team members' institutions through other ongoing activities such as the Australian Weeds Conference symposium in September 2010.

Funding opportunities for the preliminary research proposals did not arise during the term of the project but will be sought in future.

# A framework for tackling contentious commercially valued plants

## Introduction

Many plants are problematic when introduced to new environments because they naturalise and adversely affect agricultural production, other industries, natural environments and ecosystem services. For a large proportion of such species it is widely accepted that these problems exist, but for others it is a matter of contention. This contention can relate to whether a particular species is problematic or to the fact that some groups of people value the species while others experience or perceive that they experience deleterious effects from them. A common scenario is that of plants being introduced for ornamental purposes or for soil stabilisation but then naturalising to become environmental weeds. Another, perhaps smaller, group of species are those that are directly exploited for commercial gain by one group but that threaten other economic, environmental or ecosystem values. They become 'contentious commercially valued plants', and it is this group that is the subject of this report. Unless indicated otherwise, throughout this report we use the term 'contentious plant' to refer specifically to species that are contentious because they have real or perceived commercial production values but negative effects on other industries, natural environments or ecosystem services.

The usual approach to pest plant problems is to apply weed or pest plant legislation. In Australia there is Commonwealth, state and territory, and local government legislation relating to weeds. The main Commonwealth involvement arises through international border control, including formal weed risk assessment to determine whether a species not currently in the country should be permitted entry. State- and territory-level legislation generally involves allocating individual plant species to a specific class of weeds depending on the nature of the problem and the strategic goal to be applied to it. In most jurisdictions this is an all-or-nothing approach in which individual species are either permitted entry or not or declared to be weeds or not. Generally, when entry is permitted there are no subsequent Commonwealth controls on how or where a species is exploited. But plants cannot so readily be grouped into useful and problematic categories: many species have attributes that make them useful or desirable and attributes that make them problematic. Further complicating the situation is the fact that the perceptions of individuals and interest groups differ in relation to the values associated with particular species and on what constitutes an appropriate approach to its management. Disagreements inevitably arise.

Regulation of the cultivation of commercially valued plants has not been common, and those who experience negative consequences of the plants' naturalisation and spread are left to deal with them using their own resources. Prohibition of the cultivation of species that have been demonstrated to have commercial value in their introduced range is also uncommon, although potentially commercially useful species have been rejected (that is, prohibited) at jurisdictional borders on the basis of the results of formal weed risk assessment. Least common of all, perhaps, have been systematic and coordinated attempts to both capture the benefits of using a commercially valued species and minimise any adverse effects that it might have.

There are major barriers to efforts to gain benefits from plants and yet avoid or minimise any adverse effects they might have. To do so requires land managers to maintain fields, pastures, orchards or plantations of these plants while either preventing them from spreading to other areas where they might have deleterious effects or at least suppressing their 'off-site' populations to below a threshold above which their impacts are unacceptable.

Some of the barriers to achieving this balance are biophysical: as with management of any problematic species, there must be the means of detection, population control and monitoring. Other challenges are economic: a laissez-faire approach can impose considerable costs on those who do experience negative consequences of an invasive plant. A systematic, coordinated and more balanced alternative to such an approach would see a shift in costs and benefits. Measures could be introduced that transfer some of the benefits that would otherwise accrue to growers toward those who experience, or would otherwise experience, negative consequences. Another option is for the costs incurred by those who experience negative consequences to be offset to a third party—most obviously government and its agencies.

There could also be legislative and policy barriers to gaining benefits while minimising costs. Current legislation and policy do not in the main make explicit provision for facilitating both the exploitation and the control of contentious plants, which partly explains why contentious species are either unregulated or prohibited.

Finally, there are social barriers to the balanced resolution of difficulties associated with commercially valued contentious plants. It has been common for interested parties to take a confrontational approach to such situations, rather than seek consensus or compromise. This has been in keeping with the 'all or none' approach to contentious plants in practice.

Approaches to contentious plants need to accommodate differing scenarios. The scenarios vary in terms of the distribution and abundance of the plants under consideration, the plants' legislative status, their importance to the industry that depends on them, and the stage of development of that industry. Three broad classes of contentious plants can be defined:

- widely distributed and exploited plants that have commercial value but are declared weeds under legislation. Gamba grass (*Andropogon gayanus*) and olive hymenachne (*Hymenachne amplexicaulis*) are examples

- widely distributed and exploited plants that have commercial value but are not declared weeds under legislation. Para grass (*Urochloa mutica*) and buffel grass (*Cenchrus ciliaris* syn. *Pennisetum ciliaris*) are examples

- new or novel species of unproven commercial value. Species currently being proposed as sources of biofuels—such as *Jatropha curcas*, diesel tree (*Copaifera langsdorffii*) and the native tree pongamia (*Milletia pinnata* syn. *Pongamia pinnata*)—meet this criterion. None of them has yet been extensively planted in Australia. Neem (*Azadirachta indica*), a prospective horticultural crop, is a more widespread example, some being grown in informal domestic situations and some in speculative, quasi-commercial plantings.

Each of these classes of contentious plants presents its own set of challenges to be met through a combination of legislation and regulation, provision of incentives, application of penalties, and individual, corporate and community-level action to exploit and/or control the species. Decisions about how to deal with particular cases should be based on the best available information.

In this report we briefly describe and critically examine current approaches to weed risk management at the national and state and territory levels and, in particular, their relevance for dealing with contentious commercially valued plants. This includes analysis of a decision-making framework that provides a systematic way of dealing with problem plants, emphasising elements that expressly target contentious species. We review the tools available to support the decisions that are necessary and provide examples and case studies of their application. We then examine the reasons why strategic management of problem plants in general—and contentious commercially valued species in particular—is not better than it currently is. Finally, we identify knowledge gaps and research needs relevant to improving the current systems.

## Risk management for commercial weeds

In the past few decades the impacts of weeds on Australia's natural and agricultural environment have been so substantial that major changes have been made to the legislation and policies relating to weed management. The most significant change has been the development and implementation of weed risk assessment, or WRA, tools at both the national and the state and territory levels. This section reviews the current Australian weed risk frameworks—in particular, their relevance and limitations for dealing with contentious commercially valued plants. We present a decision-making framework that offers a systematic way of dealing with problem species, especially contentious ones.

### National, or pre-border weed risk assessment

In response to the substantial impacts of many invasive species across the continent, Australia has been an international leader in the development and implementation of regulatory systems aimed at minimising the chances of future introductions into the country of high-risk species.

Importation of live animals and plants into Australia is regulated by the *Environmental Protection and Biodiversity Conservation Act 1999* and the *Quarantine Act 1908*, both of which are administered by the Australian Government. Under the former Act only species that appear on a list of approved species may be imported live into Australia. Amendments to the list can occur after a thorough assessment using Biosecurity Australia's WRA system—see http://www.daff.gov.au/ba/reviews/weeds/system.

At the national level, weed risk assessments are usually completed on the individual species, although sub-specific taxa or hybrids can be assessed. Assessment is based on 49 questions about the characteristics of the species. A number of reviews have demonstrated the robustness of the Australian WRA system, both within Australia and in international comparisons. Gordon et al. (2008) compared its accuracy across six regions—New Zealand, Hawaii and the Pacific Islands, the Czech Republic, the Bonin Islands and Florida—and showed that it accurately identified major invaders 90 per cent of the time and non-invaders 70 per cent of the time.

The reviews of Biosecurity Australia's WRA system suggest that the risk of new contentious species being introduced into Australia is low. It might, however, be possible to legally import some new cultivars or hybrids of species that are currently on the permitted list and that could subsequently result in major range expansion of those species or greatly increase their negative environmental and social impacts. An example is Frio, the new cultivar of buffel grass (*Cenchrus ciliaris*), which was bred by the US Department of Agriculture to be more tolerant of cold than other cultivars. Concern has been expressed in the United States that this cultivar could result in the species spreading much further north than the current area of invasion (Darin 2006); a similar range expansion could occur in Australia where the species is limited by cold climate.

Increased genetic diversity confers higher evolutionary potential, which can augment the invasive potential of species (Lavergne & Molofsky 2007). Indeed, international research suggests that hybridisation is one stimulus for the evolution of invasiveness in plants (Schierenbeck & Ellstrand 2008), and the increased risk of multiple introductions of an invasive species needs to be considered in any national strategy for the management of invasive species.

### State and territory, or post-border, weed risk management

All Australian states and territories have legislation that aims to prevent the spread of weeds into, within or out of their respective jurisdictions and to ensure that the management of these plants is an integral component of land management (see Tables 1 and 2). The legislation defines categories of declaration and describes the requirements and responsibilities of government and landholders for achieving the objectives of the Acts.

Table 1 Classes of weeds: Australian state and territory legislation

| State/ territory | Legislation | Weed class | Action required under legislation |
|---|---|---|---|
| Australian Capital Territory | *Pest Plants and Animals Act 2005* http://www.legislation.act.gov.au/a/2005-21/default.asp | Class 1 | Species is notifiable |
| | | Class 2 | Species must be suppressed |
| | | Class 3 | Species must be contained |
| | | Class 4 | Propagation and supply are prohibited |
| New South Wales | *Noxious Weeds Act 1993* http://www.legislation.nsw.gov.au/viewtop/inforce/act+11+1993+FIRST+0+N | Class 1 | Not present in state or limited in extent; notifiable; must be eradicated and the land must be kept free of the species; sale prohibited; restrictions apply to movement |
| | | Class 2 | Not present in target region or limited in extent; notifiable; must be eradicated from the land and the land must be kept free of the species; sale prohibited; restrictions apply to movement |
| | | Class 3 | Not widely distributed in target region but likely to spread there or to other regions; species must be fully and continuously suppressed and destroyed; sale prohibited |
| | | Class 4 | Widely distributed in target region and likely to spread there or elsewhere; growth and spread of species must be controlled according to the measures specified in a management plan published by local control authority |
| | | Class 5 | Likely, by their sale or the sale of their seeds or movement within the state or part of the state, to spread in the state or outside the state; notifiable, although there are no requirements to control existing plants; sale prohibited; restrictions apply to movement |
| Northern Territory | *Weed Management Act 2001* http://notes.nt.gov.au/dcm/legislat/legislat.nsf/linkreference/WEEDS%20MANAGEMENT%20ACT%202001 | Class A/C | Reasonable effort must be made to eradicate species; must not be introduced |
| | | Class B/C | Reasonable attempts must be made to control growth and prevent spread; must not be introduced |
| | | Class C | Not present; must not be introduced |
| Queensland | *Land Protection (Pest and Stock Route Management) Act 2002* http://www.legislation.qld.gov.au/LEGISLTN/CURRENT/L/LandPrPSRMA02.pdf | Class 1 | Not commonly present in state; subject to statewide eradication |
| | | Class 2 | Established in state; subject to control programs led by local government, community or landowners; landowners must take reasonable steps to keep land free of these plants; it is an offence to introduce, keep or supply them |

| State/ territory | Legislation | Weed class | Action required under legislation |
|---|---|---|---|
| | | Class 3 | Established in state; landholders required to control these plants if their land is adjacent to an environmentally significant area |
| South Australia | *Natural Resources Management Act 2004* http://www.legislation.sa.gov.au/LZ/C/A/NATURAL%20RESOURCES%20MANAGEMENT%20ACT%202004/CURRENT/2004.34.UN.PDF | Class 1 | Notifiable and requiring destruction throughout the state |
| | | Classes 2 and 4 | Notifiable in at least part of the state and requiring destruction throughout the state |
| | | Classes 3, 5 and 7 | Control required in part of the state |
| | | Classes 6, 8 and 9 | Special provisions apply to plants declared under these classes |
| | | Classes 10 and 11 | Sale restricted |
| Tasmania | *Weed Management Act 1999* http://www.dpiw.tas.gov.au/inter.nsf/Home/1?Open | Declared weeds | Species-specific requirements |
| Victoria | *Catchment and Land Protection Act 1994* http://www.dpi.vic.gov.au/DPI/nreninf.nsf/ | State prohibited | Not present or limited in extent; targeted for eradication by state government; landowners may be directed to prevent growth and spread |
| | | Regionally prohibited | Not widely distributed; must be managed for eradication; landowners must take all reasonable steps to eradicate the species |
| | | Regionally controlled | Usually widespread in particular region(s); landowners must take all reasonable steps to prevent spread and growth |
| | | Restricted | Trade of plants or their propagules prohibited |
| Western Australia | *Agriculture and Related Resources Protection Act 1976* http://www.slp.wa.gov.au/legislation/statutes.nsf/main_mrtitle_13_homepage.htm | P1 | Movement of plants or their seeds prohibited; movement of contaminated machinery and produce prohibited |
| | | P2 | Propagation and spread must be prevented and plants must be destroyed until population is eradicated |
| | | P3 | Seed set and spread of plant parts or seeds must be prevented |
| | | P4 | Seed set and spread of plant parts or seeds must be prevented |
| | | P5 | Infestations on public lands must be controlled |

Source: Grice et al. (2008).

Table 2 Weed legislation: northern Australia

| Legislation | Purpose and components[1] | Strategies and guidelines[2] | Declared weed classes[3] | Responsible agency |
|---|---|---|---|---|
| Queensland | | | | |
| *Land Protection (Pest and Stock Route Management) Act 2002*<br><br>Land Protection (Pest and Stock Route Management) Regulation 2003 | Governs the control and management of declared plants and animals.<br>• Establishes eight principles for pest management.<br>• Provides for planning through pest management strategies and guidelines and pest management plans for state and local government lands.<br>• Enables the declaration of plants considered serious or potentially serious and imposes restrictions (including introduction, possession and sale).<br>• Provides mechanisms to help prevent weed seed spread by livestock, products, soil and machinery.<br>• Lists landowner obligations.<br>• Allows for emergency declarations and the imposition of pest control notices.<br>• Establishes the Land Protection Council to give advice and make recommendations to the Minister.<br>• Provides for establishment of pest operational boards. | Queensland Weeds Strategy 2002–2006<br>Individual species strategies and guidelines (including control methods) can be found in the Department of Primary Industries and Fisheries policy register on the website, in the right-hand column.<br>Various local government pest management plans and plans developed by other government agencies would also be available by contacting those sources. | Class 1<br>Has the potential to become a serious threat. Import, possession and sale to be prevented.<br>Class 2<br>Already spread over substantial areas, but impact is serious and control is required.<br>Class 3<br>Very common but is having a serious impact on native bushland. Control may be enforced on land that is, or is adjacent to, an environmentally significant area.<br>A local government may also prescribe any plant (other than a declared plant) as a weed within its jurisdiction. | Queensland Primary Industries and Fisheries and Department of Employment, Economic Development and Innovation<br>http://www.dpi.qld.gov.au/home.htm |
| Northern Territory | | | | |
| *Weed Management Act 2001* | The purpose of the Act is to:<br>• prevent the spread of weeds in, into and out of the Territory and to ensure that the management of weeds is an integral component of land management<br>• to ensure there is community consultation in the creation of weed management plans<br>• to ensure that there is community responsibility in implementing weed management plans.<br>The Act has provisions for:<br>• declaration of weeds or potential weeds. A person may be penalised for moving, selling or growing weeds<br>• weed management plans, weed advisory committees, designated quarantine and cleaning areas and use of a declared weed under permit. | NT Weeds Management Strategy 1996–2005<br>Katherine Regional Weed Management Strategy 2005–2010 | Class A<br>To be eradicated<br>Class B<br>Growth and spread to be controlled<br>Class C<br>Not to be introduced to the territory (includes all Class A and Class B weeds) | Department of Natural Resources, Environment, the Arts and Sport<br>http://www.nt.gov.au/nreta/ |
| Western Australia | | | | |

| Legislation | Purpose and components[1] | Strategies and guidelines[2] | Declared weed classes[3] | Responsible agency |
|---|---|---|---|---|
| *Agriculture and Related Resources Protection Act 1976*<br><br>*Plant Diseases Act 1989* | • Regulates entry and movement of declared plants.<br>• Makes provisions to prevent the sale of declared plants.<br>• Covers weed seeds as a contaminant in produce.<br>• Enables the declaration of plants for part or all of the state.<br>• Is administered by the Agriculture Protection Board. Regional Advisory Committees advise the board on weed and other protection matters.<br>• Weeds are regarded as a form of plant disease under the *Plant Diseases Act 1989*, with provisions allowing for plants to be permitted or excluded for quarantine purposes.<br>• Provides a listing of permitted and prohibited plants, with any species not on the list being prohibited until a weed risk assessment is performed. | State Weed Plan 2001<br><br>Industry Biosecurity Plans (HortGuard™, Grainguard™, StockGuard™ and BeeGuard™) prioritise protection strategies for pests, diseases and weeds for the relevant industries.<br><br>*Declared Plant Control Handbook:. recommendations for the control of declared plants in Western Australia* (Pierce & Pratt 2002) | P1 Prevention<br>Plants that cannot be introduced or spread. Most declared plants fall under this category.<br>P2 Eradication<br>Includes potentially serious weeds that are not yet widely distributed.<br>P3 Control<br>Plant infestations should be reduced over time if eradication is not realistic.<br>P4 Containment<br>Plants should be prevented from further spread.<br>P5 Special action on public land<br>Provides for control of land under the control of local government, saleyards and roadsides.<br>A local government may also prescribe any plant (other than a declared plant) as a weed within its jurisdiction. | Department of Agriculture, Western Australia<br>www.agric.wa.gov.au |

Source: www.weeds.org.au, www.nrm.qld.gov.au/pests, www.nreta.nt.gov.au/whatwedo/weeds, www.agric.wa.gov.au, Steve Csurhes, Queensland Department of Employment, Economic Development and Innovation (pers. comm.), Steve Wingrave, Northern Territory Department of Natural Resources, Environment, the Arts and Sport (pers. comm.). Compiled by Maria Kraatz.

1 This summary is by no means complete. Full explanations and copies of the relevant legislation are available from state and territory agencies.

2 Other state or territory and Commonwealth legislation can influence the management of weeds, as well as national strategies such as the Australian Weeds Strategy and strategic plans for the 20 weeds of national significance.

3 A full list of declared plants for all Australian states and territories is available on the Weeds Australia website—www.weeds.org.au. Listings are also available on individual agencies' websites.

Most Australian states and territories have developed and implemented weed risk management, or WRM, systems as decision-making tools that help determine appropriate weed management action, including the category of declaration and the priorities for weed management resources with respect to species and region or land type. The WRM systems incorporate both WRA and the feasibility of control of the weed. Systems vary between jurisdictions, but they are comparable in the requirement to assess the ecology, use, impact and management of the species (for details see Weiss & McLaren 2002; Virtue 2005; Setterfield et al. 2006; Johnson 2009). All meet the requirements of the National Post-Border Weed Risk Management Protocol (Standards Australia, Standards New Zealand & CRC for Australian Weed Management 2006) and are designed to provide transparent, objective and repeatable assessments of the risk and feasibility of controlling plant species. Their implementation by the states and territories has been an important advance.

The development of the WRM systems is evidence of an important advance in the states' and territories' willingness and ability to manage the risk of contentious commercial species. The WRM framework and its assessment tools ensure that recommendations are defendable and outcomes are not biased by lobbying from interest groups. There are, however, limitations to the systems, relating to the selection of plants to be assessed and the timing of and responsibility for review and action stages. Most systems do not have a guiding policy or framework describing how they should operate: only the Northern Territory has developed such a policy and a clear set of guiding principles.

We recommend that all states and the Australian Capital Territory clearly establish the policy objectives and purpose of their WRM system—including how species will be selected for assessment and the obligations that government has for management of the species on the basis of the assessment outcomes. The obligations should include a time frame for acting on nominations for assessment and for implementation of management recommendations following assessment. Such obligations are required under other legislation, such as that guiding environmental impact assessment.

In the absence of a clear policy on the means of selecting those species that are to be subject to weed risk assessment, the process appears ad hoc. Following substantial public conflict—including regular media coverage of government inaction (Setterfield et al. 2006)—about the beneficial use and the environmental and social impacts of gamba grass (*Andropogon gayanus*), WRM systems were used to assess and recommend declaration of the grass in Queensland, the Northern Territory and Western Australia. They were also used to assess and recommend declaration of olive hymenachne (*Hymenachne amplexicaulis*) in Queensland and Western Australia. (Olive hymenachne is also a declared weed in the Northern Territory, but this declaration occurred before implementation of the WRM system in the jurisdiction.) In contrast, the environmental, social and economic impacts of buffel grass and para grass are well known in Queensland, but the plants have not been assessed through that state's weed risk system. A more coordinated and systematic approach to the assessment of contentious commercially valued plants will help obviate inconsistencies in processes and minimise adverse outcomes.

The effectiveness of WRM systems is, however, limited if there is no requirement to act on the results within a particular time frame. When delays occur, the invasion area and the cost of effective management increase; in fact, delay can cause a situation to move beyond a threshold to one where effective action is not possible given the available resources. Despite this, government management agencies' response to weed risk assessments has been slow. For example, a WRA was completed for the ponded pasture grass aleman grass (*Echinochloa polystachya*) in Queensland in July 2008, but there has been no management response despite the WRAs conclusion that it is 'a highly invasive species that readily escapes cultivation to pose a significant threat to natural freshwater wetlands, mainly in coastal central Queensland' (Hannan-Jones & Weber 2008). The Northern Territory carried out WRAs for para grass and buffel grass in 2007, with the result that both were categorised as high risk. By November 2009, however, there had been no official management response, so there was no restriction on their planting or management.

By the time gamba grass and olive hymenachne were declared in Queensland and the Northern Territory, both species had been planted widely and had invaded natural areas outside the planted sites. Declaration brought the legal sale of, and other trade in, seed or other propagules to an immediate halt and prohibited further plantings. Enforcement of this probably prevented deliberate human-assisted spread into areas where these plants had not previously been used. For example, gamba grass had been planted on a number of properties on Cape York Peninsula and would almost certainly have been more widely planted had declaration not prevented the sale of seed. Prevention of sale and further planting can be one of the most useful devices in weed legislation, but its effectiveness is very much dependent on how extensively the species has been adopted before declaration. It can be in the interest of the proponents to delay declaration for as long as possible while private benefits accrue. As a result, the species can be widely adopted by producers in many areas before controls on further planting are introduced.

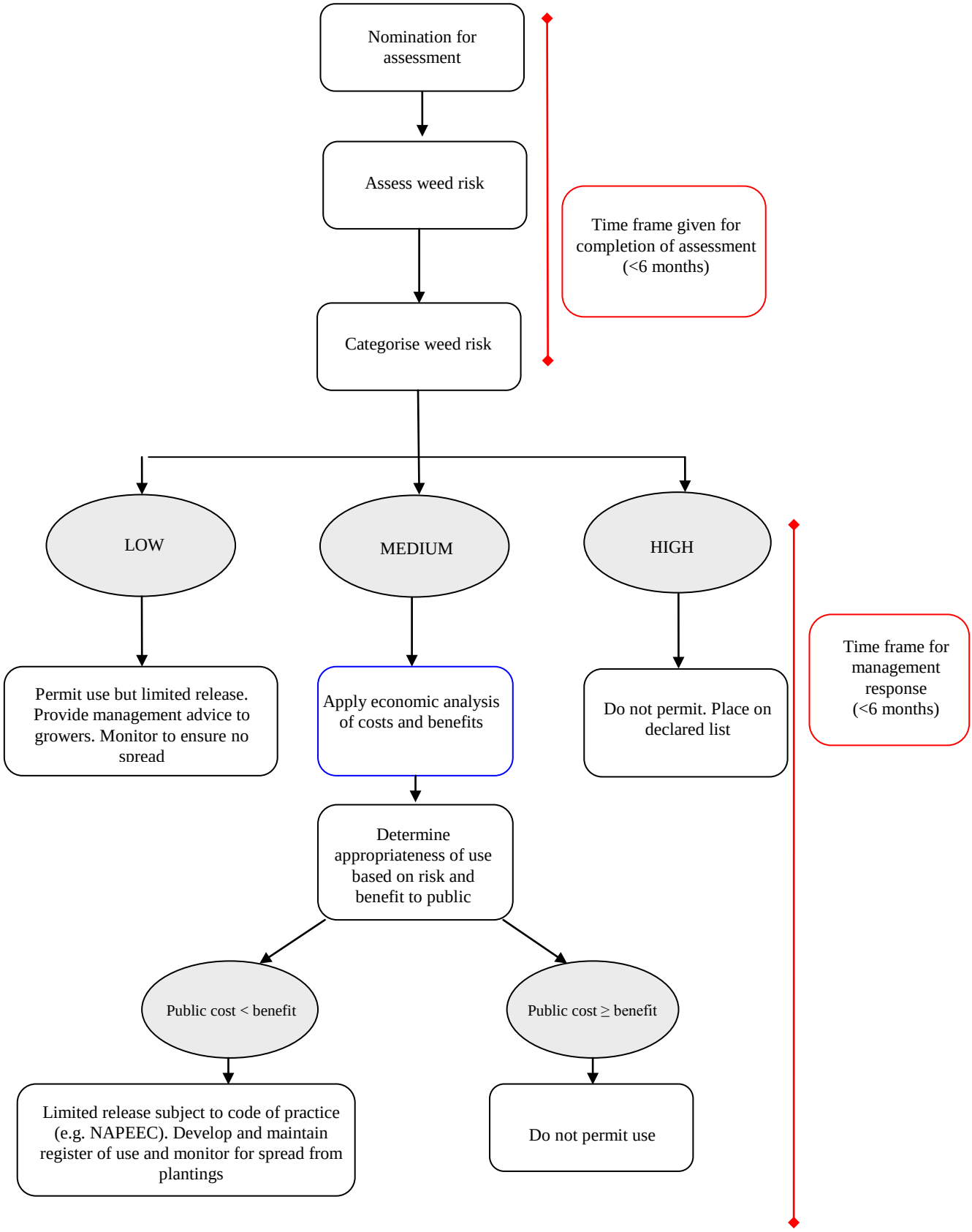
It is clear that the reason for a lack of management in the case of many commercial species has been pressure from user groups benefiting from them. In some cases the private benefits generated might have come at the expense of larger public and other private goods. WRM systems are good at identifying the high-risk species and the likelihood of management success (the feasibility of control). We contend, however, that economic assessment of the public and private costs and benefits would increase the likelihood of good management decisions and suitable action in relation to commercial weeds. Although there is a long history of assessing the costs and benefits of controlling weeds, this has been largely for agricultural weeds, where the cost of invasion can be measured in terms of production losses. Adapting these techniques and applying them to natural systems is novel and represents an important development for WRM, particularly in the case of contentious species. The use and application of these tools is discussed in the following section.

We therefore propose that WRM systems have a clear framework backed by guiding principles and a time frame. Figures 1 and 2 provide examples of appropriate decision-making processes for species not yet in the state or territory and for species already in the state or territory. The decision points at which economic analysis should occur are shown. Table 3 presents a set of guiding principles, as adapted from the Northern Territory's WRM framework. Potential outcomes are listed on the basis of WRA and feasibility of control assessments and will vary according to the legislation of each jurisdiction.

Table 3 Guiding principles for a weed risk management process: an example

| | | |
|---|---|---|
| Ecologically sustainable development and shared weed management responsibilities | 1. | Weed management is an essential and integral part of the sustainable management of natural resources for the benefit of the economy, the environment, human health and amenity. |
| | 2. | Weed management is the legislative responsibility of all land managers and land users; land managers and land users have a general duty to manage weeds. |
| | 3. | Weed management requires coordination among all levels of government in partnership with industry, land and water managers and the community, regardless of tenure. |
| Adaptive management underpinned by risk assessment | 4. | Developing priorities for and investment in weed management must be based on a risk management approach. |
| | 5. | Policy mechanisms should operate to ensure that decisions made are acted on and the effectiveness of recommended action is evaluated. |
| | 6. | The precautionary principle will be applied throughout all stages of the WRM process. The Rio Declaration defines the precautionary principle: 'where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation'. Precautionary action requires assessment of the costs and benefits of action and transparency in decision making. |
| Mitigating the threat posed by weeds | 7. | Prevention and early detection and eradication are the most cost-effective and successful techniques for managing weeds. |
| | 8. | Pre-border WRM plants that are not already present in Australia and are categorised as high weed risk should not be approved for entry into Australia. |
| | 9. | Post-border WRM plants already present in northern Australia and categorised as high risk should trigger nomination as a declared weed and other legislative actions and associated management responses to mitigate the risk posed by these species, irrespective of economic benefits. The form of the declaration for contentious plants should reflect the results of a formal assessment of net economic, social and environmental costs. |

Source: Adapted from the Northern Territory Government's guiding principles—Setterfield et al. (2008), Natural Resource Management Ministerial Council (2006).




Note: 'NAPEEC' denotes Northern Australian Pasture Plant Evaluation Committee.

Figure 1 Framework for assessing commercial species not currently present in the state or territory

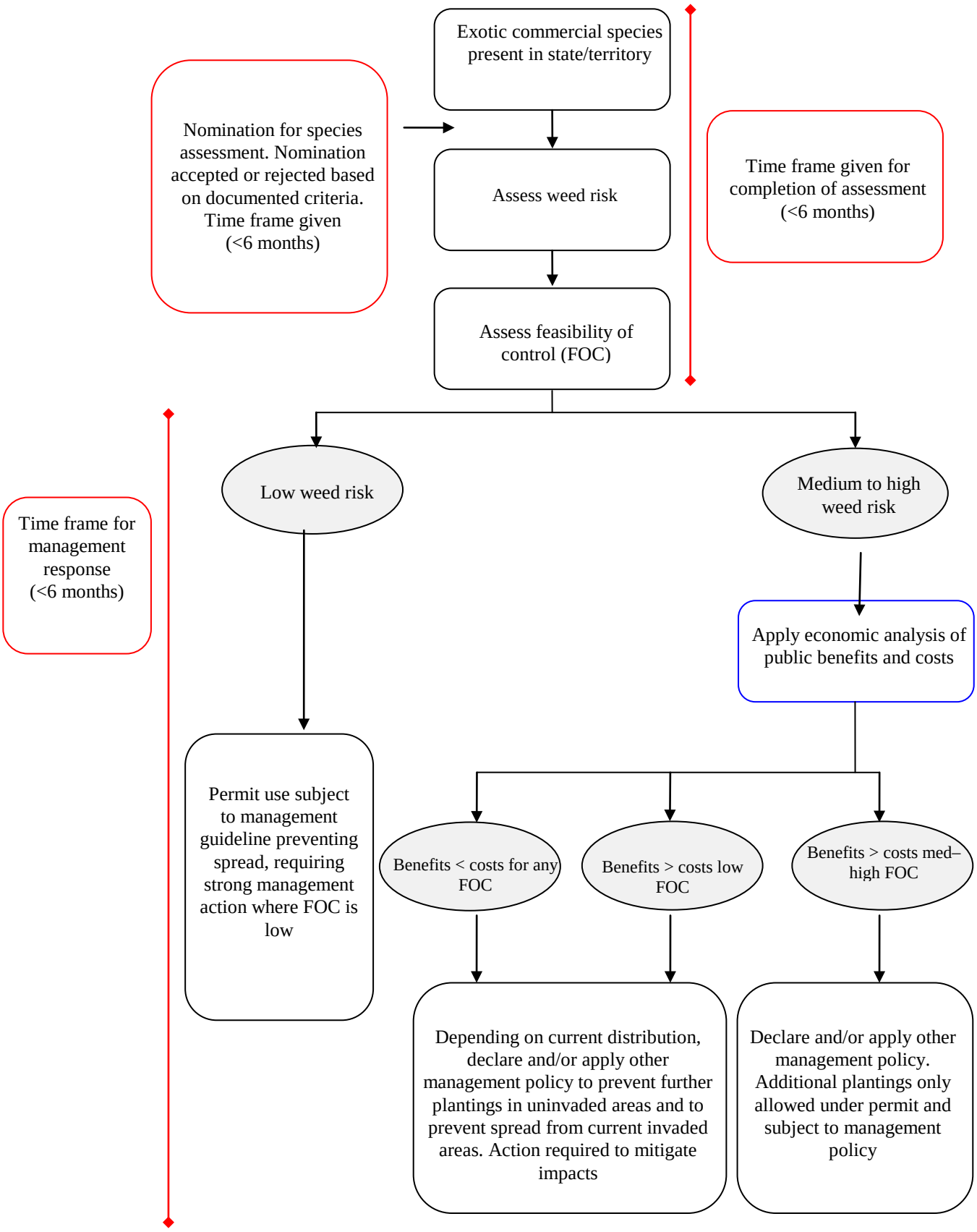



Figure 2 Framework for assessing commercial species present in the state or territory

## Economic tools for improving management of contentious species

The control of contentious plants typically involves the allocation of management resources, from both private and public sources, supported by a policy framework to ensure that efforts are coordinated. Weed managers and policy makers must first determine whether the negative impacts of the species in question are sufficient to warrant implementation of a management program and then chose the most suitable policy tools and regulatory framework for achieving the program's aims. This section focuses on the first of those tasks.

Making a choice about whether to try to control or prevent a weed invasion typically involves at least implicit consideration of the benefits and costs of different options. This might involve formal evaluation in some cases through an extended benefit–cost analysis, which is one of the main approaches that can be used in an economic evaluation of control options for invasive species (Born et al. 2005). There are advantages in conducting a benefit–cost analysis in terms of the potential to systematically consider all the different benefits and costs involved—including environmental, social and other impacts that are not reflected in markets. There are other less formal options, among them use of regulatory guidelines or decision-support tools to help identify suitable policy options when limited information is available. Economic evaluations such as benefit–cost analysis have directed management efforts for invasive species (Simberloff et al. 1997; van Wilgen et al. 1996; Zavaleta 2000), and we argue that they should be an important decision-making tool in the management of contentious species (see Figures 1 and 2).

An important stage in the analysis of environmental values is categorising the types of benefits that might be associated with controlling or avoiding pest invasion (Born et al. 2005), which can then be assessed with different market and non-market valuation techniques (Born et al. 2005; Lovell et al. 2005; Olson 2006). These can be classed as use values (direct and indirect) and non-use values (see Figure 3):

- Direct use values are benefits that directly accrue to individuals and can be either extractive or non-extractive. The absence of weeds can allow extractive use values such as harvesting from natural resources, as in fishing and agriculture. Non-extractive values involve tourism, research and education.

- Among the indirect use values associated with weed control are values that are gained indirectly from maintaining the natural resource, usually through support and protection of other economic activities. Examples are support for agriculture, fisheries, water quality and indigenous culture.

- Non-use values to society associated with weed control arise indirectly either through potential future uses or through the knowledge of the presence of the resource. These can be divided into option values (values for use in the future), quasi-option values, existence values (values for knowledge of the resource's presence) and bequest values (arising from preserving the public good for future generations). Such values can be derived without any actual current human use of the resource.

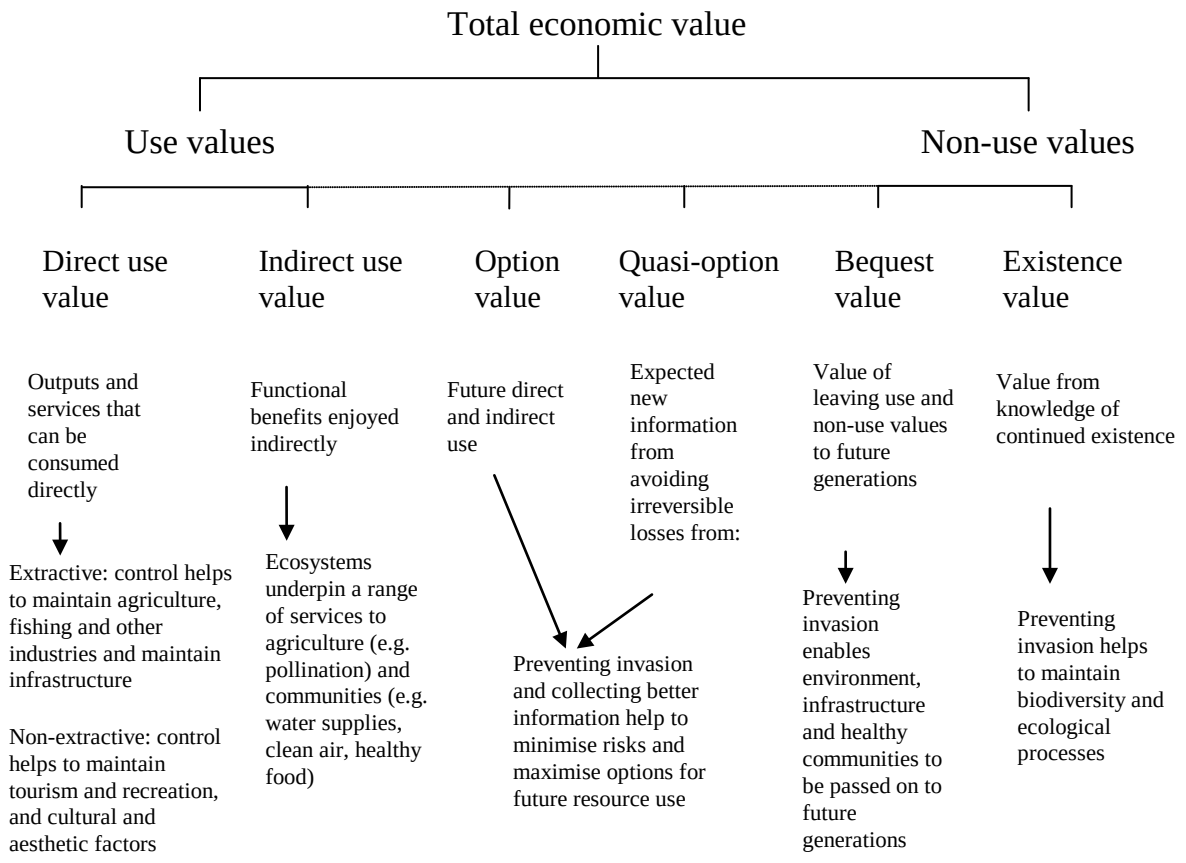



Figure 3 Total economic value and attributes of values for controlling invasive species

The different types of benefits shown in Figure 3 suggest there are several factors that complicate the application of a simple cost–benefit framework (Born et al. 2005). The conventional focus is on direct use values, using market-based benefits and costs of control. It is more difficult to assign values to the indirect use and the non-use benefits, which are the implicit focus of weed risk management (Wainger 2001). The following are among the challenges associated with applying a cost–benefit framework for weed management (and some other decision frameworks):

- Uncertainty about the current and potential impacts of biological invasions and their spatial and temporal variability makes it difficult to assess impacts precisely (Burnett et al. 2008). This is complicated by the dynamic, non-linear growth patterns of most biological pests and the difficulties of predicting spread and impacts over time (Perrings et al. 2000; Olson 2006).

- Many of the benefits of control are difficult to value, especially those involving reduced impacts on human health and the protection of environmental assets and ecological processes (Born et al. 2005; Lovell et al. 2006).

- There are many different invasive species, so both the costs and benefits of control often involve 'jointness' and complementarities.

- Species invasions usually involve multi-dimensional and partial impacts (sometimes offsetting) (Pimentel et al. 2005), requiring net marginal impacts to be considered (Born et al. 2005).

- Impacts and the costs and benefits of control vary from location to location, so it is not appropriate to assume uniform values from varied locations (Olson 2006).

Weed control generally involves externalities, public goods, and risk and uncertainty. For example, externalities occur if a grass species that has been introduced for productive purposes has the potential to cause unanticipated spillover effects. Among the consequences of weed spread can be adverse effects on biodiversity and ecosystems, on other agricultural producers, and on health. These negative externalities typically 'cascade' and intensify down watersheds from diffuse infestation points, and they affect different groups of stakeholders simultaneously. Impacts on biodiversity and ecosystems mean that there are potential public benefits involved in both avoiding and responding to weed invasion. Knowledge gaps and uncertainty about future spread and impacts call for research to generate better information and to ensure that mechanisms are established so as to avoid choices that fail to take account of longer term risks. Each of these factors establishes a role for government in the management of contentious plants. Public policy makers should ensure that public goods are protected, that impacts across the variety of interested parties are recognised, that knowledge gaps are redressed, and that the risks of longer term negative effects are minimised.

There are few examples of benefit–cost analysis being applied to the management of contentious species in Australia, even though non-market valuation techniques now offer the ability to assess different environmental and social impacts. A partial benefit–cost analysis was, however, a crucial consideration in the declaration of the invasive pastoral grass *Andropogon gayanus* (gamba grass) by the Queensland and Northern Territory Governments. For this contentious species, there were impacts of invasion that were amenable to valuation—particularly loss of infrastructure, increased fire management costs in invaded areas, and the cost of control (Setterfield & Drucker 2007). Although the impacts of invasion on ecosystem services are well documented (Rossiter et al. 2003; Brooks et al. 2008), there was no need to try to incorporate these in the benefit–cost analysis because there was sufficient evidence of substantial cost being imposed by other impacts.

Alternative approaches might be required in cases where the costs of invasion are primarily imposed on indirect or non-use values. An example would be invasion of the Northern Territory wetlands by three pastoral grasses—olive hymenachne, para grass and aleman grass. The impacts are primarily on ecosystem services, particularly native species biodiversity, and on the cultural value and uses of the wetlands. Many of these floodplains have been identified as internationally significant (through World Heritage status and through the Ramsar Convention) as a consequence of these factors, but suitable estimates of non-use and indirect values are rarely available for decision makers. The primary need is to develop better benefit–cost analysis case studies in which non-market valuation techniques are used to include values for environmental, social and cultural impacts within the wider assessment framework. In some cases decision makers can choose to default to alternative decision-making instruments, such as multi-criteria assessment, as a way of assessing trade-offs more quickly but crudely.

Economic tools offer great potential in the area of optimising weed management resources, although methods should be tested and developed for natural area protection and restoration. The basic economic optimisation approach is to maximise the production of a weighted set of objectives subject to one or more constraints, such as a budget (Wainger et al., in review). Optimisation tools should assign priority to the relative value of services, which can be represented by non-monetary metrics. To test the suitability of this approach for natural resource management, Wainger et al. developed an optimisation model to help a decision maker choose which sites should be treated for the invasive grass *Imperata cylindrica* and at what intensity to provide treatment in order to maximise the net change in a bundle of ecosystem services, subject to budget and other constraints. They used a variety of metrics—monetary and non-monetary—within a multi-attribute utility approach.

Assessment of the benefits and costs of control options is an emerging area in weed management, but we contend it is crucial if we are to use limited resources more efficiently and effectively. This research calls for multi-disciplinary teams of ecologists, economists and weed managers, initially focusing on weeds for which the impacts of invasion and the cost and effectiveness of control are well known since these are often limiting the utility of decision-making models (Wainger et al., in review).

## Why are we not adequately managing contentious species and what solutions are there?

The current national (pre-border) weed risk assessment system is designed to prevent high-risk species from entering Australia and is a robust system. The primary challenges lie with species that are already present and involve interacting policy, economic and social considerations.

### Limited implementation of existing legislation

A number of plants that offer important real or potential economic benefits to some sectors but that are invasive are declared plants under state and territory legislation (see Table 1). For example, gamba grass and olive hymenachne were declared in Queensland, the Northern Territory and Western Australia between 2003 and 2008. By the time they were declared, however, both species had been planted widely, often on the advice and encouragement of extension officers from government agriculture departments.

Under the Queensland legislation a person may not 'keep', 'release', 'take' or 'supply' a declared Class 2 plant (classes are described in Table 1 and by Grice et al. 2008) without a 'reasonable excuse'. But no growers of gamba grass or olive hymenachne hold a declared pest permit, and the definition of 'reasonable excuse' is open to interpretation. In the Northern Territory the gamba grass management plan does not specify any penalties for failure to comply with the requirements that exist for managing this species.

In some jurisdictions the implementation of legislation falls to local governments. Invasive plants might not, however, be a priority for local government, which might also lack the resources or skills and knowledge for implementation. Allocation of resources is likely to be determined by local community expectations, such that collective and consistent action throughout the jurisdiction can be difficult.

### Lack of policy in relation to non-declared species

The declaration of plants that have an established commercial use—particularly in the pastoral sector—is a fairly recent phenomenon. Species such as buffel grass and para grass, which are widespread and of considerable commercial value, were in use before most current weeds legislation was enacted. Moreover, in the case of buffel grass it took a century for its negative consequences to be generally recognised. In the absence of legislation there are no processes for limiting unwanted impacts.

A similar policy vacuum applies to other types of invasive plants—including those that have been imported into Australia, as well as translocated native species that are not yet an established problem. For example, proposed biofuels such as *Jatropha curcas* and *Milletia pinnata* (syn. *Pongamia pinnata*) and crops such as neem (*Azadirachta indica*) are of possible but unproven economic value and have considerable invasive potential in some environments. There are also novel crops of unlikely economic value—for example, diesel tree (*Copaifera langsdorffii*)—that might never be extensively planted but that are nevertheless promoted by entrepreneurs, potentially leading to many small and widely distributed plantings. At present such activities are not controlled, and the risk of escape is high.

## Social challenges to managing contentious species

Implementation of management strategies is constrained by social factors as well as policy and biophysical concerns. Perceptions and attitudes at all levels—from national, state and territory and regional weed strategists and policy makers to weed managers and landholders—are crucial to implementation. Existing policy options relating to the management of contentious species are not always implemented for various reasons. Policy development can be derailed by lobby groups or conflicting goals within or between agencies. Governments usually favour education over litigation as a means of achieving compliance, seeking to avoid alienating landholders as well as the burdens of cost and time. Local government might be reluctant to serve compliance notices as a result of personal relationships between the enforcer and landholders in the community. At the operational level, landholders might be unwilling or unable to follow policy directions. As a consequence, one of the barriers to action is human nature. Martin (2008) argued that the challenges weed managers face include 'overcoming institutional inefficiencies (economic, managerial and legal) and the behaviour of communities, including farmers, road authorities, local government officers and the nursery sector (social systems/marketing)', as well as a lack of sufficient and sustained resources. He observed that knowledge about how to adjust behaviour to improve sustainability is much less advanced than knowledge about biophysical systems.

In 1998 Bryant and Wilson argued that environmental management in general was viewed as a state-centred process. At that time political, economic and cultural determinants and the contributions of farmers, businesses and non-government organisations were scarcely recognised. Some years later, when summarising several decades of research into the adoption of technology, Pannell et al. (2006) concluded that landholders were unlikely to adopt conservation practices if their broader economic, social or environmental goals could not be met. Landholders' goals were shaped by individual circumstances and personal preferences, they argued, and adoption depended on perceptions and expectations, not objective truth.

Despite extensive evidence of the importance of the human element in land management, there has been limited progress in providing incentives for improving implementation of weed management policies. For example, there is potential to use financial incentives such as bonds and levies to achieve compliance, as opposed to penalising (or ignoring) land managers who do not comply. As Martin (2008) points out, though, innovation can meet with resistance because of a preference for 'the devil you know' (in the form of current policies and tools) rather than the 'devil you don't know' (for example, market incentives), despite there being no particular dangers in using markets to encourage innovation. On the other hand, perceived conflicts among practitioners or organisations might not be as great as is often supposed (Friedel et al. 2009), suggesting that policy initiatives might not be resisted as much as governments expect.

## Policy for post-border release of potentially invasive plants

Pre-border systems for preventing the entry of high-risk species are now in operation, but some potentially invasive plants of commercial value are already in Australia and in some cases are awaiting release. Greater control of the introduction of new species will reduce the risk of future invasions. The Northern Australian Pasture Plant Evaluation Committee has formulated the Code of Ethics & Good Practice for the Evaluation and Release of Pasture Plants. The code incorporates a step-by-step process for the release of germplasm from the Australian Tropical Crops and Forages Genetic Resource Centre at Biloela in Queensland in order to minimise the risk of releasing nuisance plants into the environment. In Queensland a Responsible Use and Management of Plants policy has been drafted; its purpose is to provide to government agencies direction on the use of any new plant or the promotion of a new use for an existing plant for any purpose, with a view to preventing unacceptable economic, environmental and social impacts caused by the potential 'weediness' of the plant (Jeff Cummings, pers. comm.).

## Potential options for alternative policy tools

Once a species has become problematic, declaration is not the only option for dealing with it, although local declaration for areas that remain free of the plant remains an option and there is provision in most states for doing this. Solutions guided by other legislation are possible. For example, Queensland's *Environmental Protection Act 1994* contains a number of provisions that could apply, including a 'general environmental duty' not to cause environmental harm 'unless [the] person takes all reasonable and practicable measures to prevent or minimise the harm'. This applies to problematic species in general, not just species that are problematic *and* commercially valued.

Regulation is also an option. Non-invasive species such as hemp, tobacco and poppies are regulated under legislation such as the *Drugs Misuse Act 1986*, with the purpose of stopping the plants spreading beyond the farm. These species are grown under licence or managed through a quota system and are overseen by boards or committees. A similar system can be applied to commercially valued invasive species, and there is scope for this in the legislation of some jurisdictions.

Several mechanisms could be used to encourage participation in the effective management of contentious weed species. Codes of practice can be developed and then applied either voluntarily or under legislative control. Voluntary codes of practice would be most effective if instigated by an industry body associated closely with, and preferably specifically associated with, the plant species that is being targeted. Compliance would be by way of encouragement—for instance, by the industry body or by the use of certification measures. A voluntary code of practice has been developed for growers of leucaena (*Leucaena leucocephala*), a commercially valuable forage shrub that is invasive in northern Australia (Walton 2003).

Subsidies could be applied to offset the costs borne by those affected by a plant grown commercially by other land users. Government subsidies are, in effect, already applied to declared plants through government contributions to detection, mapping, control and research. Another form of subsidy goes to growers: a selective tender process could be developed to support the achievement of management targets such as a reduction in the presence of a widespread species in a particular location. Apart from government expenditure on commercially valued plants (for example, buffel grass) that are being controlled on publicly owned conservation reserves, we know of no cases where subsidies are being used in such ways to deal with contentious commercial plants.

Compensation payments could be made directly to land users who are adversely affected by a contentious commercial plant. These payments would differ from subsidies in that there is no obligation to commit the funds transferred to measures to counter the plant species that is the reason for the payments.

Would-be cultivators of particular plant species could be required to pay a one-off bond before taking any action that imposes a weed risk. Bond conditions could relate to containment and control measures that must be introduced by the enterprise or more directly to the outcomes of application of those measures. Questions that would need to be resolved in developing and applying this approach concern the size of the bond, monitoring whether the conditions have been met, and deciding on the return of payments at the end of the bond period. Refunds would depend on either the eradication of all plants arising from the cultivation of the target species or conclusive demonstration that the risks were infinitesimally small. Such mechanisms represent a 'polluter pays' approach to commercial weeds (Larson 2005; Cook & Dias 2006).

Alternatively, would-be cultivators of a particular plant species could be required to pay a levy during the period they are cultivating the plant. The funds raised through the levy could be linked to management actions associated with reducing the prevalence of the target species. As with bonds, the size of the levy would need to be proportional to the risks associated with the species. In the case of an emerging industry from which major problems develop rapidly, the funds collected through the

levy might be insufficient to deal with the problem at a useful scale. Levies could be adjusted over time, in keeping with the risks encountered—a function not available with a one-off bond.

Finally, growers of contentious species could be required to take out third party insurance to cover the costs of problems that arise from the escape of the target species. This mechanism could force consideration of problem plants in the setting of property prices.

All these mechanisms are based on the assumption that naturalisation and spread of the species in question can be controlled with the effort and resources that are available.

# Containment as an approach to tackling contentious commercially valued plants

## Introduction

It has been the norm that any plant that is present in Australia and that was not declared under state or local government weeds legislation could be freely cultivated. But many species that are or were once cultivated for commercial gain have deleterious effects on enterprises, industries, environments or ecosystem services. Some very important commercial plant species are recognised as environmental weeds by some interest groups. The 'weediness' of these commercially important plants is rarely reflected in the plant being listed in pest species legislation.

The differing values, perceptions and attitudes of people with an interest in species that are or are perceived to be both useful and problematic have led to contention about how those species should be handled. A laissez-faire approach to contentious species would see proponents reaping benefits from their exploitation and specific opponents or the public bearing any costs associated with the species' adverse effects. Alternatively, action could be taken to prevent such a situation occurring by means of legislation, regulation or voluntary agreement.

At one extreme potentially valuable commercial species that have, might have or are perceived to have negative consequences could be prohibited through weeds legislation. Under such an arrangement the proponents of commercial exploitation of a contentious species would be denied the opportunity to gain the full advantage that would otherwise accrue to them, while opponents of the species would, perhaps, be able to avoid some of the negative consequences, depending on the timing of prohibition in relation to the invasion process.

In between these two extremes—that is, allowing unregulated exploitation as opposed to prohibition—there are several hypothetical options that allow exploitation but attempt to mitigate adverse consequences. In this section we explore containment as one element of a strategy that seeks to facilitate commercial exploitation of a plant species whilst mitigating any negative effects the species might have.

## 'Containment' defined

In general terms, containment involves actively restricting where a species grows (Standards Australia, Standards New Zealand & CRC for Australian Weed Management 2006), so that it does not occupy its potential range as determined by climatic, edaphic and other environmental factors. Containment is one of several broad goals advocated for dealing with problem plants, the others being prevention, eradication and suppression. Containment is often favoured when eradication is deemed impossible, the assumption being that it is more feasible than eradication. A critical practical aspect of any containment strategy is that it must be related to a specific area, although such strategies can be devised at widely different scales, from continental to the highly localised.

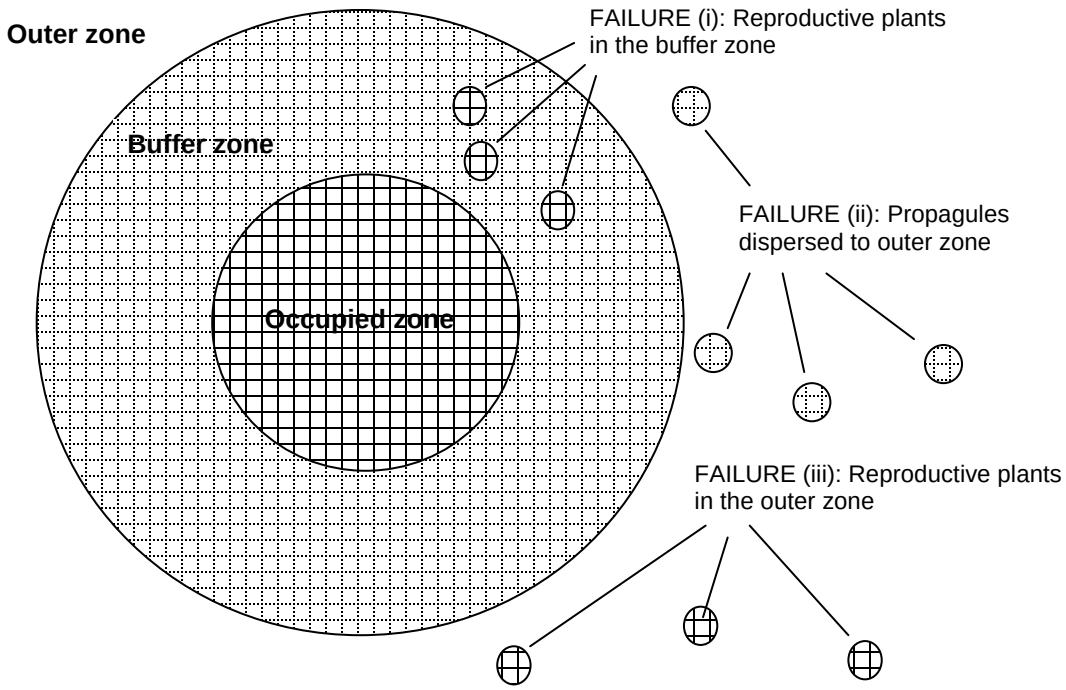
Although containment has often been advocated as a 'fall-back' option when eradication of a problem plant is thought to be impossible or not economic, it is also available as a means of helping to mitigate the negative effects of commercially exploited species that are 'weedy' or invasive. As with species that are weedy but not commercially exploited, the scale of containment strategies devised for this purpose is an important consideration. Containment targets could be delineated around individual plantings or around districts or regions in which cultivation of the species in question is permitted.

## Delimiting a containment target

Usually, the total population of an invasive species in the range it has invaded consists of multiple infestations, which might be connected to one another to a greater or lesser extent by mechanisms such as pollen transfer, seed dispersal and the transport of vegetative material. The degree of connectedness for any species will depend on pollination mechanisms, dispersal mechanisms and distances between infestations. In an extreme case the total population of an invasive species in the range it has invaded could consist of or include infestations that arose from independent introductions or naturalisations and that lack functional connections with other infestations. Invasive species are, however, more likely to conform to a metapopulation model.

This metapopulation perspective is useful in relation to the practice of containment because, regardless of a containment strategy's scale, practical application of the strategy must involve defining 'containment units'. Ideally, containment units will have no connection with other populations of the same species. Such units can be conceptualised as consisting of a zone occupied by established plants and a 'buffer' zone (seed shadow of the population) surrounding it that does not support established plants but does receive propagules from the occupied zone. The simple representation of this concept in Figure 4 does not capture the inevitable effects of landscape heterogeneity or directional dispersal, but it does allow discussion of the matter.

The success of a containment strategy can be measured in terms of events in and beyond the buffer zone. By definition, the buffer zone will receive propagules from the occupied zone. Some of these propagules can be expected to give rise to new plants. A containment strategy can be regarded as having been successful if the plants that do establish in the buffer zone are prevented from reproducing and no propagules reach beyond the buffer zone. The corollary of this is that a containment strategy will have failed if plants reproduce within the buffer zone, if propagules are dispersed beyond the buffer zone or plants reproduce beyond the buffer zone (see Figure 4).




Note: The unit consists of three zones: an occupied zone that supports established plants of the target species, including some of reproductive size or age; a buffer zone that does not contain established plants of reproductive size or age but that is within the dispersal distance of plants in the occupied zone; and an outer zone that lacks established plants of the target species and is beyond the maximum dispersal distance of plants in the occupied zone.

Figure 4 Representation of a containment unit for a hypothetical plant and three types of failure with which it could be associated

Two pieces of information are crucial to the delimitation of a containment target. The first concerns the distribution and abundance of established plants and the second dispersal characteristics. The distribution of established plants shows the location and size of the propagule source, while information about dispersal identifies the 'sinks' to which propagules might be dispersed away from the source area. Information about dispersal characteristics needs to include dispersal mechanisms and the dispersal distances and pathways that result from these mechanisms. If these two pieces of information are lacking or inadequate, the containment unit will be poorly defined and the prospects of containment will be jeopardised. If plants of the target species reproduce within the buffer zone, the area designated as the buffer zone would have to be expanded to include that area into which seeds produced in the original buffer zone are dispersed. If propagules reach beyond the buffer zone this suggests that maximum dispersal distances are greater than estimated when delimiting the containment unit (see Figure 4).

## Current status of containment of contentious species

Containment is often mentioned in relation to invasive plant species. As noted, containment is listed as one of four strategic options—along with prevention, eradication and suppression ('control')—for countering invasive plants (Grice 2000; CRC for Australian Weed Management 2006). Further, it is identified as a component of Strategic Action 1.2.2 of the Australian Weeds Strategy, as a means of meeting the objective to 'ensure early detection of, and rapid action against, new weeds' (Natural Resource Management Ministerial Council 2006). In this setting, containment is advocated as an alternative to eradication. Similarly, the *Best Practice Management Guide for Environmental Weeds* states, 'It is … essential that the expansion of any weed population be contained' (Blood 2002) and lists containment of weeds and vectors 'of spread' as one of several general management strategies, again implying that containment should be the goal when eradication is considered impractical. The

method proposed for containing invasive plants is to concentrate on 'small outlying populations and individuals while attempting to restrain further expansion …'

The notion that containment is a 'fall-back' strategy when eradication is not feasible is also expressed in relation to the impact of weeds on biodiversity in Australia's rangelands (CRC for Australian Weed Management 2006). That document states, 'If it is not feasible to eradicate a particular weed, the best option is to contain it and prevent expansion or new infestations. This can be done by minimising dispersal outside existing infestations, and by treating new infestations as early as possible'. This fails to recognise that containment can be guaranteed only if there is no dispersal 'outside existing infestations'. In the terms of the containment unit defined in Figure 4, the 'existing infestation' includes any seeds that exist in the buffer zone. 'Minimising' dispersal might reduce the rate of spread but cannot guarantee containment. The document does note, however, that the location of containment lines is crucial and, further, that features of landscapes that create 'natural barriers' to spread can be exploited in applying containment strategies.

Martin and van Klinken (2006) claim that 'successful … containments' are among the achievements resulting from Australia's investments that target weeds of national significance (Thorpe & Lynch 2000) and other weeds. Examples cited of programs where containment is specifically identified as the goal are non-native grasses such as gamba grass (*Andropogon gayanus*) and noogoora burr (*Xanthium occidentale*) in Western Australia, where efforts were made to contain the species when an attempt to eradicate it had been abandoned. Martin and van Klinken (2006) do not draw an absolute distinction between 'containment' and 'mitigation'[*], although they imply that both are strategic goals. Their assessments of management programs confound the two, and this makes it more difficult to determine the success or otherwise of containment programs.

Among other programs where containment is specifically listed as an intended goal are the national strategy for the management of rubber vine (*Cryptostegia grandiflora*) and the threat abatement plan for bitou bush (*Chrysanthemoides monilifera*) in New South Wales. In the former case the objective is to focus management effort outside a containment line in Queensland (ARMCANZ & ANZECCFM 2001; Department of Natural Resources, Mines and Energy 2004). It is important to note that the species already occurs outside the containment line, but the concept is that by targeting these infestations the likelihood of further spread beyond the containment zone will be reduced. The situation is similar with bitou bush in New South Wales: the objective is to focus control efforts north and south of containment lines close to (but within) the northern and southern limits, respectively, of the species' distribution in coastal New South Wales (NSW National Parks and Wildlife Service 2001; Department of Environment and Conservation 2006).

This brief review shows that containment is generally accepted as a useful strategic goal for invasive plant species. There have been attempts to contain particular species, including some that are commercially valued as well as being invasive. In most cases, containment targets are delineated at the scale of the plant's distribution, rather than at the scale of the infestation, population or cultivated plot. It is containment at these finer scales that is most relevant to managing contentious commercially valued species.

In spite of claims that there have been important successful attempts at containment, there is apparently little rigorous quantitative documentation of those attempts. One of the difficulties here lies in attributing containment to the measures applied to achieve it. A population that has not spread has been contained (so far), but an objective assessment would be needed to determine that it would have spread had the measures not been applied. A rigorous demonstration of the success of

[*] 'Containment plans are put in place when the core of an infestation is recognised as being too expensive to control using current technologies or budgets. Mitigation programs are conducted within containment zones, or when weeds are already extensively distributed. Ideally, containment involves eradicating the weed outside of the containment area …' (Martin & van Klinken 2006, p. 71).

containment measures would include both replication and comparison between plus and minus containment measures.

An additional complication relates to the time frame over which the success or failure of containment is documented. Invasive species do not necessarily spread at a constant rate: climatic factors, land use change, fire and other factors can dictate that reproduction and/or recruitment are episodic events, such that a false impression of the success of containment measures could arise if work to document the containment takes place during a period when reproduction, dispersal or recruitment rates are low.

Containment is not an easy alternative to eradication: there are some major challenges to achieving it and documenting its success or failure.

## The challenges of containment

Four broad groups of factors—variously relating to biophysical traits, policy options, human capacities, and attitudes and perspectives—determine the feasibility of containing a commercially cultivated plant species that is also invasive:

- *The characteristics of the species that is the target of a containment strategy*. Important species traits are those relating to growth form and phenological patterns, reproductive output, mode of reproduction, dispersal mechanisms and the dispersal patterns that arise from them, seed bank size and longevity, temporal and spatial patterns of recruitment, and generation time (see Table 4).

- *The characteristics of the landscape within which the species is cultivated.* The landscape context of any invasion is crucial to the invasion's rate and spatial pattern. Containment will be more difficult in landscapes that consist of a large area of highly suitable habitat with a high degree of connectivity between patches. It will also be problematic if suitable habitat is available in areas where access is difficult. Inaccessibility will make it difficult to detect and treat the target species and to monitor the outcomes of treatments (see Table 4).

- *The nature of the management to which the species is subjected.* Commercially exploited contentious species can be managed more or less intensively—ranging from, for example, tightly managed 'orchard' situations to extensive paddocks with little direct management of the species. The more intensive the commercial management regime, the more likely it is that containment will be feasible. Species for which commercial exploitation requires seed production or vegetative reproduction will also be more difficult to contain. A suite of additional containment measures (for example, use of sterile varieties and management practices aimed at preventing seeding) will be available for species for which reproduction is not required. When effective and efficient control methods are not available, containment will, of course, be impossible. The number of growers of a species, their spatial distribution, whether they are organised into an industry body, and any policies relating to their use of the species will also influence the feasibility of containment.

- *Social factors.* The perceptions and attitudes of interested parties will always be central to determining the feasibility of containment. In the absence of consensus on the various considerations, which is probably a common situation, the strength with which different viewpoints are held and expressed will be influential. Mutual recognition of the validity of different positions in relation to the costs and benefits of a species is likely to greatly increase the prospects of containing that species.

The list in Table 4 can be used to qualitatively analyse prospects for containing a particular species. No ranking or weighting of factors—in terms of how strongly they might influence the feasibility of containment—is implied by the order of items in the table. What is apparent is that there are numerous factors that can influence the feasibility of containment. For many invasive species there will be one

or more factors that make containment more difficult or at least mean that the resources required to provide a reasonable chance of containing the species would be a major impediment. The species and landscape characteristics listed in Table 4 are relevant to the containment of any invasive plant species. In the case of invasive commercially valued species, management and social factors can have major influences on the feasibility of containment. No single trait that makes containment more difficult necessarily precludes containment altogether.

Inevitably, knowledge of at least some of the factors influencing the feasibility of containment will be limited for many potential target species. Characteristics relating to dispersal (factors (i)e to (i)g in Table 4) are crucial in helping delineate suitable containment units. It is especially important to determine how broad the buffer zone needs to be in order to accommodate the maximum dispersal distance of the target species. Although many of the propagules of even the most effectively dispersed species fall relatively close to the parent plant, for some at least there are prospects for very long distance dispersal. This might involve mechanisms that are different from the ones responsible for most dispersal.

One contentious plant species that illustrates the challenges of containment is olive hymenachne (*Hymenachne amplexicaulis*), a perennial stoloniferous grass introduced as a pasture species for natural and artificial wetland and riparian environments. It appears to be dispersed by multiple mechanisms. Both seeds and viable pieces of stem can be dispersed in flowing water, offering the potential for relatively long distance downstream spread, especially during floods. There is, however, evidence—in the form of new infestations at considerable distances (and not simply downstream) from existing infestations—that periodic, relatively rare long-distance dispersal of this species occurs. The speculation is that occasionally seeds are dispersed long distances by highly mobile waterbirds such as the magpie goose, *Anseranas semipalmata* (Wearne, in press).

The potential of such a process of dispersal has been demonstrated for other weeds of wetlands (for example, Twigg et al. 2009). Most dispersal of hymenachne is highly directional (downstream) and confined to the source catchment. Infrequent long-distance bird-assisted dispersal, which is likely to be less predictable as far as direction is concerned, would greatly add to the difficulty of containing a population of this species. Setting a buffer zone around an infestation solely on the basis of water being the dispersal agent would fail to acknowledge the possibility of episodic long-distance bird-assisted dispersal. On the other hand, setting the buffer zone to take into account the maximum distance seeds might be carried by birds would yield a buffer zone with a much greater area. This, of course, raises the general question of the effort that needs to be expended in order to prevent plants reaching reproductive sizes or age in the buffer zone.

Table 4 Species, landscape, management and social factors and how they relate to the feasibility of containment

| | Feasibility of containment | |
|---|---|---|
| **Factor** | **Lower** | **Higher** |
| **(i) Species** | | |
| a. Growth form | Annual | Long-lived perennial |
| b. Phenological patterns | Reproduces annually | Reproduces infrequently |
| c. Reproductive output | High | Low |
| d. Mode of reproduction | Seed and vegetative | Seed or vegetative |
| e. Dispersal mechanisms | Unmanageable | Manageable |
| f. Dispersal distance | Some long-distance dispersal | Only short-distance dispersal |
| g. Dispersal direction | Non-directional | Directional |
| h. Seed-bank size | High | Low |
| i. Seed-bank longevity | Long-lived | Short-lived |
| j. Recruitment | Frequent | Infrequent |
| k. Generation time | Short | Long |
| l. Habitat range | Broad | Narrow |
| **(ii) Landscape** | | |
| a. Habitat suitability | High | Low |
| b. Area of suitable habitat | Large | Small |
| c. Degree of heterogeneity | Low | High |
| d. Difficulty of access | High | Low |
| **(iii) Management** | | |
| a. Intensity of production | Low | High |
| b. Exploitation requires reproduction | Yes | No |
| c. Detectability | Difficult to detect | Easy to detect |
| d. Control methods | Not available | Available |
| e. Number of growers | Many | Few |
| f. Spread of cultivation | Widespread | Limited |
| g. Industry body exists | No | Yes |
| h. Policy | Not regulated | Regulated |
| **(iv) Social** | | |
| a. Perceived value for production | High | Low |
| b. Perceived impact on other industries | Low | High |
| c. Perceived environmental impact | Low | High |
| d. Broad acceptance of costs *and* benefits | Poor | Good |
| e. Compliance with legislative obligations | Poor | Good |
| f. Compliance with voluntary actions | Poor | Good |

As noted, containment requires that reproduction be prevented within the buffer zone. Usually this means that all individual plants must be detected and treated before they reproduce. In the absence of a reliable broad-scale technique such as fire or very effective biological control, detection of all individuals is necessary. This means searching the entire buffer zone, and the costs of this, which are likely to represent a substantial component of a containment program, can be minimised if the

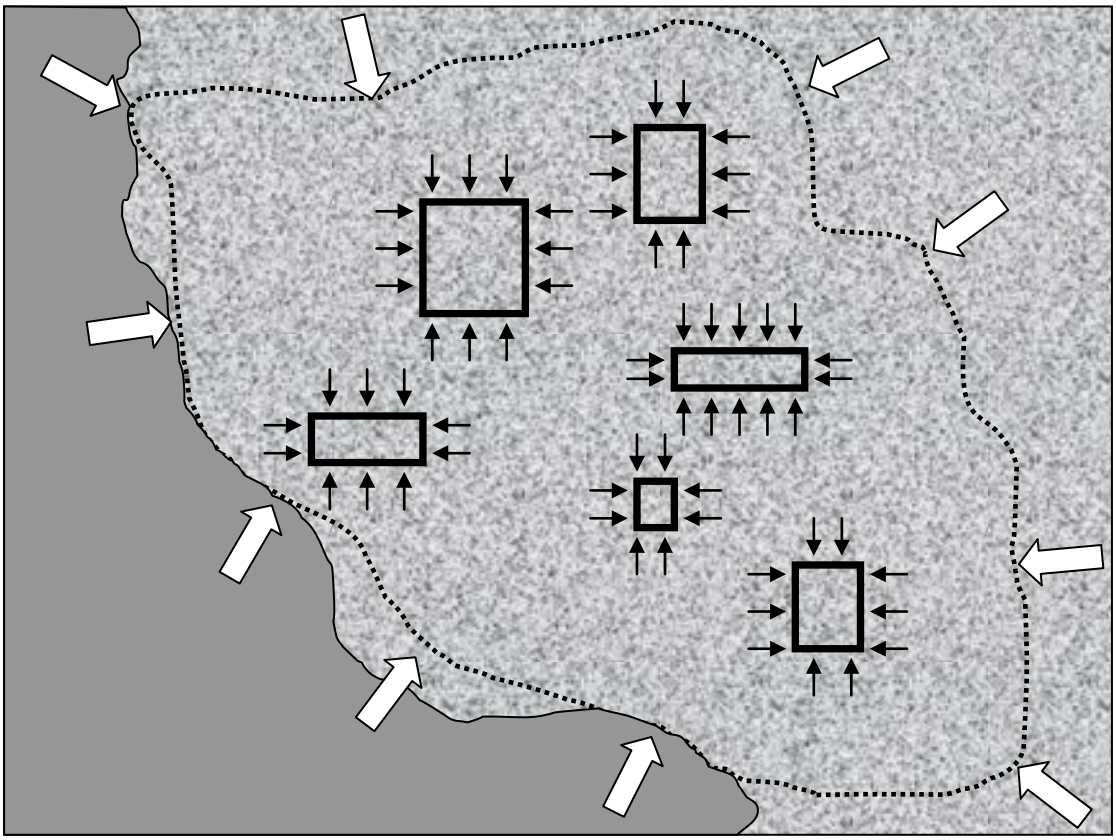
detection schedule aligns with the growth and phenological cycles of the target plant. Such alignment would mean that the detection effort occurs when plants are most detectable and no more frequently than demanded by the amount of time it takes for plants to reach reproductive size or age.

Knowledge of the dispersal mechanisms, distances and pathways is often inadequate to confidently define an effective buffer zone around target populations. When this is the case one option is to apply the precautionary principal in setting the width of the buffer zone, thus increasing the area that must be searched and treated and the costs of doing so.

## Overcoming the challenges of containment

The scale of the containment unit is an important consideration in relation to species that are being used for production. One can envisage two scales at which a containment program for a target species might be conceived. At the coarser scale, a program could be based on the concept that commercial use of the species will be restricted to a particular district. The program would then aim to restrict the species to that district but allow spread within it. Alternatively, at a finer scale, a containment program could aim to prevent spread beyond the boundaries of individual management units, properties or parts thereof. Operating at either of these scales brings with it both advantages and disadvantages.

Containment at the district scale will mean the species is likely to spread to places in the district where it is not being commercially exploited but where it could have deleterious effects. As a result, the benefits of production within the district could be fully realised but impact costs would not be minimised. The costs of containment will largely be a function of the size of the containment unit: a district-scale containment unit could well have a greater perimeter than the combined perimeters of containment units established at the management unit scale (see Figure 5). It might be possible to locate the boundaries of a district-scale containment unit in such a way as to minimise the probability of spread beyond that unit and so minimise the costs of containment. This would be done by locating boundaries at ‘break-points’ in the landscape—that is, at interfaces between more and less suitable habitat. Containment at the district scale might also call for greater consideration of who takes responsibility for the containment program.



Note: The stippled area represents suitable habitat for the species; the uniformly grey area represents unsuitable or less suitable habitat. The dotted line represents a district—perhaps a catchment or an administrative unit within which commercial exploitation is permitted. The rectangles represent areas within which the species has been sown and is being deliberately cultivated. The arrows represent the boundaries of the two possible containment units: the large block arrows show containment at the district scale; the fine arrows represent containment at the scale of individual management units. Part of the boundary of the district-scale containment unit coincides with the interface between suitable and less suitable habitat. The size and number of management units within the district dictate which containment scale (district or management unit) has the greater perimeter.

Figure 5 The relevance of the scale of the containment unit for a commercially exploited plant

If it is effective, containment at the scale of the management unit offers the advantage that the species will not have deleterious effects outside the land units in which it is being exploited. The benefits of production in the district could still be fully realised and the impact costs would be minimised. The control costs would again be a function of the combined area of multiple containment units. Operations at this scale might simplify the decision about who takes responsibility for individual containment units, making it more likely that units become the responsibility of individual landholders. This would necessitate the capacity to attribute failures of containment to particular containment units and so to the individuals responsible for them, which is particularly difficult when containment units are close to one another.

On balance, it seems that implementation at the scale of the management unit is the preferred approach to containing commercially exploited species, although establishing containment units that have a short perimeter would greatly reduce the effort required to contain the population. One way of doing this is to position the units' boundaries in places where the prospects of dispersal or establishment, or both, are lower.

History suggests it is unlikely that users of commercially valued contentious plants will voluntarily contain the species they exploit. In Australia the only such species for which there is anything like a voluntary arrangement is leucaena (*Leucaena leucocephala*). The Leucaena Action Network was

established by growers of leucaena in response to broad recognition that leucaena was widely naturalised and problematic. Although the development of codes of practice that incorporate procedures for containment might be a step in the right direction—in that there is acknowledgment of both the values and the problems associated with the species and some effort is made to redress the problem—it does highlight some shortcomings. One of these is that individual growers might be reluctant to take responsibility for infestations that are not on their own properties. This is because naturalised populations would have existed before establishment of the voluntary arrangement and, even for populations that arose after the arrangement was introduced, it will often be difficult to ascribe them to particular growers. Second, many growers might elect not to be involved in a voluntary arrangement. Third, there is little incentive to document the effectiveness or otherwise of the protocols that are voluntarily established, either in general terms (to determine whether the protocols are effective when applied) or specifically (to determine whether the protocols are being effectively applied in individual cases).

It might be possible to use a certification process to strengthen voluntary arrangements for containing commercially valued contentious species. Such a process could involve individual enterprises being certified as conforming to agreed procedures that are designed to achieve containment. It would need to be monitored and evaluated to help ensure that the prescribed procedures were being followed. As with any voluntary measure, however, it is unlikely that all enterprises cultivating the target species would meet the certification requirements or that all growers would be motivated to comply. It would be crucial that market systems recognised the values that containment was designed to protect.

The alternative to voluntary containment protocols is regulation. Such an approach obviously must relate to measures that individual growers, industry bodies or third party agencies (for example, contractors and local governments) are obliged to introduce in order to contain a commercially exploited contentious species. Containment regulations would inevitably impose costs, among them those associated with monitoring, compliance and efficacy. Regulations could aim to control any of a number of aspects relating to cultivation of the species:

- the districts in which cultivation is permitted
- the individual land parcels on which cultivation is permitted
- producers who may cultivate the species—that is, allowing cultivation under permit
- the locations within a landscape at which cultivation is permitted—for example, precluding areas close to dispersal pathways or susceptible habitats
- the procedures that must be followed if cultivation takes place
- the ways in which products and waste derived from the species are harvested, processed, disposed of or transported.

Different species will pose different challenges, depending on their status at the time of the containment attempt. Important factors include how widespread the species is, whether it is the subject of specific legislation or regulations, its real or perceived value as a commercial plant, and whether it is associated with an industry body or lobby group. Especially in the case of novel species—that is, plants that are not yet widely cultivated or for which there may not yet be a reliable or well-developed market—there are opportunities to develop containment protocols and procedures even before the species becomes problematic. Novel crops are, however, often promoted by ‘champions’, who might argue that there is little evidence that problems will in fact arise. This circumstance could be resolved by adopting an objective weed risk assessment process and by creating a precautionary culture—even one that obliges growers to keep any species they cultivate within the confines of their own land.

In general, failure to contain populations within the invaded range would cancel out any efforts made on a subset of populations. Anything short of 100 per cent compliance with containment protocols opens up the likelihood of containment failure, ultimately across the entire potential range. The greater the connectedness of suitable habitat across the potential range, the greater the risk posed by failure to contain a single population.

Regardless of the approach that is taken, the social barriers to containment are best managed by engaging interested parties in a constructive way. Establishment of a cohesive framework involving mutual acceptance of the validity of different perspectives and learning from the experiences of others is more likely to lead to support for legislative and voluntary measures. There is also a need for alignment between on-ground measures that reflect up-to-date knowledge of the biology of target species and of the landscape and regional function of the species, the management system at enterprise and industry levels, and the policy environment and the social context within which containment is attempted.

## Knowledge gaps and research needs

As a strategy for managing the deleterious impacts of invasive plants, including commercially valued contentious species, containment is a widely acknowledged prospect but has been little researched. There is a need to understand what it takes to contain different kinds (functional groups) of species at different scales and to measure the effectiveness of containment measures at different spatial and temporal scales. The relationship between the feasibility of containment and the risk of impact might provide a useful matrix for helping to decide whether or not to attempt containment and how much effort to expend. As part of this analysis it would be useful to more comprehensively document past or current attempts at containment, describing the methods used, measuring the costs and benefits derived, and determining the factors that contributed to success or failure. It seems that there are few examples where sufficient information is available to allow analysis of this nature, and rarely will quantitative data be available.

To respond to the policy challenges it would be helpful to develop templates for containment of different plant species and scenarios. There might be useful precedents in other areas of natural resource management. Application of measures such as bonds, levies, insurance tools, lease agreements, ‘environmental’ tenders and certification could be systematically and quantitatively explored. The economics of containment relative to other strategic approaches should be explored for different kinds of species and production systems and for different stages in the processes of both invasion and industry development.

Finally, there is a need to better understand the social challenges associated with achieving containment in practice (Forrest 2008). This should include examination of the influence of social values on willingness to modify practice and the effectiveness of different policy approaches. In particular, it is important to understand the probable effects of different types and levels of incentives designed to gain compliance with best containment practice.

# Conclusion

Invasive plant species of commercial value present challenges for a variety of interested parties—from policy makers to on-ground managers—involving disputation about the benefits and costs of such species and how best to regulate and manage them. Systems for managing the potential introduction of new species have been refined, but the legacy of earlier introductions remains.

We conclude that existing legislation could be improved or more effectively applied, that there are a number of tools that could support better decision making, and that there are gaps in knowledge that currently hinder progress. In support, we propose better processes for making strategic decisions about contentious invasive plants of commercial value.

# Appendix A Workshop participants

The workshop on best practice for making strategic decisions about invasive plants of commercial value was held at the Holiday Inn in Darwin on 22–24 April 2009. The following individuals participated:

- Bob Miles, Miles Consulting Services, Yeppoon
- Gabrielle Vivian-Smith, Queensland Department of Primary Industries and Fisheries, Brisbane
- Helen Murphy, CSIRO, Atherton
- John Clarkson, Queensland Parks and Wildlife Service, Mareeba
- John Rolfe, Central Queensland University, Rockhampton
- Keith Ferdinands, Northern Territory Department of Natural Resources, Environment, Arts and Sport, Darwin
- Leo Duivenvoorden, Central Queensland University, Rockhampton
- Margaret Friedel, CSIRO, Alice Springs
- Neil MacLeod, CSIRO, Brisbane
- Nigel Ainsworth, Victorian Department of Primary Industries, Melbourne
- Owen Stanley, Charles Darwin University, Darwin
- Peter Whitehead, Charles Darwin University, Darwin
- Rieks van Klinken, CSIRO, Brisbane
- Samantha Setterfield, Charles Darwin University, Darwin
- Tara Martin, CSIRO, Brisbane
- Tony Grice, CSIRO Townsville.

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# Best Practice for Making Strategic Decisions about Invasive Plants of Commercial Value

by T. Grice, M. Friedel, S. Setterfield, K. Ferdinands, J. Clarkson, J. Rolfe and N. MacLeod

A number of plant species introduced into Australia are important for their commercial value but also can become invaders. Divergent perspectives on these commercially valued invasive species have led to contention among interested parties, and a concerted effort is urgently needed to resolve these conflicts.

A central step towards resolution is the development and application of assessment and policy frameworks that incorporate an understanding of the ecological, economic and social factors involved.

The intention of this research was to provide a foundation for objective, comprehensive and coherent approaches to resolving controversial weed problems. The project was therefore designed to identify approaches to a more thorough analysis of economic, environmental and social costs and benefits and to explore policy, regulatory and management options for dealing with species that are both weedy and beneficial.

This research outlines better processes for making decisions about contentious invasive plants of commercial value. It therefore proposes that weed risk management (WRM) systems have a clear framework backed by guiding principles and a time frame.

This project was funded in Phase 1 of the National Weeds and Productivity Research Program, which was managed by the Australian Government Department of Agriculture, Fisheries and Forestry (DAFF) from 2008 to 2010. The Rural Industries Research and Development Corporation (RIRDC) is now publishing the final reports of these projects.

Phase 2 of the Program, which is funded to 30 June 2012 by the Australian Government, is being managed by RIRDC with the goal of reducing the impact of invasive weeds on farm and forestry productivity as well as on biodiversity. RIRDC is commissioning some 50 projects that both extends on the research undertaken in Phase 1 and moves into new areas. These reports will be published in the second half of 2012.

This report is an addition to RIRDC's diverse range of over 2200 research publications which can be viewed and freely downloaded from our website www.rirdc.gov.au. Information on the Weeds Program is available online at www.rirdc.gov.au/weeds

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