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LEADING THE SEARCH FOR WEED SOLUTIONS

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Estimating the investment needed for eradication

by F Dane Panetta, Oscar Cacho, Susie Hester, Simon Brooks and Nikki Sims-Chilton

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Foreword

Branched broomrape is a parasitic weed on many broadleaved plants including canola, carrot, lettuce, tomato, capeweed, vetch and medic. Seeds remain viable for up to 10 years in soil and it is found across southern Australia. Siam is potentially a serious weed of tropical and subtropical coastal areas where the rainfall exceeds 1,000 mm per annum. It can cause allergic reactions in humans and deaths of cattle have been reported in other countries.

The objective of this project was to develop estimates of the duration and total cost of the national cost-shared eradication programs for branched broomrape (*Orobanche ramosa*) and Siam weed (*Chromolaena odorata*).

The research was specifically focussed on Siam weed in Queensland and branched broomrape in South Australia. However, the results of the research have been formulated in terms of national eradication campaigns for these weeds.

Given the 2008 levels of investment used, the model predicted it would take on average an additional 73 years to eradicate branched broomrape in South Australia at an average additional cost (net present value) of $(A) 67.9 million. In no scenario was eradication possible in 20 years or less for Siam weed, but assuming a 50-year time frame for eradication, the total cost (present value) of eradicating Siam weed was predicted to be $(A) 10.1 million.

The research has implications for governments, industry stakeholders, and land managers as it can act as a guide to future investment decisions. This project is one of thirty-nine 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 2000 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
Managing Director
Rural Industries Research and Development Corporation

Acknowledgments

We are very grateful to Nick Secomb and Phil Warren for their continued support in providing data from the branched broomrape eradication program.

This report is part of the National Weeds and Productivity Program (NWPRP), which is funded to 30 June 2012 by the Australian Government with the goal of reducing the impact of invasive weeds on farm and forestry productivity as well as on biodiviersity.

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What the report is about

This report details the methods used for predicting the cost of the national eradication of branched broomrape (*Orobanche ramosa*) and Siam weed (*Chromolaena odorata*). The report also provides estimates of the costs of such eradication programs over various time frames.

Who is the report targeted at?

The report is targeted at policy makers to help inform the cost, length and feasibility of future investments aimed at eradicating branched broomrape and Siam weed.

Where are the relevant industries located in Australia?

The research was specifically focussed on Siam weed in Queensland and branched broomrape in South Australia. While the research is relevant to policy makers and land managers in these states in particular, it is also of interest to federal administrators involved in national cost-sharing arrangements for weed eradication. The results of the research have been formulated in terms of national eradication campaigns for these weeds.

Background

If an eradication program is to be successful it is essential that sufficient funding is available for completion of the program. In Australia, national cost-shared weed eradication programs have usually been started with poor, if any, estimates of anticipated program duration and hence the amount of resources that would be required to achieve eradication. This is understandable to a point, because during the early stages of an incursion there will be uncertainties about its extent and the critical biological attributes of the target. But periodic reviews of these programs have been carried out in an ad hoc manner, in circumstances of very high uncertainty about possible duration and thus resource requirements.

Aims/objectives

The objective of this project was to develop estimates of the duration and total cost of the national cost-shared eradication programs for branched broomrape (*Orobanche ramosa*) and Siam weed (*Chromolaena odorata*).

Methods used

Researchers used two different approaches for the eradication programs. For branched broomrape they acquired historical data in order to build an economic model designed to provide estimates of program duration and the resources required. For Siam weed researchers adopted the slightly different approach of estimating the resources required in order to achieve eradication within different time frames, based on combinations of various rates of progression and reversion.

For the branched broomrape program the researchers were able to establish relationships that describe the rates of progression from active to monitoring status for individual infestations (over time) and rates of reversion from monitoring to active status, as well as relationships that predict rates of detection of newly infested area.

In both cases the researchers used a stochastic dynamic model that employs key relationships to predict how long it will be until completion of the eradication programs that included:

- detection of new infested area
- rates of progression to monitoring status and reversion to active status for branched broomrape, and
- rates of progression to monitoring status and reversion to active status for Siam weed

Data was also acquired on program expenditure and its allocation between different activities; for example, searching, control and administration.

Results/key findings

The effort to achieve weed eradication consists of the search effort required to define the extent of an incursion plus the search and control effort required to prevent reproduction until extirpation occurs over the entire infested area. Researchers have estimated the total costs of the programs until their predicted completion. These costs have been apportioned between different activities, such as searching, weed control, administration, research and communication.

Given the 2008 levels of investment used, the model predicted it would take on average an additional 73 years to eradicate branched broomrape in South Australia at an additional cost (net present value) of A$67.9 million. For the final 20 or so years, however, fewer than 10 hectares of infested area might remain, so there could be scope to shorten the program's duration considerably through application of expensive methods such as fumigation. Estimates of program costs varied between A$63 million and A$75 million, with control and searching being the largest components—at 53.6 per cent and 23.8 per cent respectively.

In no case was eradication possible in 20 years or less for Siam weed. In order for eradication to be achieved in 25 years, the rate of progression from active to monitoring status needs to be consistently high (more than 0.8 of active infestations should progress to monitoring stage within 12 months) and reversion coefficients of less than –0.275 should be achieved and maintained. Since 2004 the rate of progression in the Siam weed eradication program has been considerably lower (range 0.118–0.136). In the same period the reversion coefficient has varied between –0.082 and –0.253. These figures suggest that a longer eradication time-frame is more suitable. It should also be noted that for the purposes of this analysis it was assumed that there were no further detections of infestation.

These figures suggest that, unless major improvements are effected in the management of this weed—a recent substantial increase in program investment might help in this regard—a longer time frame is more suitable. Note that in this analysis researchers assumed that no further infested area is detected, which is probably unrealistic.

Assuming a 50-year time frame for eradication, the total cost (present value) of eradicating Siam weed was predicted to be A$10.1 million. The largest component of this cost was searching (65.2 per cent), consisting of ground searching (57.8 per cent) and helicopter searching (7.4 per cent). Administration accounted for the second-largest component (23.8 per cent). The total costs of eradication were not much different when shorter time frames were considered—ranging from A$9.6 million for a 40-year program to A$8.2 million for a 25-year program.

Implications for relevant stakeholders

The research has implications for governments, industry stakeholders, and land managers as it can act as a guide to future investment decisions.

However, the researchers believe the estimates for both program duration and cost are conservative because they are not anticipating major increases in the total infested area. Significant increases in newly detected areas would obviously extend the program and give rise to substantial additional costs.

Recommendations

Through the application of a simple stochastic dynamic model researchers have been able to make predictions of the duration and cost of two ongoing national cost-shared eradication programs. The work can be relatively easily extended to other weed eradication targets, essentially requiring simple modifications in programming to reflect the maximum seed persistence expected for the target in question.

This has proved a fertile area for investigation, and there are still a number of aspects that remain to be explored. The most important of these is the definition of parameter combinations that would allow eradication within defined time frames and the linkage of these combinations to on-ground practice. In the absence of cost-effective tactics for directly depleting the soil seed bank, every effort should be made to ensure that plants do not achieve reproductive status.

Introduction

If an eradication program is to be successful it is essential that sufficient funding is available for completion of the program (Panetta 2009). In the case of weeds such programs can last decades. In Australia, national cost-shared weed eradication programs have usually been begun with poor, if any, estimates of anticipated program duration and hence the amount of resources that would be required to achieve eradication. This is understandable to a point, because during the early stages of an incursion there will be uncertainties about its extent and the critical biological attributes of the target. But periodic reviews of these programs have been carried out in an ad hoc manner, in circumstances of very high uncertainty about possible duration and thus resource requirements.

In this project we provide estimates of duration and cost for two major national cost-shared eradication programs—branched broomrape in South Australia and Siam weed in Queensland. Furthermore, for branched broomrape we demonstrate how, on the basis of the available information, these estimates would have changed during the course of the program. The nature of such temporal trends is an additional tool that can be used when determining eradication feasibility.

We used two different approaches for the eradication programs. For branched broomrape we acquired historical data in order to build an economic model designed to provide estimates of program duration and the resources required. For Siam weed we adopted the slightly different approach of estimating the resources required in order to achieve eradication within different time frames.

In the simplest terms, the effort to achieve weed eradication consists of the search effort required to define the extent of an incursion plus the search and control effort required to prevent reproduction until extirpation occurs over the entire infested area. Using cost data acquired from records for both of our case studies, in conjunction with estimates of program duration, we estimate the total costs of the programs until their predicted completion. These costs are apportioned between different activities—such as searching, weed control, administration, and research and communication.

The model

We developed a stochastic dynamic model (programmed in Visual Basic and run within Excel) for predicting the trajectory of total infested area, and hence program duration. This model was employed in different ways for each of the case studies.

Branched broomrape

For branched broomrape (*Orobanche ramosa*) the model was based on three functions (see Figure 1):

- the discovery of new infested area
- the rate of progression of infestations from active status (plants detectable) to monitored status (no recruits or regrowth detected for at least 12 months—Panetta 2007)
- the rate of regression of infestations from monitored to active status.

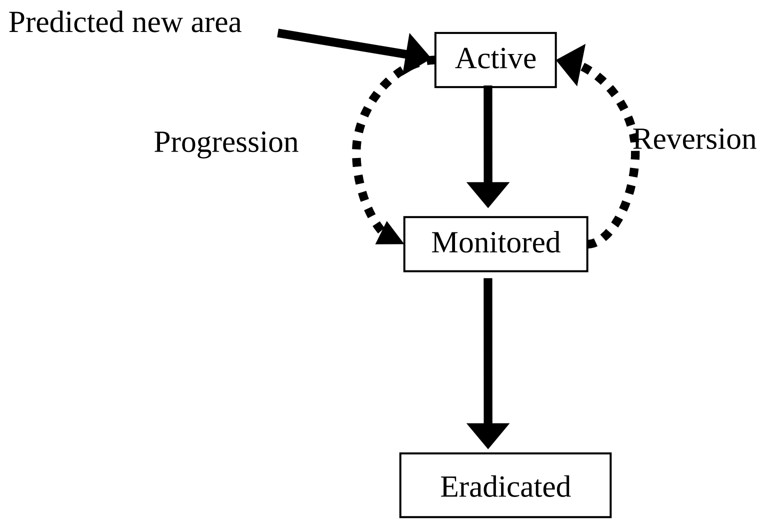


Figure 1 The functions on which the stochastic dynamic branched broomrape eradication model was based

Note that throughout this report we employ the concept of ‘gross’ infestation area (the area that must be searched for the target), as opposed to ‘net’ infestation area (that over which the target is controlled). Gross area is always considerably larger than net area, which gross area subsumes.

Predictions of future detection of new infested area were based on temporal trends in this variable (Figure 2).

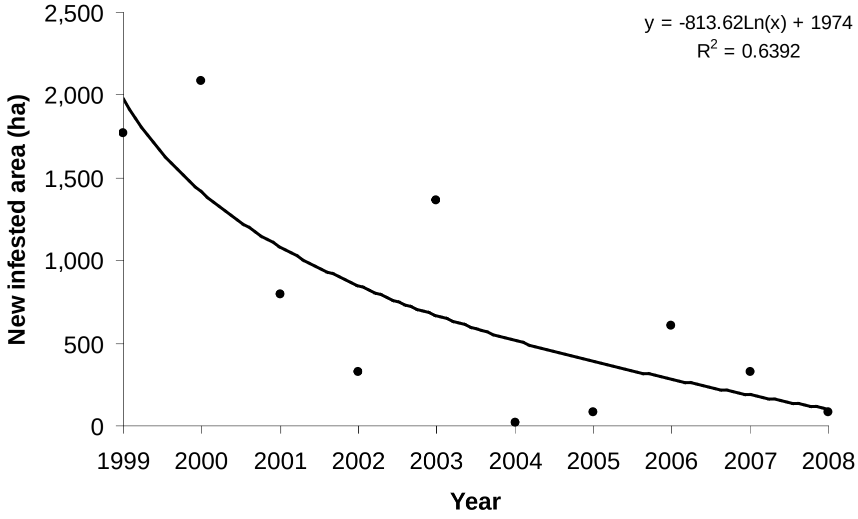


Figure 2 Detection of new infested area during the branched broomrape eradication program

The rate of progression from the active phase to the monitoring phase (0.696 ± 0.138, mean ± SD) was calculated from the data for all years (1999–2000 to 2007–08) of the eradication program (see Table 1).

Table 1 Progression factors (proportion of infestations progressing from active to monitoring stage): branched broomrape infestations, 1999–2000 to 2007–08

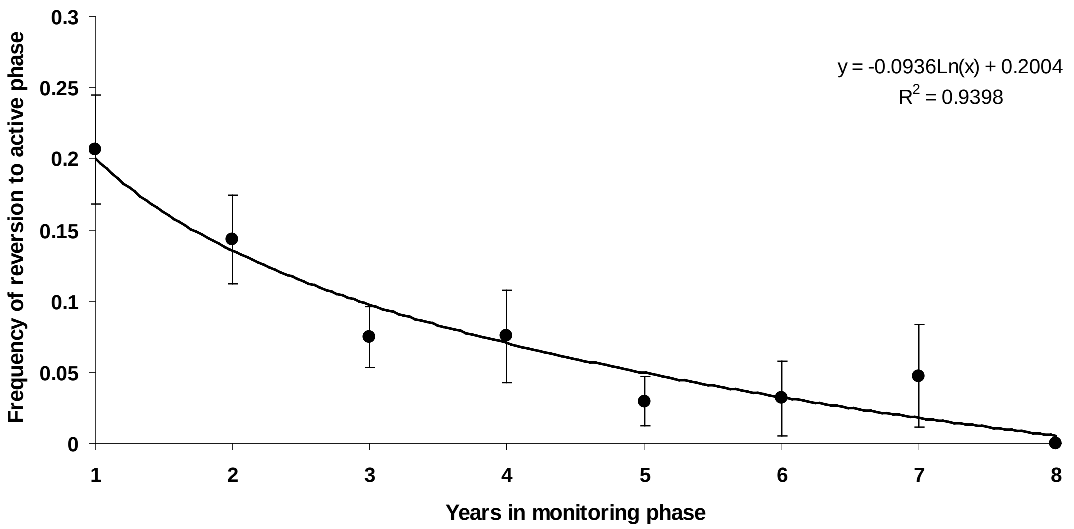
Years	Proportion progressing
1999–2000	0.616
2000–2001	0.667
2001–2002	0.853
2002–2003	0.414
2003–2004	0.838
2004–2005	0.628
2005–2006	0.686
2006–2007	0.771
2007–2008	0.795
Mean	0.696
SD	0.138

Reversion from monitored to active status could be calculated only from 2000–01 onward because the first year in which infestations could reach monitoring status was 2000. Thereafter, for each year and each stage of the monitoring phase (for example, 1, 2, 3 … *n* years since last detection—see Table 2) the rate of reversion to the active phase was calculated by expressing the number of infestations reverting as a proportion of the total number of infestations in that stage. These rates were then regressed against the number of years without detection, and the resulting relationship was used to model reversion of infestations from the monitoring to the active phase (see Figure 3).

Table 2 Categorisation of infested area relative to the time since last detection: branched broomrape, 2003, 2006 and 2008

Years since last detection	Area (ha)		
	2003	2006	2008
0	4113	3150	1634
1	167	1134	1769
2	1097	345	871
3	886	831	1003
4	70.8	11.3	20.1
5	–	929	744
6	–	579	5.3
7	–	68.6	558
8	–	–	816
9	–	–	29.4
10	–	–	–
Total	6334	7048	7450

Note: 'Zero years since last detection' denotes active infestations. The criterion for eradication is 12 years since last detection.



Note: Bars represent standard errors. The reversion coefficient for this function is –0.0936.

Figure 3 Reversion from the monitoring to the active phase as a function of time in the monitoring phase: branched broomrape infestations

Although there is still some uncertainty about potential seed persistence for branched broomrape, the operational criterion for eradication of an infestation of the species is lack of detection for 12 consecutive years (Panetta & Lawes 2005). We adopted this assumption.

The model operated on annual time steps corresponding with annual searches for the weed. It allowed the user to specify both the maximum period and the number of Monte Carlo simulations to be employed. We specified a 200-year time frame and 50 simulations for the results presented herein. In order to determine how predictions might have changed with time, the model was run initially for 2008 and then for conditions existing in 2006 and 2003. Insufficient data were available to estimate functions 1 to 3 before 2003, and 2006 represented a year in which new detections led to an almost 10 per cent increase in total infested area (Panetta & Lawes 2007).

Siam weed

Overall, the data available for the Siam weed (*Chromolaena odorata*) eradication program are not as consistently recorded or as detailed as those for branched broomrape. We therefore took a different approach, assuming that the Siam weed incursion had been delimited—that is, there would be no discovery of additional infested area in the future—and exploring the parameter space for the progression and reversion functions. (In other words, we determined what the time to eradication would be for various combinations of these values.) We then calculated progression factors and reversion coefficients from the available data so that comparisons could be made with the values that would allow eradication within various time frames. Maximum seed persistence was assumed to be seven years (Setter et al. 2007).

Economic data

Branched broomrape

Data on program expenditure on branched broomrape between July 2001 and June 2008 (P Warren, pers. comm.) were used to calculate model inputs because complete data for 2008–09 were not available. Expenditure was divided between four activities—treatment, searching, administration, and research and communication. Average values of these allocations were used for the purpose of predicting future program costs, and we assumed that the relative allocation between the various activities would not change with time. The economic inputs are detailed in Table 3.

Table 3 Economic and associated information used in the branched broomrape model, 2007–08

Activity	Input
Search ($/ha)	2.77
Area searched (ha)	333 000
Control ($/ha)	341.27
Area treated (ha)	1 634
Administration ($)	532 831
Research and communication ($)	352 269
Discount rate	0.06

In order to make the results from the 2006 and 2003 model runs comparable with those for the 2007–08 situation, deflation factors were incorporated to adjust all costs to net present value.

Siam weed

For the purpose of modelling eradication costs over time for Siam weed, we categorised annual expenditure into helicopter search costs, on-ground search costs, control costs, research and communication costs, and costs of program administration. Data from annual reports for the years 2005–06, 2006–07 and 2007–08 were used to derive average values for expenditure in each cost category (NRMW 2006; DPI&F 2007; DPI&F 2008). When it was not clear whether costs for a particular operational activity were for control or related to on-ground searching (these activities occur simultaneously), costs were divided according to the proportion of total ground area searched and controlled. Nominal costs were subsequently converted to real values using the Gross Domestic Price Deflator index (ABS 2008).

Average annual costs for administration and research and communication are considered fixed since they do not vary with area and were calculated as A$143 231 and A$37 715 respectively. In contrast, the costs of control do vary with area and averaged A$272.40 per hectare (see Table 4). Although ground and helicopter search costs are usually variable costs, in the model it is assumed that the average values for each type of search, once calculated, remain unchanged because the entire gross infestation area continues to be monitored. The average values used in the model are A$22.40 per hectare and A$2.50 per hectare for ground and helicopter searching respectively (see Table 4).

Field surveys under the eradication program are done on the ground, in the air and on water. Ideally, they are carried out every six months until zero recruitment occurs (DEEDI 2009). Ground surveys are conducted on foot, with all-terrain and four-wheel-drive vehicles and with field staff using GPS points from past surveys to locate Siam weed ‘hot spots’. Any Siam weed detected is controlled, and a 200-

metre radius around the controlled site is subsequently surveyed on foot to locate additional infestations. The area in which Siam weed plants were found and controlled—the 'area controlled' in Table 4—was 159 hectares at the end of 2007–08 (DEEDI 2009).

Table 4 Economic and associated information used in the Siam weed model, 2007–08

Activity	Input
Ground search ($/ha)	22.40[a]
Area searched—ground (ha)	15 565
Helicopter search ($/ha)	2.50[a]
Area searched—helicopter (ha)	17 906
Control ($/ha)	272.40[a]
Area controlled (ha)	159
Research and communication ($)	37 715[a]
Administration ($)	143 231[a]

a Values based on real prices.

The additional area surveyed around detections of Siam weed is known as the 'total infestation area' (the gross infestation area), although it does contain some land that is unsuitable for the weed—that is, cultivated land and water bodies. The 'area searched—ground' was calculated as 15 565 hectares; the 'area searched—helicopter' was calculated as 17 906 hectares.

Results

Branched broomrape

On the basis of current (2008) levels of investment, the model predictions were that it would take on average an additional 73 years to eradicate branched broomrape in South Australia (see Figure 4a) at an average additional cost (net present value) of A$67.9 million (see Table 5). Eradication was achieved in less than 100 years in all 50 simulations (see Figure 4b). In addition, it should be noted that for the last 20 or so years of the program less than 10 hectares of infested area might remain (see Figure 4a), so there could be scope to shorten the program's duration considerably through the application of expensive methods such as fumigation. Estimates of program costs varied between A$63 million and A$75 million (see Figure 4c), with control and searching being the largest components, at 53.6 per cent and 23.8 per cent respectively (see Table 5).

When the model was run for circumstances occurring in 2003 and 2006, the average program duration and total cost (net present value) were predicted to be 159 and 94 years and A$91.3 million and A$72.3 million respectively (results not presented). These results suggest a significant improvement in eradication prospects from 2006 onward, although it is clear that eradication of this species has been and remains a long-term prospect.

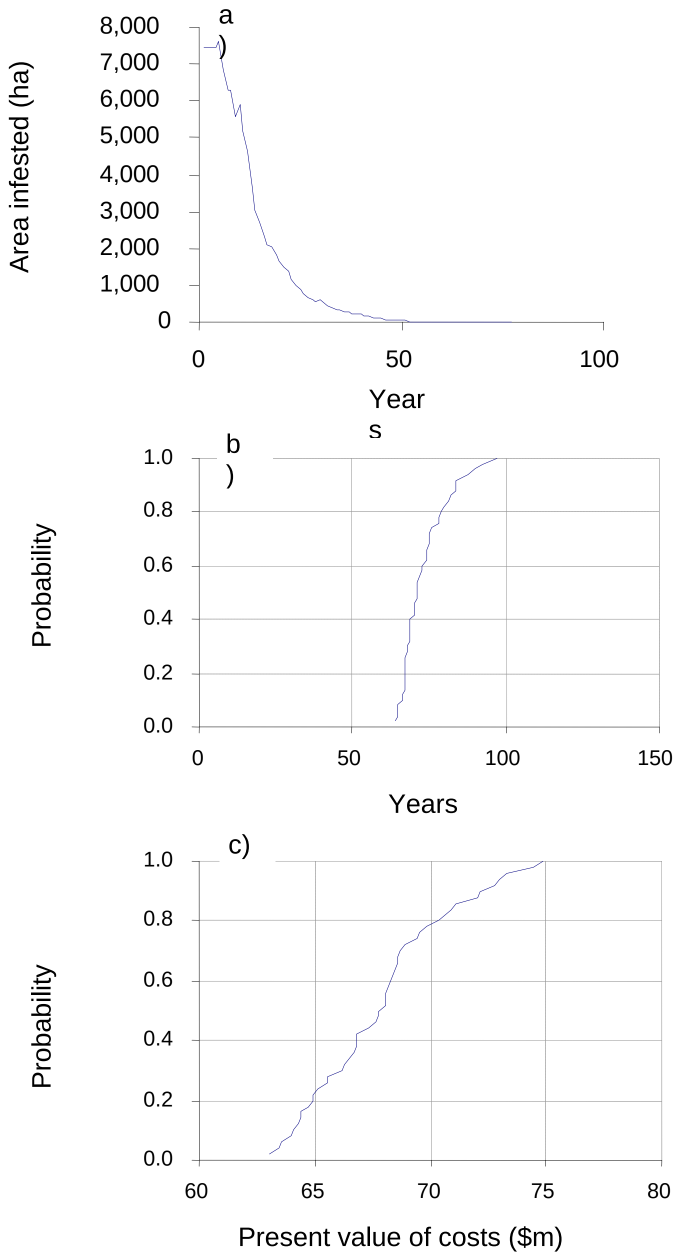


Figure 4 Predicted trend in total infested area (a) and cumulative distribution functions for (b) time to eradication and (c) total program cost: branched broomrape eradication program

Table 5 Predicted costs for the branched broomrape eradication program, from 2007–08 until completion, by program activity

Activity	$m (present value)	%
Control	35.9	53.6
Search	16.0	23.8
Administration	9.2	13.8
Research and communication	6.0	9.0
Total costs	67.0	100.0

Siam weed

Our modelling approach allowed us to determine isoquants that represent various combinations of progression factors and reversion coefficients (see Figure 5) that would allow for eradication of Siam weed within given periods.

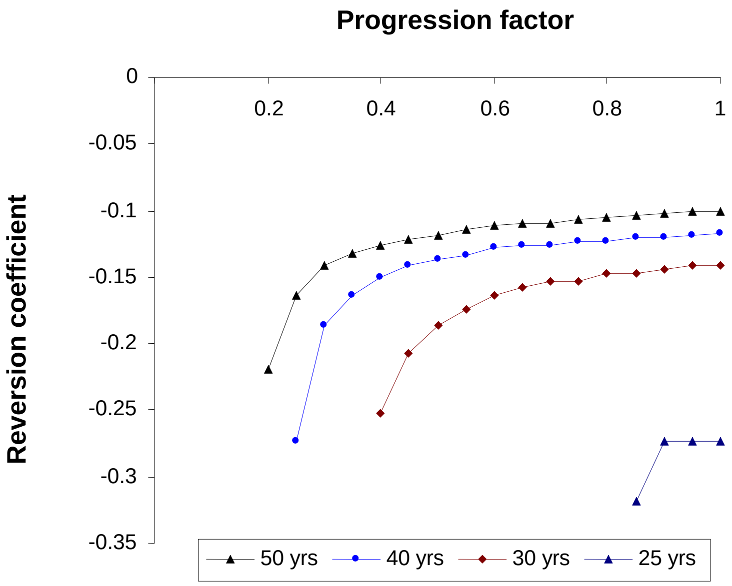


Figure 5 Isoquants describing the parameter space that will allow for eradication of Siam weed within given time frames

In no case was eradication possible within 20 or fewer years. Furthermore, it can be seen that, in order for eradication to be achieved in 25 years, the rate of progression from active to monitoring status needs to be consistently high—more than 0.8 of active infestations should progress to monitoring stage within 12 months—and reversion coefficients of less than –0.275 should be achieved and maintained.

Since 2004 the rate of progression in the Siam weed eradication program has been considerably lower (range 0.118–0.136—see Table 6). During the same period the regression coefficient has varied between –0.082 and –0.253 (see Table 7). These figures suggest that, unless major improvements are achieved in the management of this weed, a time frame in the order of 50 years to eradication is more suitable. Note that in this analysis we assumed that no further infested area is detected, which is probably unrealistic.

Table 6 Progression factors: Siam weed infestations, 2003–04 to 2007–08

Year	Proportion progressing
2003–04	0.139
2004–05	0.094
2005–06	0.078
2006–07	0.056
2007–08	0.118
Mean	0.118
SD	0.130

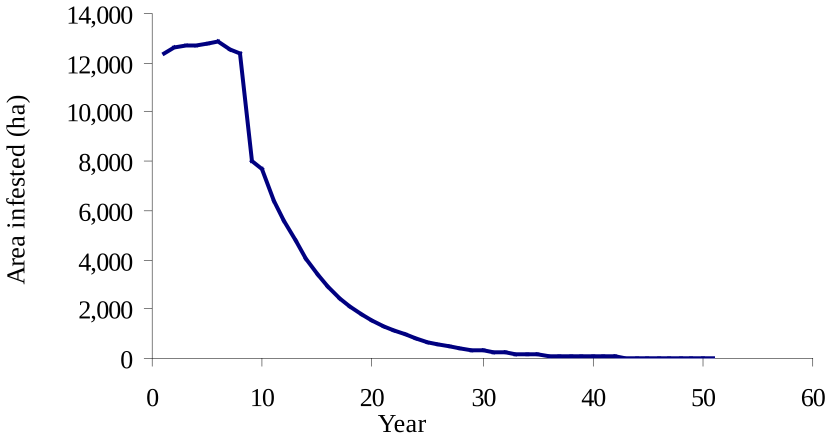
Note: The progression factor represents the proportion of infestations progressing from the active to the monitoring stage.

Table 7 Reversion coefficients: Siam weed infestations, 2003–04 to 2007–08

Year	Reversion coefficient
2003–04	–0.242
2004–05	–0.253
2005–06	–0.223
2006–07	–0.186
2007–08	–0.082
Mean	–0.197
SD	–0.069

Note: See note to Figure 3 for derivation of the coefficients.

From Figure 6 it can be observed that Siam weed would be eradicated from most of the infested area by year 30.



Note: See Figure 5 for the relevant isoquant.

Figure 6 Predicted trend in gross infestation area under a 50-year time frame for eradication of Siam weed

Given a 50-year time frame for eradication, the total cost (present value) of eradicating Siam weed was predicted to be A$10.1 million (see Table 8). The largest component of this cost was searching (65.2 per cent)—ground searching (57.8 per cent) and helicopter searching (7.4 per cent). Administration accounted for the second-largest component (23.8 per cent).

Total costs of eradication were not much different when shorter time frames were considered, ranging from A$9.6 million for a 40-year program to A$8.2 million for a 25-year program (results not presented).

Table 8 Predicted costs of the Siam weed eradication program over a 50-year time frame, by program activity

	$m (present value)	%
Control	0.5	4.7
Search—helicopter	0.7	7.4
Search—ground	5.8	57.8
Administration	2.4	23.8
Research and communication	0.6	6.3
Total costs	10.1	100.0

Discussion

Branched broomrape

In our view, the estimates of both program duration and cost are conservative because we are not anticipating major increases in total infested area on the basis of temporal trends in this variable (see Figure 2). Significant increases in newly detected area, and thus the pool of infestation in the active phase (see Figure 1), would obviously extend the program and give rise to substantial additional costs. In addition, the model is non-spatial: the distribution of infested area through the landscape could be expected to affect program costs—in particular, in terms of travel time.

It is worth considering the extent to which the program's duration and cost could be reduced through improved management practices. Barring further detection of infestations, the rate of progression from active to monitoring status and the reverse transition (see Figure 1) are crucial parameters in this regard. Relatively small areas can be controlled by fumigation, but the most widely applied method of controlling infestations (and hence influencing their activity status) is host denial—that is, preventing the establishment and growth of the species that are parasitised. Although cereal crops are not hosts and the broadleaved weeds that are hosts to branched broomrape are effectively controlled within this management context, it is difficult to control branched broomrape hosts without also eliminating the legume component in the pasture phase of cropping rotations. This is when it is most difficult to achieve progression to the monitoring phase and when most reversions from the monitoring to the active phase occur (Panetta & Lawes 2007).

Another way of achieving more rapid eradication would be to use methods that directly target soil seed banks of branched broomrape. Comparison of this eradication program with one targeting another parasitic weed—witchweed, *Striga asiatica* L. (Kuntze)—is relevant in this context. By the end of 2007 the witchweed invasion in the United States had been reduced from a high of 200 000 hectares in the early 1970s (Eplee 2001) to approximately 900 hectares (R Iverson, pers. comm.). Soil fumigants, although very effective in killing witchweed seeds, were too expensive for general use. When combined with treatments that prevented reproduction of the target species, however, the use of ethylene as a germination stimulant made it possible to eradicate an infestation in about three years (Eplee 1992). A cost-effective method of rapidly reducing soil seed populations of branched broomrape would undoubtedly increase the speed of eradication: this has been an area of considerable research activity in South Australia (Matthews et al. 2006; Virtue et al. 2006; Williams et al. 2006). Until such a method becomes available, however, the program will remain largely reliant on natural attrition of the seed bank in combination with sustained prevention of its replenishment.

We made a number of assumptions about the allocation of future expenditure between different program activities. For example, both administration and the combined research and communication expenditure were treated as fixed costs, and high levels of investment in control and searching were maintained throughout the program. Some of these assumptions are perhaps better justified than others. It is unlikely that administrative costs would decrease substantially until at least the final years of the program. The need for research might decrease, but there could be a compensatory requirement for an increase in communication in order to maintain a high level of public awareness and support until completion of the program. The cost of control is a direct function of the remaining infested area and so does not offer much scope a priori for manipulation.

Whether it would indeed be necessary to continue to search hundreds of thousands of hectares for new infestations at a stage when only a few hundred hectares (or less) remained infested is debatable. To date there has been only limited research into the optimisation of investment allocation between the search and control functions (see, for example, Hester et al. 2008). Mehta et al. (2007) comment on the fact that decision makers often allocate fixed resources to specific activities over multiple periods; they identify possibilities for updating management strategies through varying the search effort over time.

We believe there is considerable scope for improving estimates of future costs of eradication programs by exploring the potential effects of different temporal patterns of investment on both the program's duration and the cost.

This study quantified only one component (that is, costs) of an economic analysis of the branched broomrape eradication program. The most recent full analysis of the program (Econsearch 2008) considered a 30-year period from the inception of the program until 2029. Over this time frame the total incremental costs (net present value) were A$75.46 million and total incremental benefits were A$258.52 million, yielding a benefit–cost ratio of 3.43. Interestingly, the benefit–cost ratio of a containment program over the same time frame was 3.85. Determining a benefit–cost ratio for the program over a longer time frame (such as that which our model suggests might be required) is obviously a separate exercise, but the fact that an alternative management strategy is favoured economically in the shorter term suggests that eradication is not likely to be chosen over longer periods.

Siam weed

As with the branched broomrape program, in the case of Siam weed our estimates of both program duration and cost are conservative because we assumed that no further infested area will be detected—that is, that the incursion has been delimited. It is highly probable that this assumption will be violated. For example, the total known infested area increased by 1700 hectares between 2007 and 2008 (DEEDI 2009). As with the branched broomrape program, significant increases in newly detected area, and hence the pool of infestation in the active phase and requiring repeated annual searching and control effort, would extend the program and incur substantial additional cost.

As noted, a major problem with the eradication program to date has been the failure to achieve high levels of progression of infestations from the active to the monitoring stage; for example, by May 2009, 79.7 per cent of infestations were in the active phase (DEEDI 2009). This would be to a large extent a failure to prevent seed production because site visits were too infrequent. It is to be expected that increased investment in the program, and the resultant employment of more field staff, will assist in this regard, as will the use of herbicides that are more effective in preventing seed production when reproductive plants are detected (Patane et al. 2009). Rates of reversion from the monitoring to the active phase have also been higher than desirable, but this could be expected to be a function of seed bank dynamics, which are not so easily managed. As with the branched broomrape program, however, there is an active research effort to identify compounds or processes that might serve to deplete Siam weed seed banks more rapidly than might occur in the absence of intervention (S Brooks, unpubl. data).

A marginal economic analysis carried out in 2008 (and focusing solely on Queensland) suggested that moving from a continuing containment program to an eradication program would yield a significant benefit at all discount rates. At a 5 per cent discount rate a net present value of A$36 million and a benefit–cost ratio of 23:1 would be achieved for the combined benefit to agriculture and the environment (Goswami 2008).

In our model, with a 50-year time frame for eradication, total program costs amount to A$10.1 million (present value). Total investment in the Siam weed eradication program has recently increased from A$0.598 million a year to A$1.33 million (BJ Wilson, pers. comm.). The model predictions of program costs (see Table 9) suggest that this increased investment might lead to better outcomes than have been predicted. It is also of note that the model predicts it will cost less to eradicate Siam weed over a shorter time frame, which is obviously an incentive to try to achieve eradication more quickly. It remains to be seen, however, whether the recently increased investment will translate operationally into the substantial changes in the progression factors and reversion coefficients required to reduce the time to eradication (see Figure 5).

Table 9 Annual cost for the first 20 years of three different time frames for eradication of Siam weed

Year of program	**Time frame (years) and cost (present value in A$)**		
	25	**40**	**50**
0	626 411	626 411	626 411
1	592 103	592 103	592 103
2	558 755	558 774	558 755
3	527 013	527 095	527 013
4	497 375	497 517	497 375
5	469 215	469 439	469 196
6	441 291	441 879	441 143
7	415 545	416 298	415 335
8	374 614	379 311	387 125
9	352 367	356 951	361 615
10	327 892	333 164	338 180
11	307 419	312 358	316 573
12	288 323	292 806	296 619
13	271 037	274 832	278 164
14	254 986	258 158	261 069
15	240 141	242 720	245 207
16	226 289	228 375	230 466
17	213 320	214 976	216 734
18	201 145	202 449	203 920
19	189 699	190 716	191 940
Total	7 374 942	7 416 333	7 440 094

Compared with the branched broomrape program, we made similar assumptions about the allocation of future expenditure between different program activities. The effects of varying these assumptions remain unexplored at this stage, but we consider that estimation of the program's duration is the most important aspect of the present research.

Conclusion

Through the application of a simple stochastic dynamic model we were able to make predictions of the duration and cost of two ongoing national cost-shared eradication programs. The work can be relatively easily extended to other weed eradication targets, essentially requiring simple modifications in programming to reflect the maximum seed persistence expected for the target in question.

This has proved a fertile area for investigation, and there are still a number of aspects that remain to be explored. We consider the most important of these to be the definition of parameter combinations that would allow eradication within defined time frames and the linkage of these combinations to on-ground practice. In the absence of cost-effective tactics for directly depleting the soil seed bank, every effort should be made to ensure that plants do not achieve reproductive status.

Finally, in both of the programs we investigated we assumed that further detection of infested area will be minimal or negligible. This is more likely to be the case for branched broomrape than for Siam weed. To that extent, our predictions for the latter case—that is, potential eradication within 25 years—are probably optimistic.

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Branched Broomrape and Siam Weed –
Estimating the investment needed for eradication

by F D Panetta, O Cacho, S Hester, S Brooks and N Sims-Chilton

This report estimates the duration and total cost of the national cost-shared eradication programs for branched broomrape (*Orobanche ramosa*) and Siam weed (*Chromolaena odorata*).

There is potential to do much more work in this area. The model discussed in this report can be relatively easily adapted to other eradication targets by changing the values for maximum seed persistence, and there is a need to directly link progression and regression functions to on-ground practices for both branched broomrape and Siam weed.

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.

Solutions to weeds in Australia require a long-term, integrated, multi-stakeholder and multi-disciplinary approach. RIRDC is seeking project applications that involve collaboration between stakeholder groups, and where possible, including external contributions both monetary and in-kind.

This report is an addition to RIRDC's diverse range of over 2000 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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Cover photos: L: Branched broomrape; R: Siam Weed. Source: Wikipedia Feb. 2011

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