CRC for Australian Weed Management

#8

Technical Series

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The economic impact of weeds in Australia

Report to the CRC for Australian Weed Management

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Front cover: *Permanent tree cover plays a critical role in achieving long-term control of serrated tussock.* Photo courtesy of Victorian Serrated Tussock Working Group.

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This report starts in many ways from the earlier work by Harry Combellack, who estimated the economic impact of weeds in Australia two decades ago. Seven of us prepared the present report, and we can now appreciate the time and effort that he must have put into his pioneering research.

Suzanne Blair edited the report for us. Bernie, Ross and Rob, Computer Support Staff in the UNE Faculty of Economics, Business and Law, kept our PCs and Macs in operation.

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List of Acronyms

ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
ALRA	Aboriginal Land Rights (Northern Territory) Act 1976
AVCARE	National Association for Crop Production and Animal Health
CDEP	Commonwealth Development Employment Program
CFCU	Caring for Country Unit of the NLC
CLC	Central Land Council
CRC	Cooperative Research Centre
CRDC	Cotton Research Development Corporation
CRCTSM	CRC for Tropical Savannas Management
CSIRO	Commonwealth Scientific Industrial Research Organisation
DBIRD	Department of Business, Industry and Resource Development
DEWRSB	Department of Employment, Workplace Relations and Small Business
DIPE	Department of Infrastructure, Planning and Environment
DNRE	Department of Natural Resources and Environment
DOTARS	Department of Transport and Regional Services
DPIF	Department of Primary Industries and Fisheries
GRDC	Grains Research and Development Corporation
ILC	Indigenous Land Corporation
MIA	Murrumbidgee Irrigation Area
NHT	Natural Heritage Trust
NLC	Northern Land Council
NTA	Native Title Act 1993
NTETA	NT Employment and Training Authority
PWC	Parks and Wildlife Commission of NT now in DIPE
RSP	Regional Solutions Programme, funded by DOTARS
QDPI	Queensland Department of Primary Industry
QDNRM	Queensland Department of Natural Resources and Mines
ROA	Rest of Australia
SRDC	Sugar Research and Development Corporation
TEALMES	Top End Aboriginal Land Management Employment Scheme
TPZ	Temperate Perennial Zone
WONS	Weeds of National Significance

Executive Summary

1 Weeds have a wide variety of impacts on society, the environment and the economy. Some of the economic impacts are benefits but most are costs.

2 The costs of particular weeds in given areas have been estimated by many writers in a rich literature on the assessment of the impacts in agriculture. Only Combellack (1987) has attempted to estimate the nationwide impact of weeds in general.

3 In his innovative study, Combellack valued the economic costs of weeds in 1981–82 to be $2,096m. New methods of weed control and techniques of farm management have since been developed, and new weed species now occur. Therefore the current costs of impacts cannot be readily compared with those of 1981–82.

4 The nationwide impact of weeds needs to be re-estimated to provide a more recent benchmark that reflects current costs, prices and technologies, and the current distribution of impacts within the community. A current estimate provides useful information for decisions on the allocation of resources, cost sharing, and management of specific weed problems.

5 In this report, we attempt to estimate the economic costs of weeds across Australia. In addition, we offer an economic framework to help consider the problems that weeds create, and the generation and use of information to resolve those problems.

Method

6 Impacts can be measured as the direct financial costs of control (herbicide, etc), losses in production, changes in net money revenue, and changes in welfare. Economists prefer change in welfare as the concept of an impact and use the notion of economic surplus to measure it. The economic framework presented here allows us to estimate and integrate these different measures.

7 We attempt to obtain information on these measures of impact for a five year period ending in 2001–02, and so use 2001–02 as the base year for the values. We estimate all impacts from prices, costs and quantities that can be observed. We attempt to be comprehensive, to avoid double-counting and to incorporate checks on the magnitudes of the impacts. We estimate a range of weed costs rather than a single estimate to reflect uncertainty in the data.

8 We estimate the impacts in a 'top-down' approach, that is by each agricultural industry, by natural environments, by public lands, and by indigenous land, rather than in a 'bottom-up' approach by individual weeds. Data are best collected, and the analytical techniques can best be applied, in a top-down manner.

9 We attempt to estimate the impacts on agricultural land, national parks, other public land and Indigenous land. Agricultural land comprises 59.7 per cent of Australia's land area, national parks and nature reserves cover 5.7 per cent, and Indigenous land covers 14.3 per cent. The remaining 20.3 per cent comprises other public land and private land that is not used for agriculture.

Agriculture

10 The financial costs of weed control in agriculture were estimated as the costs of chemicals, the associated money costs such as fuel for vehicles, and the cost of hired and contract labour. There appeared to be no consistent, reliable data on the costs of owner/operator labour for application of chemicals and other activities in weed control, so these expenditures were omitted.

The financial costs of weeds in 2001–02, in $m, were:

	Low	High
Crops	1,033	1,121
Livestock	315	345
Horticulture	17	53
Total	**$1,365**	**$1,519**

The range of estimates allows for low and high estimates of the costs of crop and pasture chemicals, and for geographic, seasonal and commodity variations in chemical use and other costs of weed control. Many factors limited our ability to assess changes in these costs over time. They included increases in resistance to herbicides, widespread adoption of low or no till farming, the introduction of new weeds, the spread of existing weeds, increased education in the efficient use of chemicals, and integrated weed management strategies.

11 The yield losses in agriculture were estimated from the percentage losses in each agricultural industry and the existing average gross margin in the industry. The losses in 2001–02 by groups of industries in $m were:

Crops	346
Livestock	1,870
Horticulture	2
Total	**$2,218**

12 The total financial impact of weeds in agriculture can be assessed as the sum of financial costs (paragraph 10) and yield losses (paragraph 11). The total impact may therefore be summarised as the range from:

- a lower estimate of $3,583m (= 1,365 + 2,218), to
- an upper estimate of $3,737m (= 1,519 + 2,218).

But even the upper end of this range is an underestimate because it only includes the cost of weed control and the value of lost production where estimation has been possible.

13 The total impact of weeds was also measured as the loss of economic surplus. This loss of annual net benefits was calculated as an annual average over the five-year period 1997–98 to 2001–02. The range in values and the mean estimates of economic surplus in $m were:

Minimum	3,442
Mean	3,927
Maximum	4,420

Thus weeds lead to an economic loss to Australian agriculture ranging from $3,4442m to $4,420m, with mean loss of $3,927m. Around 80 per cent is a loss to producers because their net incomes are lower. The remaining 20 per cent is a loss to consumers because prices are higher and available quantities of agricultural outputs are lower than they would otherwise have been.

14 The mean loss of economic surplus to groups of industries was, in $m:

Crops	1,518
Livestock	2,409
Horticulture	na
Total	**$3,927**

15 The range of estimates of the loss in economic surplus ($3,442m to $4,420m in paragraph 13) encompasses the range of estimates of the sum of financial costs and yield loss ($3,583m to $3,737m in paragraph 12). Further, the mean surplus loss, $3,927m, exceeds the upper estimate of financial costs and yield losses ($3,737m). The yield losses have been calculated on the basis of change in per hectare gross margins to just the producer. So we would expect the surplus estimates to be higher because they include, amongst other things, efficiency losses to the whole sector.

Natural environments

16 Natural environments were taken to be National Parks and other areas listed as natural in National Heritage Trust agreements. The total expenditure on weed control in these natural environments in 2001–02 was at least $19.597m.

17 Of this total, 42.3 per cent was the direct cost of control by National Parks and Wildlife Services, 33.2 was salaries and indirect costs of the Services, and 25.5 per cent was Natural Heritage Trust funding for other agencies and groups. The aggregate expenditure on weed control by the Services has been rising rapidly in recent years.

18 This cost of weeds in natural environments is a lower bound because it excludes the value of the many ecosystem functions and benefits that are lost when weeds invade natural environments.

19 We estimated a monetary value for biodiversity protection, in terms of the extra funds allocated to protect a single threatened plant species. A value of $68,700 appears to be placed on the benefit of protecting a plant species that is threatened by weeds in agriculture and production forests. This value refers to changes at the project level and not to impacts as a whole. So we cannot apply it directly to the estimation of nationwide impacts but it can be applied in benefit-cost analyses where species are protected in similar land use and management environments.

Public authorities and other public land

20 The total expenditures by Commonwealth and state agencies (other than the National Parks and Wildlife Services), other government authorities, local government and other public land managers in 2001–02 were at least $80.775m.

21 We could allocate 64.3 per cent of this total as follows: 51.3 per cent was for the direct costs of co-ordination, inspection, survey and treatment, 5.7 per cent was for education and extension, and 7.3 per cent was for salaries and other administration. We could not allocate the remaining 35.7 per cent between these categories.

22 There is considerable variation between states in these government expenditures, and the proportions allocated to each category. There is an increasing reliance, in some states, on community groups to undertake weed management. The case studies indicate that the total cost avoided by governments, as a result of this volunteer effort, is considerable.

23 Commonwealth authorities spent at least $8.252m on weed management and research in 2001–02.

Indigenous land

24 The financial costs of weed control on Indigenous land in the Northern Territory over the period 1998–99 to 2001–02 were $3.045m per year.

Overall

25 The results may be summarised as follows, all to the nearest million dollars. We use the economic surplus results for agriculture.

	Low	Mean	High
Costs of control and losses in output			
Agriculture	3,442	3,927	4,420
Costs of control only: no losses in output			
Natural environment	20	20	20
Public authorities	81	81	81
Indigenous lands	3	3	3
Commonwealth research	8	8	8
Total	**$3,554**	**$4,039**	**$4,532**

If there were no weeds, incomes to agricultural producers and benefits to consumers of food would therefore rise by $3,927m per year in the mean case and a further $112m per year of taxpayer expenditure would be released for productive investment elsewhere.

26 We have presented the results as a range of estimates from $3,554m to $4,532m, because it is impossible to estimate the single value of any impacts at any given time. But clearly this range demonstrates that the economic impact of weeds is a significant problem of land use and resource management, if not the major problem, at the present time. Consequently, weed control generates substantial benefits on both private and public land, and research into weed management enhances those benefits.

27 Our estimate undervalues the total economic impact of weeds in Australia in several important respects. We were unable to collect some data from the agencies and persons we contacted, and in particular were unable to estimate the impacts of weeds on the outputs of natural environments. Further, we have adopted lower bound values where judgements were necessary, and have only begun to estimate the opportunity costs of volunteer labour, increasingly used on public lands. We did not attempt to estimate the impacts in urban areas or to estimate any health impacts.

1. Introduction

1.1 A national problem

The introduction of a plant to a nation or region has provided many benefits to societies over the centuries. The introductions have supplied food, shelter, medicines and aesthetic enjoyment. But these benefits have often been accompanied by costs, particularly when the plant invades agricultural and natural ecosystems beyond its intended area. These invasions have many adverse impacts on agriculture, the environment, society and the economy. As invaders, these plants are considered to be weeds.

According to Williamson and Fittler (1996), approximately 10 per cent of plant introductions into Australia have become weeds that cause significant economic and environmental damage. Over 2,700 plant species have now been documented as weeds (Lazarides, Cowley and Hohnen 1997), and over 370 have been declared to be noxious by State and Territory governments. A list of the weeds of national significance has been compiled to focus national efforts to resolve the problems that weeds create (Thorp and Lynch 2000). The top 20 weeds were selected, from the 72 nominees, on the basis of their relative invasiveness, relative spread characteristics, and relative impact on the economy, the environment and society. This short list provides a basis for targeting funds and control activities.

The area occupied by weeds indicates the national importance of the problem, and the percentage of Australia occupied by each of the top 20 weeds is shown in Table 1.1 (from Thorp and Lynch 2000). The annual costs of treatment and control were provided for weeds of group 1 but not for those of group 2 – hence the two groups. As the table shows, many individual weeds occupy large areas and several of these each occupy more than five per cent of Australia's land mass.

Table 1.1. The per cent of Australia occupied by each of the top 20 weeds

Weed	Per cent	Weed	Per cent
Group1		*Group 2*	
Bitou bush	3.0	Alligator weed	0.4
Blackberry	9.0	Athel pine	1.0
Gorse	3.0	Bridal creeper	5.0
Lantana	5.1	Cabomba	0.5
Mimosa	1.0	Chilean needle grass	0.2
Parkinsonia	12.4	Hymenachne	1.0
Parthenium	5.6	Mesquite	5.3
Prickly acacia	2.3	Pond apple	0.4
Rubber vine	7.7	Salvinia	5.0
Serrated tussock	2.2		
Willows	0.8		

The impacts of weeds are more relevant for management decisions and policy formation than information on the areas that they occupy. Thorp and Lynch (2000) report that some $50m is spent annually to control just the eleven weeds of group 1. The nine weeds of group 2 threaten over one thousand special conservation areas such as Ramsar Treaty Wetlands, Significant Wetlands of Australia, Natural Heritage Areas, and World Heritage Areas. These are large impacts and large threats to the nation.

The areas occupied by weeds also must be assessed in the context of the areas of various land uses in Australia. Data from the Australian Yearbook 2001 and 2002 (Australian Bureau of Statistics 2002 and 2003) give the information of Table 1.2.

The area under private agricultural use includes both freehold and lease land. The area cited as under agricultural uses may be slightly higher than the area actually under agriculture because of rocky and otherwise unsuitable land that is included in the lease land. The area classified as national parks also includes nature reserves and some land classified as both park and wilderness areas. These data show that agricultural land clearly dominates land use.

1.2 A range of economic impacts

The economic impacts of weeds include monetary and non-monetary costs, and may also include monetary and non-monetary benefits. For example, blackberries restrict human and animal access, entangle animals, harbour vermin, increase fire hazard, reduce pasture production, impede establishment of plants, and reduce naturalness and biodiversity (James and Lockwood 1998). But these costs are accompanied by benefits. Blackberries enhance the habitat for some bird species, provide a source of nectar and pollen to increase honey production and reduce steam bank erosion. In the same way, the negative and positive impacts of prickly acacia are illustrated in Table 1.3.

The challenge of course is to value the wide range of impacts, or at least the most important of them, and so we now review past attempts to do so.

Table 1.2. The distribution of land uses in Australia

Tenure	Uses	Area m ha	Percentages of Australia
Private land	Agricultural uses	459.550	59.7
	Other uses	23.020	3.0
Public land	National parks	44.324	5.7
	Other	132.686	17.3
Indigenous land		109.620	14.3
Total area		**769.200**	**100.0**

Table 1.3. A range of economic impacts for prickly acacia on the Mitchell grass downs of central western Queensland

Monetary benefits	Monetary costs	Non-monetary costs
Increased lambing	Control costs	Environmental damage
Better fleece weights	More capital expenditure	More feral pests
Drought insurance	Increased mustering costs	More erosion
Improved stock condition	Less grass production	
Less supplement costs	More tyre damage	
Improved micron width	More drain maintenance	
	More medical attention	
	More fence damage	

Source: Miller (1996)

1.3 A brief review of economic estimates

There have been many estimates of the control costs and production losses for specific weeds. For example, Sloane, Cook, and King (1988) estimated that weeds cost the wool industry $600m per year or 10 per cent of the total value of the wool clip. Vere and Dellow (1984) estimated that the cost of controlling blackberry, plus the value of the lost production, was $4.7m in central western NSW alone. James and Lockwood (1998) estimated that the cost of controlling blackberry in 1984 plus the lost agricultural production, was $41.5m to the nation as a whole. In the dry tropical savannas of northern Queensland, a medium density infestation of rubber vine is estimated to reduce beef production by 25 per cent, increase management costs by $10 per hectare, and increase mustering costs by 36 cents per hectare (Adamson and Lynch 2000).

Serrated tussock invades pastures of the tablelands, particularly in New South Wales. Vere and Campbell (1979) estimate the costs of control, as the year one cost of replacing the weed by improved pasture, to be $24.4m. The net loss in terms of reduction in potential wool income, was $11.8m and the ratio of money benefits to money costs for controlling the weed was 1.7.

Siam weed is a woody perennial shrub that climbs to 20 metres. The seeds are easily spread by the movement of soil, pasture seed or livestock, and the plant invades horticultural crops (especially banana, citrus and mango), sugar plantations, and cattle pasture throughout coastal Queensland. Adamson, Bilston and Lynch (2000) estimate the expected annual losses to all crops would be $291m per year if no management were to occur.

There are some state-wide estimates of the impacts of weeds. For example, New South Wales Agriculture (1998) offers a weed control strategy for the whole state. The starting point is the statement (p1) ‘weeds are a huge environmental and economic burden on New South Wales; costing more than $600m per annum in control and lost production alone’. This state-wide measure of impact was a clear justification for their program but so was the distribution of the weeds: ‘…most areas of the state have now been invaded by a diversity of weed species affecting the environment, productivity, and aesthetics of the infested areas’. (p1).

In an innovative nationwide estimate for all weeds, Combellack (1987) calculated that weeds created financial costs of $2,096m in Australia (Table 1.4). The estimate covered both direct costs of control and yield losses. The direct losses were the costs of cultivation, herbicides, and labour in application. The yield losses comprise losses for both weeds that were not sprayed and weeds that were sprayed but not controlled. In livestock/pasture activities, the yield losses include loss of productivity, carcass damage, reduction in wool quality and poisoning of stock. The estimate covered crops, pastures, horticulture and other land, which included forests in the establishment phase, control of aquatic weeds, industrial buildings, railways, fence tracks, and national parks.

Table 1.4. Financial losses due to weeds in Australia $m 1981–82

Industry	Type of impact	Cost	Totals
Cropping	Direct	762	
	Yield losses	508	1,270
Pasture	Direct	44	
	Yield losses	450	494
Horticulture	Direct	42	
	Yield losses	171	213
Other land uses	Direct	119	
	Yield losses	?	119
Total area			**$2,096**

Source: Combellack (1987)

The index of producer and wholesale prices rose 2.18 times from 1981–82 to 2001–02. If the costs of herbicides, labour and the price of agricultural output, had risen at the same rate, the financial cost of $2,096m in 1981–82 would be $4,559m in 2001–02. But even if this total were correct for 2001–02, the relative prices of outputs and inputs have changed, the industry shares of the costs have changed, and the distribution of costs and benefits have changed since 1981–82. The estimated current value of $4,559m is therefore not easily applied to current discussions on policy formation.

The economic estimates provided to date are mainly agricultural, because weeds cause major impacts on agriculture and data are relatively easier to collect for the agricultural industries. But impacts have also been estimated for environmental weeds. Leys (1996) reports that $1.7m was spent in 1995–96 on the control of weeds over an area of 4.3m hectares in National Parks in New South Wales. Mimosa pigra can replace whole plant communities and threatens 39 environmental reserves in the Northern Territory. Possingham *et al*. (2002) report that $3m per year is spent on control of this species. The Northern Australia Quarantine Strategy locates and eradicates an average of two newly naturalised plants with weedy potential each year, and spends $3.6m per year to do so.

Only a portion of the rich literature on the measurement of these costs and benefits has been reviewed here. But clearly, weeds have many kinds of economic impacts even though only the costs of weed control, losses of yield, and changes in money revenue have routinely been measured. The remaining benefits and costs are usually unpriced, or have proved too difficult to measure because data were scarce. The first step in the estimation of the economic impacts of weeds is therefore to define the concepts to measure them.

1.4 Economic concepts to measure the impacts

Ideally the economic impacts of weeds should be measured in terms of changes in costs and benefits to the community as a whole. These changes should include all costs and all benefits to whoever they accrue. The standard economic concepts of this loss are welfare (economic surplus), net revenue and opportunity cost.

Welfare: the net well-being of the whole community, measured as the sum of producers surplus and consumers surplus. The former is the profit to the producer, which is money revenue minus variable money costs. The latter is the net benefit to the consumer, which is the difference between the amount that the consumer is willing to pay and the amount the consumer has to pay. The amount the consumer has to pay is of course market price.

Net money revenue: the monetary net revenue from control, or the monetary net cost of an invasion.

Opportunity cost: income that is foregone because of the weed invasion, due to yield losses and changes to lower-profit enterprises for example. These are sometimes called indirect costs, and are sometimes measured as a loss of *net* income and sometimes as a loss of *gross* income.

Financial costs: the direct money costs of control, including weedicide and the cost of labour and vehicles to apply it. They are sometimes called direct costs.

The change in welfare, or total economic surplus, is the economist's preferred measure of impact because it values the net benefit from control of weeds, or the net costs of an increase in weeds, to the whole community in ways that capture basic notions of well-being. It also nets out the financial costs and opportunity costs.

1.5 Objectives and plan of the report

The broad goal of this report is to estimate the value of the current economic impact of weeds for all land users and all land uses across Australia. The specific, and more realistic, objectives are to estimate the financial costs of control and lost production in agriculture, the loss of welfare in agriculture, the expenditures to control weeds in natural environments, the financial costs of control to government agencies that administer public land of various kinds and the financial costs of other public authorities, and the costs of weed control on Indigenous lands.

The impacts are easier to measure for agriculture because most outputs and inputs have money values, and much data have already been collected. We will therefore attempt to cover welfare losses, opportunity costs and financial costs in agriculture in detail. We will attempt to obtain detailed sets of financial costs for natural environments, public lands and public authorities, and Indigenous lands. We will use case studies to illustrate further key impacts and key relationships.

Values for all these kinds of estimates can help to:

- stimulate general awareness of weed issues,
- identify specific problems,
- resolve specific problems, and
- influence decisions.

Values for the welfare changes, and the net cost of a weed invasion or the net benefit of control, can also help to:

- determine the overall level of government funding,
- allocate funds between programs, and
- prioritise projects and policies within a program.

The next section introduces the economic principles and procedures for estimating values for the impacts. Values of the agricultural impacts are presented in Sections 3 and 4, and the costs of weeds in natural environments are documented from expenditures by the National Parks and Wildlife Services and other agencies in Section 5. Section 6 presents the expenditures by the remaining public authorities and Section 7 covers Indigenous lands. Finally, Section 8 summarises the results, reviews the strengths and weaknesses of the report, and addresses the relative size of weed impacts and other natural resource impacts. This section also indicates the major gaps in knowledge that we found in the course of this work.

2. The measurement of economic impacts

2.1 A framework for measurement

A common way to estimate an impact is to determine just the direct cost of weed control, that is the cost of herbicide and the labour and the equipment used to apply it. These costs are relevant but they are only part of the impact of weeds. The opportunity costs are also important, and these are the losses in production and losses in value of output due to a weed invasion. The framework of Figure 2.1 incorporates both the expenditure on weed control (E) and the loss in production (L), and provides a general way to think about the problems of weeds.

The curve L^1L^2 is a 'loss-expenditure frontier' that shows the lowest weed losses for each level of control cost, for a given weed in a given situation (McInerney 1996). Without any control, losses would be at the maximum of L^1 at one end of the frontier. As control expenditure increases from 0 to E_H and beyond, losses decline but at a diminishing rate. With the maximum possible control, losses would be at their minimum level but would still be positive.

Horticulture typically involves high control expenditures per hectare but low production losses so is depicted at position X_H, whereas livestock and grazing activities typically involve low control costs per hectare but high production losses (X_E). Crops may be depicted in the middle of the frontier (X_C) with substantial control costs and substantial losses.

Expenditures and losses are both impacts and so both must be estimated and aggregated to determine the total impact. The total cost of the impact (C) is therefore defined by the identity:

$$C = E + L \qquad (2.1)$$

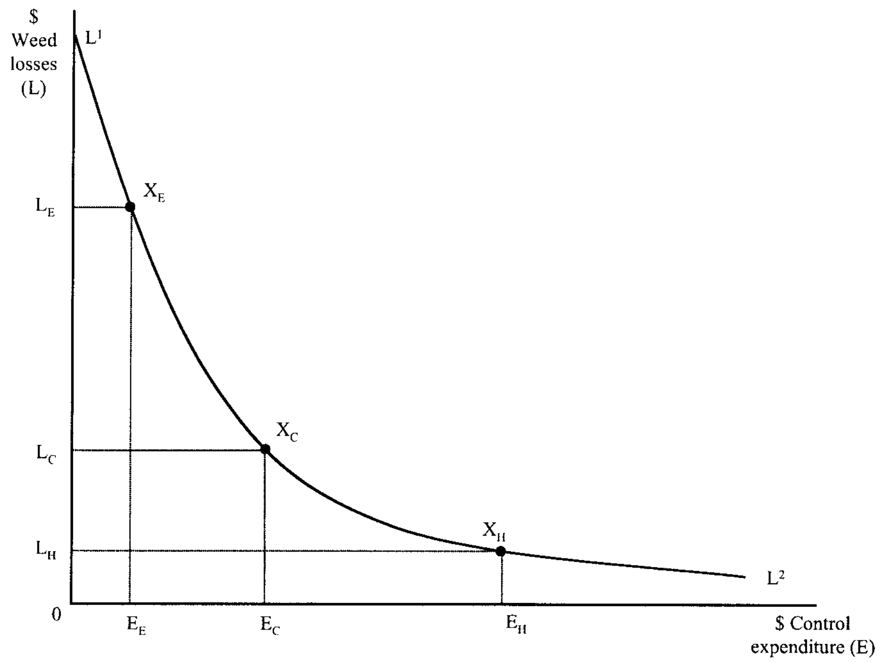
Weed management can be thought of as a choice between levels of E and L.

The impact of weeds on the natural environment, and the application of research to reduce weed problems, can be addressed in the same way as the impact of weeds on agriculture (Figure 2.1). Therefore this framework provides a general way to think about the management of weeds in all environments and situations. For example, choice of management strategies should avoid the comparison of losses with those of a weed-free environment (which is the point of origin 0) because that state is usually unattainable. Similarly, use of the expenditure (E) alone has no particular relevance to choices because the implied comparison is, again, with the weed-free situation and losses (L) are usually involved too.

2.2. Measurement of welfare impacts

The weed impact (C) is perhaps best measured as a loss in economic welfare. This approach measures the effects of weeds upon producers and consumers within an industry, and includes the direct and indirect financial costs within

Figure 2.1. A framework to estimate the impact of weeds



the calculations. The approach is applied by aggregating weed impacts for functional groups of weeds in industry-focussed estimates of economic surplus.

An introduction to the economic surplus concept is given in Figure 2.2, which depicts the supply function (*S*) of an industry such as wheat. The supply function is the amount of output that producers would supply at various prices and so can be interpreted as the cost of production. The presence of weeds has two impacts upon wheat production.

(a) Variable costs of production are increased because of the use of various herbicides and the increased tillage to control weeds. This increase in the cost per unit of output leads to an upward shift in the supply function, from point *a* to point *b* for a given quantity Q_X. This can be termed the E or expenditure effect.

(b) The competitive effects of weeds leads to a yield loss. There is a lower level of wheat output for a given cost of production. This is represented by a leftward shift in the supply function, from point *a* to point *c* for a given cost of production P_X. This can be termed the L or loss effect.

As noted in equation (2.1), the effects are additive and the total impact of the weed is measured as (E+L). The combined effect of weed expenditure and weed losses due to weeds is to shift the supply function from $S_{\text{no weed}}$ to $S_{\text{with weed}}$ as shown in Figure 2.2. That is, we shift from point *a* to point *d*.

The shift in the supply curve to the left due to weeds reduces the welfare of both producers and consumers. Producers lose when the economic loss from the decrease in production is greater than the gain from the increased market price. Consumers lose because market supply has contracted and price increases, so they now consume less but they pay more to do so.

The total loss in economic surplus is the sum of these losses to producers and consumers, and measurement of the total is illustrated in Figure 2.3. The weed-free price and quantity at equilibrium (point *a*) are P_0 and Q_0. The effect of weeds is to shift the supply curve left and the price and quantity at the new equilibrium (point *d*) are P_1 and Q_1. The area of economic surplus with weeds (*bde*) is clearly less than the area of economic surplus without weeds (*bac*), and the difference represents the economic cost of weeds. The total welfare impact of a weed is therefore measured as the loss (*bac*) – (*bde*). This loss is measured in Section 4.

2.3 Measurement of financial and opportunity costs

The direct financial costs of weed control are the expenditures on labour and herbicides by landholders, local government and state government agencies such as National Park and Wildlife Services, or Local Control Authorities. The opportunity costs of weeds are the yield losses due to crop competition and the costs associated with changes in land-use and the reduction in stock carrying capacity in pastoral systems. The appropriate monetary measure of the impact of weeds is the sum of direct financial costs of control plus these opportunity costs from current infestation levels. Indeed, opportunity costs can usually only be reduced by increasing the weed control effort and so increasing financial costs.

Figure 2.2. Change in a commodity supply function due to the expenditure (*E*) and loss (*L*) effects from a weed invasion

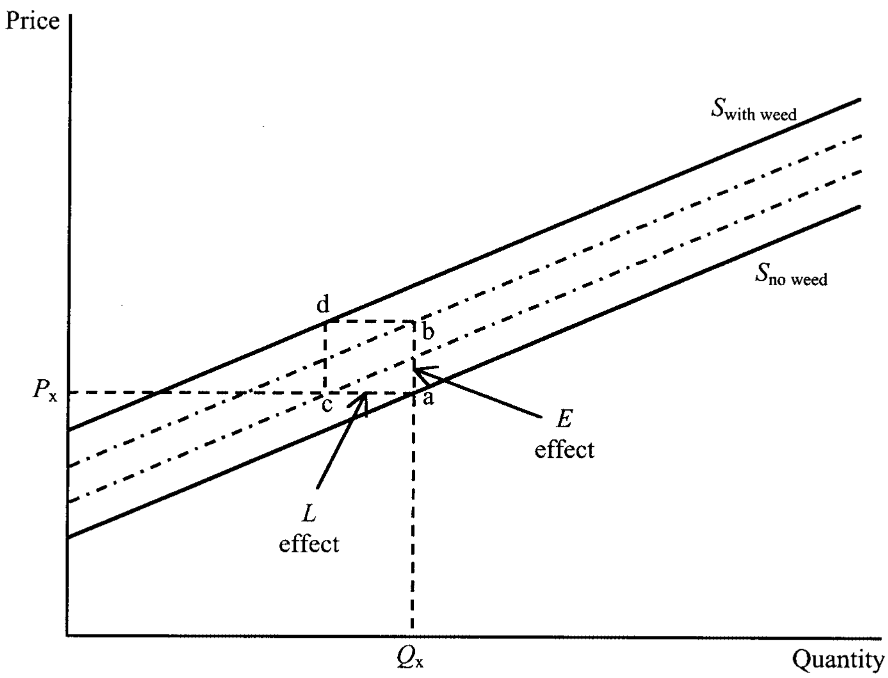
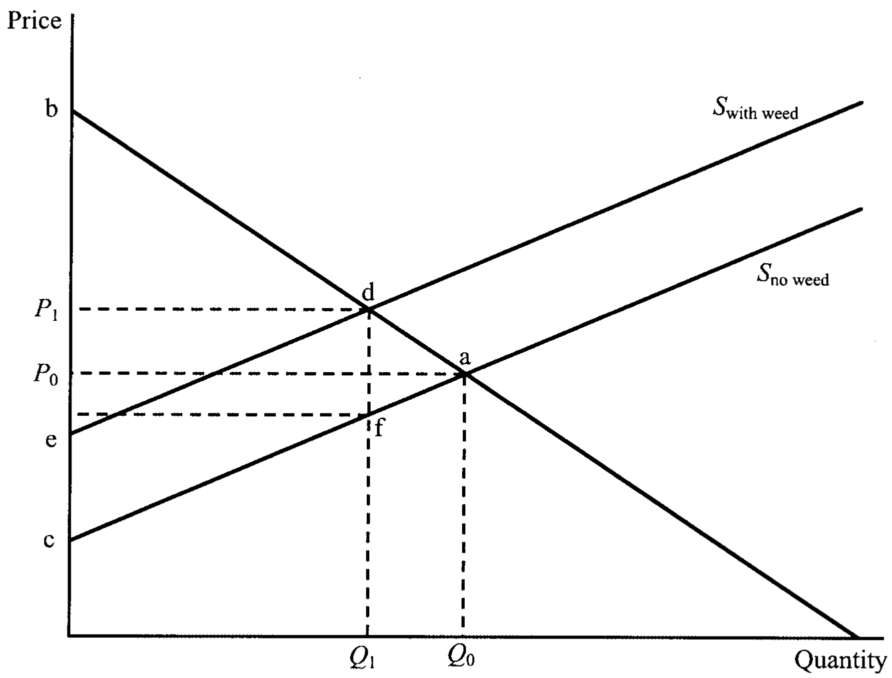


Figure 2.3. Measurement of the change in economic surplus due to a weed invasion



2.4 Issues in measurement

Level of measurement: Economic impacts occur at several levels. In the case of agriculture, weeds may affect a single farm (say a wheat farm), an industry (all wheat farms), the whole sector (all agricultural producers), and the community (all producers and all consumers). Impacts can also be economy wide, and so include all the flow-on effects of weed invasions or control to other industries and sectors.

The impacts at farm level are typically measured as changes in financial costs and money revenue. Partial budgeting and gross margin analyses are suitable ways to estimate these on-farm impacts. The impacts at the industry and community level are typically measured as changes in welfare. Changes at the economy level are usually measured as flows of money through the economy and calculated through large computer models of the national economy.

Incidence of the impact: the incidence of the impacts is, in many ways, as important as their size. While agricultural producers may initially pay all the money costs of weed control on their land, they may be able to pass on some costs to consumers through a higher product price. Similarly, an increase in output in one region, due to weed control, may lead to a decrease in sales of the output from another region, so impacts are linked within an industry.

All or some weeds? A policy-relevant measure of weed impact does not require estimates of the costs of all individual weeds. In most situations, it is impossible to estimate the cost of an individual weed at a national level. Although the opportunity costs could be derived for individual weeds if sufficient data on weed distribution were available, direct control costs could not be assigned to individual weeds. For example, in cropping systems a range of herbicides are effective on weeds such as annual ryegrass, wild oats and brome species. In grazing systems a broadleaf weed weedicide will simultaneously control Paterson's curse, thistles, capeweed and a range of flat weeds (eg dandelion). Consequently, it is better to think of weeds in terms of functional groups. Also, cultural methods of weed control (such as tillage, fallow and rotational changes) are not specific to any weed type.

2.5 Method and data collection

In the previous CRC for Weed Management Systems, much effort was devoted to determining the appropriate way to measure the impact of weeds, and the economic and social benefits from CRC research. Vere, Jones and Griffith (1997) concluded that weed impact should be measured at an industry level (such as the wheat industry or lamb industry) rather than at the farm level. But further, a policy-relevant measure of impact need not assess effects on all industries, but rather 'just' on those having a significant input to the Australian economy. Thus minor industries such as deer farming need not be considered.

As we have noted, the cost of control and weed impact are not always attributable to individual weeds. We therefore estimate the impacts in a 'top-down' approach that is by each agricultural industry, by natural environments, by public lands, and by Indigenous land, rather than a 'bottom-up' approach by individual weeds.

Data are collected, and the analytical techniques can best be applied, in a top-down manner.

Our approach may therefore be set out as a set of procedures.

- Estimate where possible the change in welfare, or economic surplus, as the preferred measure of impact.
- Estimate where possible a change in net money revenue as a useful proxy for welfare. The change in net money revenue is an estimate of the change in surplus at the initial quantity.
- Derive the financial costs and opportunity costs due to weeds, where welfare or money revenues cannot be estimated.

The application of these procedures is detailed in the following sections where they are applied to agriculture, natural environments, public lands and indigenous lands.

We use 2001–02 as the base year for all estimates because that is the most recent year for which data are widely available. Where possible, we will attempt to obtain data for the five previous years to establish a trend and so explore whether 2001–2002 was an unusual year. We attempt to avoid double counting by concentrating on the primary effects at industry level, and by addressing each major type of land and land use separately. Cross checks are explicitly incorporated for agriculture, which turns out to have the highest measurable impact due to weeds. This check involves estimating impact as (financial loss + opportunity cost) in Section 3 and as economic surplus in Section 4.

3. Agricultural land: financial costs and yield losses

The cost of weeds to Australian agriculture includes the financial cost of weed control (E in Figure 2.1) and the opportunity cost of lost production where weeds are present (L). Opportunity cost is frequently measured as the value of lost production, that is the reduced returns associated with reductions in yield and/or reductions in prices. The financial and opportunity costs associated with the presence of weeds in Australian agriculture are estimated in this section. The total cost (E + L) from this approach is related to the total loss of economic surplus, which is estimated in Section 4. The results from each approach are compared at the end of Section 4.

3.1 Basis for assessment

There are over 410 million hectares of land actually in agricultural production in Australia. This total is dominated by beef production (over 240 million hectares), due largely to the extensive nature of the beef industry in northern Australia. Approximately 20 million hectares of land are used for grain production. Close to 60 per cent of this area is farmed by specialist grain producers and the remainder by mixed farmers. Clearly, broadacre grazing and crop production together dominate land use. The gross value of agricultural production is in the order of $30b (Australian Bureau of Statistics 2001), again dominated by beef and crop production.

The number of farms in each major agricultural industry, their average size, and indicative gross margin, provide the basis on which to assess the financial costs and opportunity costs. These data, and their sources, are detailed in Table 3.1. The number of farms and their sizes are based on data from the Australian Bureau of Agricultural and Resource Economics and the Australian Bureau of Statistics, supplemented by industry estimates where necessary.

The gross margins for each of the industries are obtained from state departments of agriculture and industry reports, and all identified in the notes to Table 3.1. Indicative, or 'proxy' gross margins were estimated where an industry comprises a range of sub-industries, or comprises a number of commodity groups. For example, a gross margin for oranges has been adopted as a proxy for fruit production because citrus dominates Australia's fruit production. Similarly, the gross margin adopted for 'Sheep-Beef' production comprises an average of appropriate gross margins for sheep and beef enterprises. The gross margins provide a base on which to assess per hectare production losses incurred despite typical weed control activities for that enterprise.

There are a number of smaller and emerging enterprises in Australian agriculture such as the alpaca, sesame and tea tree oil industries. They are explicitly omitted, so the use of the information in Table 3.1 would under-estimate the aggregate financial costs of weed control and yield losses associated with weeds. These industries have been excluded because they represent a small proportion of total Australian agriculture. Little reliable data exists in relation to their structure or costs, and in many cases they may have been reported as part of the operations of the major industry sectors.

Table 3.1. Number of operations, areas and gross margins by agricultural industry

Industry	Number of farms	Area per farm (ha)	Gross margin used for analysis ($ per ha)
Grain	14,487[a]	816[e]	208[k]
Dairy Cattle	12,725[a]	228[a]	776[l]
Beef Cattle	18,215[a]	9897[a]	113[m]
Grain–Sheep/ Grain–Beef	16,893[a]	1223[a]	162[n]
Sheep – Beef	8,272[a]	5090[a]	116[o]
Sheep	11,791[a]	4627[a]	119[p]
Cotton	560[b]	848[f]	755[f]
Sugar	4,850[c]	85[g]	812[q]
Rice	2,000[d]	75[h]	1442[r]
Fruit	10,196[c]	10[i]	540[s]
Vegetables	3,929[c]	23[j]	744[t]

Notes:

[a] Five year average to 01–02 (Agsurf 2003).

[b] Five year average total hectares planted in Australia (Agsurf 2003) divided by five year average hectares planted on average operations (Boyce 2002).

[c] Australian Bureau of Statistics (1998).

[d] www.rga.org.au/rice/growingau.asp.

[e] Five year average to 01–02 (Agsurf 2003).

[f] Five year average (Boyce 2002).

[g] Five year average total area of production divided by the number of producers reported by Australian Bureau of Statistics (1998).

[h] Five year average total area of production divided by the number of producers reported by the Rice Growers Association (www.rga.org.au).

[i] Productivity Commission (2002). Most citrus operations are 10 hectares or less. Australian Citrus Growers Incorporated (2003, www.austcitrus.org.au) report 2,500 growers operating 32,000 hectares which is an average operation size of 12.5 hectares. As a proxy for all fruits, a smaller estimate is appropriate.

[j] The Australian Potato Industry Council (2003, www.horticulture.com.au) report 2,000 growers operating 42,000 hectares which is an average of 22.5 hectares.

[k] NSW Agriculture (2001–2003) for long fallow Central West NSW.

[l] Davies, Alford and Hollis (1999). Gross margin for NSW South coast divided by the number of hectares reported by ABARE (2003).

[m] NSW Agriculture (2001) Inland Weaner Store Gross Margin, 2003. Native pastures.

[n] Average of grain and sheep-beef gross margins assumed 50:50 composition.

[o] Average of sheep and beef gross margins assumed 50:50 composition.

[p] Average of sheep-meat (NSW Agriculture 2001–2003) for 2nd cross lamb gross margin), and sheep-wool (NSW Agriculture 2001–2003) 21 mi wether gross margin). The gross margins assumed 50:50 composition.

[q] SRDC (2002) www.srdc.gov.au Average of plough out and fallow out crop systems – Mackay.

[r] NSW Agriculture (2001–2003) Medium Grain Rice Summer Murrumbidgee.

[s] Productivity Commission (2002). Gross margin reported for Citrus Production in the MIA.

[t] NSW Agriculture (2001–2003). Fresh winter potato production.

3.2 Estimation of financial costs

The industry-by-industry estimate of the financial costs of on-farm weed control (Table 3.4) is based on the information on chemical costs in Table 3.2 and on non-chemical control costs in Table 3.3. This financial cost of weed control to Australian agriculture is estimated to be in the order of $1,365m to $1,519m per annum. The process for estimating these costs is now described.

The estimates of chemical costs associated with weed control were based on data on the average cost of crop and pasture chemicals by industry in 2000 from the Australian Bureau of Statistics. These data were indexed to 2001–02 using the ABARE index of prices paid for chemicals and estimated per hectare of production using the average size of farm operations reported by the Australian Bureau of Agricultural and Resource Economics. The ABS estimate of expenditure on crop and pasture chemicals comprises the range of chemicals used in each farm enterprise type including fungicides, insecticides and pesticides as well as herbicides. So the proportion of this expenditure likely to relate to weedicide and weed control was determined from relevant gross margins, previous reports and consultation with industry representatives.

Geographic, commodity and annual diversity introduce considerable variability to the proportion of expenditure that is likely to be attributable to herbicides. A range of expenditures, as reported in Table 3.2, has been introduced to accommodate this variability and so the total cost of chemicals for weed control is estimated to be between $820m and $974m per annum. The Australian Bureau of Agricultural and Resource Economics report that total factory gate sales of herbicides in 2000 were $965m, confirming that the present estimate is the right order of magnitude. This figure of $965m does not include retail margins and some sales from non-AVCARE members, but it may also include non-agricultural application of herbicides.

The direct expenditure on weed control includes the costs of application and other activities such as weed chipping, slashing, grazing strategies and tillage practices. Published estimates of these additional costs are not comprehensive. An assessment of the cost of weeds, pests and disease in the Australian wool industry (Sloane, Cook and King 1988) identified that for each $1.00 spent on weedicide, an additional $0.30 – $1.00 was likely to be spent on application of that chemical. Further, this addition could rise to $2.00 when the costs of on-farm mechanical weed control, such as cutting, slashing and ploughing, are included. With the exception of sugar and cotton, an estimate within this range ($0.60) has been applied across all the agricultural industries. So if the average annual weedicide costs were between $34.92 and $38.80 per hectare for grain enterprises, an average additional $22.12 per hectare would be spent on application and other on farm activities (Table 3.3). Specific estimates of additional costs were available for sugar and cotton from industry sources.

The relationship identified by Sloane, Cook and King (1988) is dated and specific to the wool industry. But the lower end of this range provides a basis for application here in relation to pasture and crop management. Significant changes in land management (such as widespread adoption of low or no till practices) over the last decade, and difficulties in relating farm activities to just weed control, were considered when adapting this

Table 3.2. Chemical costs for weed control by industry

Industry	Crop & pasture chemical costs ($/ha)[a]	Percentage of crop & pasture chemicals used for weed control[b]		Expenditure on crop & pasture chemicals ($ /ha)		Expenditure on crop & pasture chemicals ($m per industry)	
		Low	High	Low	High	Low	High
Grain	38.80	90%	100%	34.92	38.80	413	459
Dairy Cattle	5.49	80%	90%	4.39	4.94	13	14
Beef Cattle	0.16	80%	90%	0.13	0.15	23	26
Grain-Sheep / Grain-Beef	13.20	80%	95%	10.56	12.54	218	259
Sheep-Beef	0.64	80%	90%	0.51	0.57	22	24
Sheep	0.56	80%	90%	0.45	0.5	24	27
Cotton	658.03[c]	15%	20%	98.70	131.61	47	63
Sugar	82.50	90%	100%	74.25	82.50	31	34
Rice	186.28	90%	99%	167.65	184.42	25	28
Fruit	1,081.13	2.0%	20%	21.62	216.23	2	22
Vegetables	992.58	2.5%	20%	24.81	198.52	2	18
Total						**$820**	**$974**

[a] *Crop and Pasture Chemical Expenditure (Australian Bureau of Statistics 2000) apportioned across the number of production hectares per farm (Table 3.1) and indexed to 2001–02 using the ABARE Index of Prices Paid for Chemicals.*
[b] *Ranges determined on the basis of gross margins, consultation and previous reports.*
[c] *Boyce (2002).*

relationship for the present study. As shown in Table 3.3 the total cost of additional on farm costs of weed control is estimated to be in the order of $545m per annum.

The total financial cost of weed control is presented in Table 3.4 and was aggregated from the results in Tables 3.2 and 3.3. For example, the low estimate of the total financial cost in the grain industry is $674m (Table 3.4). This comprises $413m as the low estimate of expenditure on chemical costs in Table 3.2 plus $261m of additional non-chemical costs from Table 3.3. The total financial cost for all agricultural industries lies between $1,365m and $1,519m per annum.

The total financial cost does not include the cost of all labour. In the absence of a suitable basis on which to apportion the imputed value of on-farm labour to weed control activities, 'owner' labour has been excluded. The value of rates paid by land holders for 'vermin and weed' control has also been excluded. If 50 per cent of the reported payments were used for weed control, the total direct costs of weeds to Australian agriculture would increase by some $8m per annum (Australian Bureau of Statistics 1998, estimate for 1997–98 adjusted to 2001–02). The estimated range of $1,365m to $1,519m per year (Table 3.4) is therefore an underestimate.

Table 3.3. Non-chemical control costs by industry[a]

Industry	Non-chemical costs of weed control ($ per ha)	Non-chemical costs of weed control ($m per industry)
Grain	22.12	261
Dairy Cattle	2.80	8
Beef Cattle	0.08	15
Grain – Sheep / Grain – Beef	6.93	143
Sheep – Beef	0.33	14
Sheep	0.29	16
Cotton	99.00	47
Sugar	30.00	12
Rice	105.62	16
Fruit	71.35	7
Vegetables	67.00	6
Total		**$545**

[a] *All estimates, except cotton and sugar are assumed to follow the relationship identified by Sloane, Cook & King (1988), whereby for each $1 spent on chemical, there is another $0.3 – $1 spent on application and up to another $1 for other on farm activities associated with weed control. $0.60 has been adopted for this analysis in consideration of the chemical and non-chemical costs of weed control associated with grain production and changes to weed management practices in the time since Sloane, Cook & King (1988). This ratio has been applied to a midpoint estimate of herbicide expenditure per hectare. Estimates for cotton and sugar are sourced from the Cotton Research & Development Corporation (CRDC 2002) and McLeod (1996).*

Table 3.4. Total financial cost of on-farm weed control

Industry	($m)	
	Low	High
Grain	674	720
Dairy Cattle	21	22
Beef Cattle	38	41
Grain-Sheep / Grain-Beef	361	402
Sheep – Beef	36	38
Sheep	40	43
Cotton	94	110
Sugar	43	46
Rice	41	44
Fruit	9	29
Vegetables	8	24
Total	**$1,365**	**$1,519**

3.3 Estimation of lost production

We now turn to the estimation of the opportunity costs of weed production. Little detailed data are available on production losses due to weeds, but a conservative approach using the available information can demonstrate the magnitudes involved. For each of the enterprise types, production losses due to weeds have been estimated as a percentage loss (Table 3.5).

They are calculated on the basis of per hectare gross margins, but they can be considered in terms of reduced per hectare carrying capacity in dry sheep equivalents, reduced tonnage, litres, or other measure of production per hectare. These losses occur despite current weed control measures of the 'average' farmer in that industry. The estimates for each industry are calculated as the difference between the gross margin reported and the gross margin that would have been likely in the absence of weeds. The latter gross margin includes the additional production. The data have then been aggregated to the industry level with information from Table 3.1.

Weeds are estimated to cause production losses in excess of $2,218m per annum in Australian agriculture (Table 3.5). This is a conservative estimate because a number of additional costs in each of the industries were identified, but not included due to difficulties in measurement. For example, a number of noxious weeds lead to animal deaths, many weed seeds contribute to 'vegetable' matter losses in fibre sales and additional marketing

Table 3.5. Production losses from weeds, by industry

Industry	Yield losses (%)	Source	Loss ($/ha)	Other losses (not quantified)	Total industry
Grain	6.5	Jones *et al* (2000)	14	Additional losses may result from presence of foreign plant matter in grain/additional grading costs	171
Dairy Cattle	5	[a]	41	[b]	118
Beef Cattle	5	[a]	6	[b]	1,068
Grain-Sheep Grain-Beef	5	[a]	9	[b]	176
Sheep-Beef	5	[a]	6	[b]	256
Sheep	5	[a]	6	[b], and Discounted wool clip. Losses can be highly significant. Difficulties in estimation estimation arise when attributing discounts to weeds or leguminous pastures (Sloane, Cook & King 1988)	
Cotton	15	CRDC (2003)	133	Cotton sales are rarely discounted for the presence of vegetable matter and any discounts that do occur usually result from the presence of cotton trash itself	
Sugar	5.2	Mcleod (1996)	45		18
Rice	2.5	Pers comm. NSW Agriculture (2003)	37	Presence of weed seeds in rice grain may result in discounts and additional grading	
Fruit	1	assumed	5		1
Vegetables	1	assumed	8	Presence of weed matter in some produce may require additional sorting	1
Total					**$2,218**

a Sloane, Cook & King (1988) was used as the basis for these pasture based industries.

b Stock deaths associated with a number of weeds can be significant. In many cases this may be seasonal and dependent upon the availability of other feeds.

efforts may be required in cases where weed seed/trash is prevalent. Similarly, $2,218m should be also considered conservative because it is based on major industries only. This estimate should therefore be considered the lower bound of the annual costs of lost production.

3.4 Results and discussion

The total cost of weeds to Australian agriculture is the sum of the on-farm costs of control and the opportunity costs from lost production. The results show that:

- the lower estimate is $3,583m (= 1,365 + 2,218), and
- the upper estimate is $3,737m (= 1,519 + 2,218).

But this range itself is a lower bound because it only includes the cost of weed control and the value of lost production where estimation has been possible.

These results for the cost of weeds in Australian agriculture are composed of costs to the cropping, livestock and horticultural industries. The results by industry in Tables 3.4 and 3.5 may be regrouped on this basis, as below in Table 3.6.

Table 3.6. Summary of costs by industry groups $m

Industries	Financial costs		Opportunity	Total costs	
	Low	High	costs	Low	High
Crops	1,033	1,121	346	1,379	1,467
Livestock	315	345	1,870	2,185	2,215
Horticulture	17	53	2	19	55
Total	**$1,365**	**$1,519**	**$2,218**	**$3,583**	**$3,737**

The opportunity cost component of this total is dominated by losses in the beef industry. In the absence of alternative estimates of these losses, an estimate from the sheep grazing has been adopted. It is highly likely that losses to both the northern and southern Australian cattle industries will vary from the five per cent used in this study. Anecdotal evidence indicates that actual losses would exceed the five per cent that is adopted here. This provides further evidence that these estimates of total are lower bounds and also suggests the need for further assessment of losses in the grazing industries of Australia.

4. Agricultural land: losses of economic surplus

We now turn to the reduction in benefits to producers and consumers due to weed invasions. These are measured as producers surplus and consumers surplus respectively, and collectively they are termed 'economic surplus'.

4.1 Basis for assessment

The changes in the economic surplus from weed invasions or weed control are estimated from the following equations (Alston 1991), with reference to the price and quantity equilibriums of Figure 2.3.

$$\Delta CS = P_1 Q_1 Z(1+{}^1/_2 Z\eta) \quad (4.1)$$

$$\Delta PS = P_1 Q_1 (K - Z)(1+{}^1/_2 Z\eta) \quad (4.2)$$

$$\Delta ES = \Delta CS + \Delta PS = P_1 Q_1 (1+{}^1/_2 Z\eta) \quad (4.3)$$

$$Z = \frac{K\epsilon}{\epsilon + \eta} \quad (4.4)$$

where ΔCS, ΔPS and ΔES are the changes or losses in consumers surplus, producers surplus and total economic surplus respectively, K is the vertical shift in the supply function expressed as a percentage of initial price (P_1), Z is the percentage reduction in price arising from the supply shift, and η and ϵ are the absolute values for the elasticity of demand and the elasticity of supply. Elasticities measure the slope of the demand and supply curves.

Estimates of all these parameters are now obtained and the economic surplus equations (4.1 to 4.4) are solved for each individual commodity.

The scenario for the calculation of K is the comparison of 'with-weeds' and 'without-weeds' situations. Therefore, we are measuring the maximum production and surplus gain that could be achieved if weeds were eliminated from an agricultural industry, and we are using the 'with-weeds' situation as the starting point. The specific calculation for K is the vertical distance in the shift in the supply curve (d–f) divided by the price P_1 in Figure 2.3.

4.2 Data collection

A range of input data was required to estimate the effect of weeds on economic surplus. The key inputs were the equilibrium quantities (Q_1) and prices (P_1) in Figure 2.3, demand elasticities (η), supply elasticities (ϵ) and the supply shift parameter for each industry (K) due to the presence of weeds.

Table 4.1. Production Q_1 (kilotonnes)

	Average	1997–98	1998–99	1999–00	2000–01	2001–02
Wheat	22,482	19,224	21,464	24,758	22,108	24,854
Oats	771	937	909	584	650	773
Barley	6,534	6,484	5,987	5,032	6,743	8,423
Canola	1,709	856	1,690	2,426	1,775	1,797
Lupins	1,500	1,561	1,696	1,968	1,055	1,220
Field Peas	368	316	298	357	455	416
Chickpeas	204	199	188	230	146	258
Sorghum	1,830	1,081	1,891	2,116	1,935	2,129
Maize	376	271	338	406	345	521
Sunflowers	117	98	209	147	70	63
Soybeans	80	54	109	105	62	70
Rice	1,348	1,331	1,390	1,101	1,643	1,275
Sugar	4,957	5,567	4,998	5,448	4,162	4,610
Dairy[1]	10,456	9,439	10,178	10,847	10,545	11,271
Wool	663	700	687	671	652	607
Lambs/Mutton	648	600	617	629	714	679
Beef/Veal	2,003	1,939	1,987	1,991	2,025	2,072

[1] unit is megalitres

Table 4.2. Prices P_1 ($/tonne)

	Average	1997–98	1998–99	1999–00	2000–01	2001–02
Wheat	209	198	187	195	232	232
Oats	143	172	110	103	137	192
Barley	166	180	134	141	174	203
Canola	370	-	-	-	-	-
Lupins	200	196	156	145	205	298
Field Peas	284	272	294	297	219	340
Chickpeas	545	488	461	448	648	678
Sorghum	161	182	142	131	163	188
Maize	192	216	173	161	187	225
Sunflowers	480	-	-	-	-	-
Soybeans	360	-	-	-	-	-
Rice	216	226	213	213	208	220
Sugar	308	343	357	257	253	332
Dairy[1]	28.7	29.4	28.5	26.2	29.0	30.3
Wool	4,204	4,443	3,234	3,573	4,501	5,267
Lambs/Mutton	2,045	2,000	1,784	2,049	1,735	2,657
Beef/Veal	2,184	1,626	1,810	2,043	2,371	3,072

[1] *unit in cents/litre*

The equilibrium quantities and prices were obtained from ABARE (2003), except for the prices for canola, sunflowers and soybeans. These prices were derived from NSW Agriculture (various). The actual quantities and prices used were derived as the average for the five-year period 1997–98 to 2001–02. The data for cotton were obtained from Hoque *et al*. (under review). The data for each commodity are given in the Tables 4.1 and 4.2.

Table 4.3. Elasticities

	Supply elasticity (ϵ)	Demand elasticity (η)
Wheat	0.25	6.17
Oats	0.20	2.20
Barley	0.20	2.20
Canola	0.20	2.20
Lupins	0.20	2.20
Field Peas	0.20	2.20
Chickpeas	0.20	2.20
Sorghum	0.20	2.20
Maize	0.20	2.20
Sunflowers	0.20	2.20
Soybeans	0.20	2.20
Cotton	1.50	2.20
Rice	0.36	2.20
Sugar	0.36	2.20
Dairy	1.13	3.00
Wool	0.90	1.40
Lambs / Mutton	1.38	1.40
Beef / Veal	0.10	1.40

The supply and demand elasticities used for each industry (Table 4.3) were obtained from a number of sources including ABARE (1999), Brennan and Bantilan (1999), Griffith *et al*. (2001), Hill, Piggott and Griffith (2001), Jones *et al*. (2000) and Myers, Piggott and MacAulay (1985).

The supply elasticities are lower than the demand elasticities, which suggests that the changes in producer surplus will be higher than the changes in consumers surplus.

The *K* parameter has been calculated for weeds in a number of previous studies for winter crops (Jones *et al*. 2000, Jones *et al*. in press), cotton (Hoque *et al*. under review) and wool (Vere, Jones and Griffith. 2003). This parameter is one of the most important variables in determining the loss in economic surplus and there is considerable uncertainty surrounding its exact values. For this reason, a risk analysis was used to incorporate a range of values of *K* for each agricultural industry. A triangular distribution was specified with minimum, most likely and maximum values for *K* (Table 4.4). A variety of approaches were used to estimate *K* for those industries with no previous estimates. For the livestock industries a grazing simulation model (developed by Jones) was used in conjunction with survey data of weeds in grazing systems (Dellow *et al*. 2002; Quigley 1992) to estimate a range of *K* values for various levels of weed composition. For summer oilseeds and coarse grains, values of *K* were obtained by extrapolating the values of the winter crops with changes resulting from discussions with weed scientists regarding differences in weed burdens and crop competitiveness.

Table 4.4. Supply shift parameters *K*

	Minimum	Most likely	Maximum
Wheat	0.10	0.15	0.20
Oats	0.10	0.15	0.20
Barley	0.10	0.15	0.20
Canola	0.10	0.15	0.25
Lupins	0.10	0.20	0.30
Field Peas	0.15	0.20	0.40
Chickpeas	0.15	0.20	0.40
Sorghum	0.10	0.15	0.20
Maize	0.10	0.15	0.20
Sunflowers	0.10	0.15	0.20
Soybeans	0.10	0.15	0.20
Cotton	0.25	0.30	0.35
Rice	0.10	0.15	0.20
Sugar	0.10	0.15	0.20
Dairy	0.10	0.20	0.30
Wool	0.10	0.20	0.30
Lambs / Mutton	0.10	0.20	0.30
Beef / Veal	0.10	0.20	0.30

4.3 Results

The results of the stochastic simulation of the economic surplus loss due to weeds are given in Table 4.5. The economic surplus results in the table (rows 3, 6, 9, and 12 of results) are the actual results generated in the simulation. The consumer and producer surplus are also actual results and are calculated separately, as shown in Equations (4.1) to (4.4). So the economic surplus will not always be exactly equal to the sum of consumer and producer surplus. The economic surplus results are the totals and so they are reported and used as the estimates of the impacts.

The mean, standard deviation, and the 5th and 95th percentiles are all reported in Table 4.5. The percentile results give the range in losses from the simulations. The changes in consumer surplus, producer surplus and total economic surplus are reported for the winter crop, summer crop and livestock industries. The results represent the scenario of 'with' and 'without' weeds and give a measure of the maximum economic gain that could be achieved if weeds were eliminated from these agricultural industries. Further results for each industry are shown in Table 4.6.

Table 4.5. Results of stochastic simulation for losses in consumer surplus, producer surplus and total economic surplus due to weeds in winter crops, summer crops and livestock industries ($m)

	Mean	Standard deviation	5th percentile	95th percentile
Winter crops				
consumer surplus	62	5	54	70
producer surplus	1,061	100	894	1,227
economic surplus	1,122	105	949	1,296
Summer crops				
consumer surplus	59	5	51	67
producer surplus	337	29	288	386
economic surplus	396	34	339	453
Livestock				
consumer surplus	609	71	492	728
producer surplus	1,800	215	1,441	2,153
economic surplus	2,409	270	1,962	2,856
Total				
consumer surplus	729	72	612	850
producer surplus	3,197	241	2,793	3,597
economic surplus	3,927	294	3,442	4,420

Table 4.6. Loss in mean consumer surplus, producer surplus and economic surplus for individual agricultural industries ($m)

	Consumer surplus	Producer surplus	Economic surplus
Wheat	27.91	688.92	716.82
Oats	1.39	15.34	16.73
Barley	13.76	151.37	165.13
Canola	8.92	98.08	107.00
Lupins	5.09	56.04	61.13
Field Peas	2.23	24.57	26.80
Chickpeas	2.37	26.04	28.41
Sorghum	3.73	41.04	44.77
Maize	0.92	10.08	10.99
Sunflowers	0.71	7.85	8.56
Soybeans	1.82	20.07	21.90
Cotton	12.28	18.01	30.30
Rice	6.28	38.38	44.66
Sugar	32.98	201.57	234.56
Dairy	177.69	471.75	649.44
Wool	230.17	358.04	588.20
Lambs / Mutton	140.63	142.67	283.30
Beef / Veal	58.87	824.12	882.99

The main impacts due to the presence of weeds may be summarised as follows.

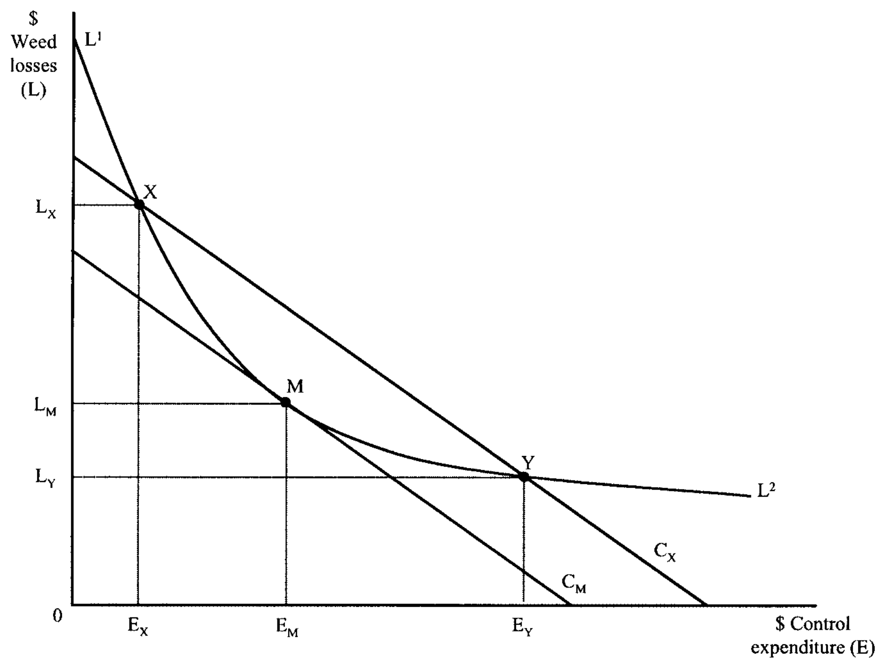
- The mean loss in economic surplus was $3,927m per annum.
- The range in this loss was $3,442m to $4,420m.
- The composition of the mean loss was $1,122m in winter crops, $396m in summer crops and $2,409m in the livestock industries.
- The majority of this loss was borne by producers ($3,197m loss in producer surplus) rather than consumers ($729m loss in consumer surplus).

The range of estimates of the loss in economic surplus ($3,442m to $4,420m in Table 4.5) encompasses the range of estimates of the sum of financial costs and yield loss ($3,583m to $3,737m in Section 3.4). Further, the mean surplus loss ($3,927m) exceeds the maximum loss of financial costs and yield losses ($3,737m). We would expect the surplus estimates to be higher because they include efficiency losses to the industries as well as the financial costs and yield losses.

4.4 Discussion

Consider again the economic framework outlined in Section 2 and its loss-expenditure frontier. The lines C_X and C_M in Figure 4.1 are iso-cost lines, which indicate the combinations of L and E that sum to the same total cost. So any combination of L and E along C_X results in the same total cost. And any combination along C_M results in the same total cost, but the total cost of C_X exceeds that of C_M.

Figure 4.1. The best combination of control expenditure and weed losses



Case study: Benefits of CRC research into annual grass weeds in the temperate perennial zone

Annual grass weeds, in particular vulpia *spp.*, can reduce agricultural output in the temperate pasture zone (TPZ) of south-eastern Australia. Vere, Jones and Griffith (2003) estimated the impact as the cost of weeds, and then proceeded to determine the economic return from research by the CRC for Australian Weed Management into this problem. They addressed an important issue that is usually ignored in impact studies; what are the benefits of doing something about the problem? This involved constructing two scenarios; with-CRC research and without-CRC research.

The study combined the results of a survey that derived the extent of various weeds in the TPZ and a grazing systems simulation model that calculated the returns from alternative ecological compositions of a pasture. This model was used to measure the wool industry supply shift parameters associated with various weed infestation scenarios.

The study also introduced variability into the economic surplus calculation in recognition of the fact that there is considerable uncertainty in our understanding of losses. The study divided Australia into two regions; the TPZ which benefited from CRC research and the rest of Australia (ROA) which in this case was not a beneficiary of the CRC research. An important part of this analysis is that it measured the benefits of changing the level of weed infestation from current levels, rather than assuming that weeds can be totally removed (that is, a no weed scenario). The results are summarised below, and show the changes in economic surplus for the with- and without-CRC research scenarios.

Economic surplus results for the effect of CRC research into annual grass weeds on the wool industry

	Mean	Standard deviation	Coefficient of variation
Economic surplus ($m)			
– with CRC	107.7	35.6	33.1
– without CRC	49.4	20.0	40.5
– net CRC benefit	58.3	23.1	39.7
Producer surplus ($m)			
– TPZ with CRC	153.8	51.0	33.1
– TPZ without CRC	70.4	28.5	40.5
– ROA with CRC	-47.8	15.9	33.3
– ROA without CRC	-21.7	8.8	40.6
Consumer surplus ($m)			
– with CRC	1.7	0.6	33.3
– without CRC	0.8	0.3	40.5

The loss-expenditure frontier, in a sense, defines the technical possibilities at any given time as explained in Section 2. An increasing level of weed control from E_x at X toward E_M at M reduces weed losses and reduces total weed cost from C_x to C_M .

The role of research, and the best combination of loss and control, can be depicted within the framework of the figure. The purpose of research is to shift the whole frontier $L^1 L^2$ toward the origin at 0, so to reduce total costs.

The maximum benefit from weed control involves a choice between control and loss. If the existing position is X, where surplus loss = L_x and control cost = E_x the total cost is:

$$C_x = (L_x + E_x)$$

Let the best combination of control and loss be at M where the loss is L_M and control cost is C_M. The total cost now is:

$$CM = (L_M + C_M)$$

The avoidable cost, which is the maximum benefit of weed control, is equal to $(C_X – C_M)$.

5. National Parks and natural environments

We now turn to the estimation of the economic impacts of weeds on natural environments.

5.1 Scope

There are no consistent, national or even state-wide, data on the effects of weeds on the outputs of goods and services from natural environments. There are no market-based prices for the values of these outputs either. The available data are just the expenditures by National Parks and Wildlife Services on weed management, and the expenditures of National Heritage Trust (NHT) funds by other bodies on weed control in natural environments. Thus nationwide impacts in national parks and natural environments can only be estimated in terms of the costs of weed control. These expenditures have been collected and are summarised for the year 2001–02 in Table 5.1, with changes over time in Tables 5.2 and 5.3. These data are supplemented by estimates of the costs and benefits of weed management for biodiversity protection in two important cases, namely individual national parks and weeds of agriculture and production forests.

5.2 Data Collection

Expenditures were collected directly from the head office for each National Parks and Wildlife Service throughout Australia. Expenditures that had been collected on a regional basis were aggregated to the state level. The initial list of persons to contact in each service was compiled from the agency's website, from advice from colleagues within the CRC for Australian Weed Management, and from personal contacts.

Each state appears to have a different system of record keeping, and appears to control different types and species of weed. Some states give priority to large infestations within the National Parks and nature reserves while others give priority to declared weeds only. For these reasons, expenditures on weed control were aggregated across all weeds.

The expenditures comprised the direct costs and indirect costs of weed control. Direct costs included the on-ground expenditures on weedicide, labour, contractor costs, and other materials. The indirect costs included the depreciation of equipment, mapping, surveillance and research that were attributable to weed management. Salaries were an additional cost allocated to weed management.

The National Parks and Wildlife Service of New South Wales provided a breakdown of the total expenditure into (a) direct costs of wages and treatment, (b) indirect costs including the allocation of capital to weeds management, and (c) the proportion of salaries devoted to weeds management. The Services in Queensland, South Australia and the Australian Capital Territory provided just direct and indirect costs. The other states provided data on the direct costs alone.

Expenditures on weed control in natural ecosystems outside national parks were collected from the 2001–02 annual report of the National Heritage Trust. An appendix to that report listed approved projects including many on weed control. The total expenditures on these projects for each state were extracted. Individual groups, catchment committees, and landcare committees undertook the projects.

5.3 Results: expenditures on weed management

The results in Table 5.1 include the direct costs of labour and treatment for all services, and the total costs with the additional expenditures on salaries, capital and other indirect costs of weed management for some authorities. The total costs are, of course, more comprehensive and show that expenditures on weed control totalled at least $19.597m in 2001–02. The total of the direct costs for national parks was $8.282m.

Table 5.1. Weed management expenditure by Australian National Parks and Wildlife Services and NHT funding for natural ecosystems: 2001–02.

States and Territories	Direct costs of labour and treatment $m	Total costs $m
Commonwealth of Australia	1.631	1.631[a]
New South Wales	1.133	5.583
Queensland	0.933	1.400[b]
South Australia	0.313	0.688[b]
Tasmania	0.210	0.210[c]
Victoria	2.800	2.800[a]
Western Australia	0.784	0.784[a]
Australian Capital Territory	0.373	0.522[d]
Northern Territory	0.105	0.981
Other natural environments	na	4.998[e]
Total	**$8.282**	**$19.597**

na is not available

[a] *Data on salary and capital costs were not provided, so this figure includes just the direct costs of labour and treatment.*

[b] *Indirect or capital costs were provided and are included in this value. But salary costs were not provided.*

[c] *Data cover only five of the seven regions in Tasmania, and for one district include just the cost of labour.*

[d] *Includes imputed cost of voluntary labour and depreciation on machinery, but excludes the costs of salaries.*

[e] *National Heritage Trust funds for weed control for preserving natural ecosystems other than national parks. The funds mainly apply to coast care programs, beaches, river catchments, wetlands, lakes, waterways and islands.*

The allocation of National Heritage Trust funds to control of weeds in natural environments totalled $4.998m in 2001–02. Of this total, $1.259m was allocated to New South Wales, $0.717m to Queensland, $0.267m to South Australia, $0.631m to Tasmania, $0.604m to Victoria, $0.151m to Western Australia, $0.102m to the Australian Capital Territory, and $1.267m to the Northern Territory.

The trends in expenditure on weed management over the years have varied widely between the states according to the need for weed control, and the availability of budgets (Table 5.2). For example, over the four years from 1997–98 to 2001–02 expenditure in New South Wales increased 113 per cent per year from a base of $1.013m in 1997–98 to a total of $5.583m in 2001–02.

The total weed expenditures by the National Parks and Wildlife Services of New South Wales and Victoria, as percentages of total budgets, are shown in Table 5.3. In NSW, expenditures increased from 0.94 per cent of the total budget in 1997–98 to 1.96 per cent in 2001–02, and in Victoria the proportion increased from 1.36 per cent in 1989–99 to 2.42 per cent in 2001–02.

Table 5.3. The increase in weed control expenditure the National Parks and Wildlife Services of New South Wales and Victoria, relative to total Service budgets

Year	Total budget $m		Per cent spent	
	NSW	Vic	NSW	Vic
1997–98	108	na	0.94	na
1998–99	na	103	na	1.36
1990–00	239	108	0.82	1.49
2000–01	258	116	1.96	1.98
2001–02	285	116	1.96	2.42

na: not available.

Table 5.2. Weed management expenditure by Australian National Parks and Wildlife Services: rates of growth in recent years[a]

State	From	To	Time span years	Value in 2001–02	% annual increase
New South Wales	1997–98	2001–02	4	5.583	113%
Queensland	1997–98	2001–02	4	1.400	12%
South Australia	1997–98	2001–02	4	0.688	0%
Tasmania	na	na	na	na	na
Victoria	1998–99	2001–02	3	2.800	33%
Western Australia	1997–98	2001–02	4	0.784	0%
Australian Capital Territory	1998–99	2001–02	3	0.522	71%
Northern Territory	na	na	na	na	na

na: not available.

[a] *Footnotes 'a' to 'd' in Table 5.1 also apply to their respective states in this table.*

5.4 Results: impacts of biodiversity protection

The problem

The estimates so far have omitted impacts on the potentially important outputs of biodiversity and the other services of the natural environment. The framework of Figure 2.1 indicates that the total cost of weeds is the expenditures on control (which are shown in Table 5.1) plus any losses of these outputs. The expenditures total $19.597m so this value is clearly an underestimate of the true impact of weeds on natural environments. Indeed, these costs may only be a small part of the problem. If we value the losses in outputs at a range of percentages of the monetary loss we have the results of Table 5.4.

Table 5.4. Alternative potential costs from the loss of biodiversity

Loss (% and $m)		Total impact $m	Loss (% and $m)		Total impact $m
0%	0.000	19.597	100%	19.597	39.194
25%	4.899	24.496	150%	29.396	48.993
50%	9.780	29.396	200%	39.194	58.791
75%	14.670	34.295	300%	58.791	78.388

Thus, if the decision-makers believe that the unpriced losses in outputs are equal to the monetary losses, the total impact of weeds is $19.597 + $19.597 = $39.194m. The following two examples document expenditures on specific weeds, and the case study on the next page offers a value for biodiversity protection from weed control that may be used in further benefit-cost analyses of weed management.

Scotch broom on Barrington Tops

Scotch broom is a leguminous shrub, native to Europe, and invades pastoral and woodland ecosystems and adjoining river systems in cool, high rainfall regions of southeastern Australia.

The largest single occurrence of scotch broom in Australia occupies 10,000 hectares in Barrington Tops National Park in NSW, which itself occupies 80,000 ha. This infestation is eliminating native herbs and tree seedlings from the understorey, preventing the re-establishment of eucalyptus in the overstorey, and threatening rare and endangered species in this World Heritage Area (Odom *et al*. 2003).

A substantial quantity of time and money has been invested to control this infestation. Over the last decade, an average of $95,892 per annum (as an annuity at a six per cent discount rate) has been spent to control broom to preserve this one special conservation area. An annual cost of $95,982 forever is equivalent to a lump sum expenditure of $1.598m.

This expenditure is the minimum value of the environmental benefit of preserving this threatened environmental reserve. Conservation must have been worth this much or it would not have been undertaken.

Mimosa pigra at Kakadu National Park

The Australian Department of the Environment and Heritage undertakes on-ground eradication and control projects for mimosa pigra and parkinsonia (survey only) at, and surrounding, Kakadu National Park.

Funding from the National Heritage Trust to manage mimosa over the period 1996–97 to 2002–03 comprised $4.855m specifically to reduce the impact this weed of national significance (Department of Environment and Heritage 2003). This funding complements expenditure by state and Northern Territory agencies for the same purpose. None of it was spent on framework and capacity building.

In the same period, the Department spent $5.600m of its own funds on mimosa, of which $5.040m was to prevent new weed problems and $0.560 was for framework and capacity building. The total over these seven years was therefore $10.455m ($4.855 + $5.600) or an average $1.494m per year. Thus protection of the special conservation area must have been worth at least $1.495m per year – or this money would not have been spent. Assuming the control of the weed has been successful, the minimum value of the biodiversity, and all the other environmental services that are protected, is $1.494m per year.

Case study: The value of biodiversity protection from weed control

The decision-makers judgement on the value of biodiversity protection can sometimes be isolated from their actual expenditures on weed control. But the influence of other considerations must first be separated out, and this can be sometimes accomplished if we have a number of such expenditures for a number of decisions. We have separated out such a value from the range of control costs nominated for 35 weeds in the WONS report (Thorp and Lynch 2000). The analysis is shown in Appendix 1.

The costs of control between these 35 weeds did not vary with the available data on the characteristics of weeds or with the current and potential areas occupied by them. But they did vary with other factors. Weeds of forests, and weeds of both forests and agriculture, attracted lower expenditures. Weeds that had a medium to high effect on the number of threatened species in a number of states attracted higher expenditures.

But further, the variation in these expenditures indicates that decision-makers place a value of $68,700 per year on the benefits of protecting one threatened species, and a value of $6,000 per year on the benefits of protecting one special conservation area that the particular weeds are threatening.

These values cannot easily be applied across the board to value the impact of a loss of threatened species or conservation areas because they refer to changes at the margin. But they can be incorporated in benefit-cost analyses as the value of biodiversity protection where one of the objectives of weed management explicitly is to preserve these kinds of threatened species from these kinds of weed.

5.5 Discussion

There are several difficulties in the estimation of the impacts of weeds in natural environments, and they are due to the lack of competitive markets for the outputs of these environments. Thus there are no prices to observe for the values of outputs and more fundamentally there are no data on the quantities of each of the goods and services that these environments provide to the community. Equally there are no systematic data to relate weed spread to the loss of goods and services. For these reasons we have estimated the impact as just the expenditure on weed control.

But we have been able to estimate the value of biodiversity protection for problems that involve weeds of agriculture and forests. This value may be applied to benefit-cost analyses of individual weed management projects.

But there is another, and more fundamental, effect of the lack of markets. Markets provide an arrangement where demands can come together with supplies to move toward an equilibrium. No such arrangement can exist for these environmental goods and services because they lack market prices. Thus we do not know how much should be spent on weed control in natural environments, and the community has no mechanism that continually allows for adjustments to a better level of control as exists in agriculture.

6. Public authorities, public expenditures and other public lands

Weed management expenditures on public lands, and by public authorities on both public and private land, are now reported and discussed.

6.1 Scope

In addition to national parks and nature reserves, there are many other kinds of public lands in Australia. These include state forests, crown lands, travelling stock routes and reserves, land adjacent to roads and railways, land adjacent to water reservoirs, and urban parks. We attempt to include all of these and so public land is taken to be all land not classed as freehold, pastoral leasehold, national park or indigenous land. A variety of organisations manage these public lands and, as the results will show, a significant amount of money is spent each year to manage weeds on them. Voluntary labour provides a valuable further resource, so this aspect is discussed as well.

6.2 Data collection

Procedures

Each state and territory distributes public money for weed control and management to a variety of organisations.

(i) Commonly, there is one central department of agriculture, natural resources or the environment, which undertakes operational programs such as treatments, surveys, and research and extension activities. These activities are undertaken for both declared and undeclared weeds, and on public and private land. Where public land is involved, a large proportion of this money is spent on the direct control of weeds. In contrast, where private land is involved, weed expenditure is largely directed towards research and extension activities.

(ii) Other state and territory authorities often undertake weed management activities, including those responsible for maintenance of road and rail infrastructure, state forests, and reserves such as stock routes. In many states, private contractors undertake control on these lands.

(iii) In some states, local government authorities contribute significant amounts of money to state authorities that undertake weed control on local roads and reserves on their behalf. Where this is not the case, weed management expenditure by the many individual shire councils on urban parks and local roads is rarely reported to a central authority, and the collection of such data was found to be impossible.

The central departments and other state authorities in each state and territory were therefore contacted. In most cases, we then contacted additional public land managers in the state, including private rail operators, water authorities and local governments.

Commonwealth authorities that undertake research into weeds management were contacted in the same systematic way, following the same procedures. Data on the quantities of volunteer labour were sought, but necessarily in a less systematic manner. Three useful case studies are reported out of the thousands of weed control projects undertaken by volunteers.

Data sought

Each organisation was asked for details of weed-related expenditure for 2001–02 and the previous years. Where documented data were not available, estimates of annual expenditure were requested. In most cases, the data could be classified into three categories:

- operational programs,
- programs that involve research and extension, and
- administration.

The results are summarised by states and territories in Table 6.1, and details for each state are provided in Appendix 2. The data omissions are listed in the discussion, and below the respective tables for each state or territory in the appendix.

6.3 Results: expenditure by state and territory authorities

Expenditure on weed management activities by all Australian state and territory public authorities for 2001–02 is summarised in Table 6.1. The total expenditure on weed management activities was $80.775m, with expenditure in Queensland and NSW being the largest at $26.811m and $19.865m respectively.

Each of the main government departments responsible for weed management in each state could provide expenditure details for 2001–02. But these data were difficult to collect in states where weed management is fragmented between many organisations and levels, and where there is increasing reliance on voluntary labour to control weeds.

Table 6.1. Weed management expenditure by state public authorities and other public land managers, 2001–02

States and Territories	Coordination, inspections, surveys, treatments ($m)	Education, training, extension & research	Salaries, admin, other indirect costs & in-kind contributions ($m)	Total ($m)
New South Wales	12.922	2.326	4.617	19.865
Queensland				26.811
South Australia	8.293	0.662	0.770	9.726
Tasmania				1.991
Victoria	13.269	1.300	0.000	14.569
Western Australia	6.248	0.303	0.470	7.021
Australian Capital Territory	0.663		0.021	0.684
Northern Territory	0.095	0.000	0.013	0.108
Total	**$41.490**	**$4.591**	**$5.892**	**$80.775**

Expenditures in Table 6.1 are not sub-divided into the three categories for Queensland or Tasmania, because some authorities in these states were unable to do so. Tables B and D in Appendix 2 show the expenditures for the authorities that could provide this information.

In a few cases such as New South Wales and Queensland, time series data were supplied which showed that expenditure had increased slightly over recent years. Data for the Northern Territory were incomplete but showed that expenditure in roadside weed control was increasing. Expenditure by local government in Queensland had been increasing at four per cent per annum since 1999–00 and the weed control budget of VicRoads has been increasing slightly.

6.4 Results: expenditure by Commonwealth authorities on surveillance and research

The Commonwealth Department of Agriculture, Fisheries and Forestry, CSIRO, and Co-operative Research Centres all undertake surveillance, research and other activities concerned with weed management. These expenditures are additional to those undertaken by the states, and expenditures by four authorities are listed in Table 6.2 for 2001–02.

Table 6.2. Expenditure on weeds by Australian Commonwealth authorities, 2001–02

Authority	$m
Department of Agriculture, Fisheries & Forestry [a]	4.043
CSIRO [b]	0.390
CRC for Australian Weed Management	3.566
Cotton CRC	0.253
Total	**$8.252**

[a] *Included in this category are the Australian Quarantine and Inspection Service, the Bureau of Rural Sciences, NHT funding for weed related projects by the Natural Resource Management area and expenditure by the Biosecurity Australia and Plant Health sections of the Department of Agriculture, Fisheries and Forestry.*

[b] *Included in this category is the CSIRO Division of Plant Industry. The Divisions of Entomology and Sustainable Ecosystems also undertake weeds based research, but their data were not available by the time of writing.*

6.5 Results: expenditure of time by volunteer labour

Volunteer labour plays a major part in weed management in Australia, particularly on public land. Formal and informal groups of volunteers, including Landcare, Bushcare, RiverCare and CoastCare have been tackling the problem for some time. Community groups largely rely on the volunteer labour of members to achieve their weed management goals. In-kind and monetary donations from individuals, local organisations, state and federal governments allow the purchase of other resources which enable weeds to be managed more efficiently and often more successfully.

There are undoubtedly a large number of groups and a very large number of volunteer workers involved, and so the total number of hours offered is clearly likely to be very high. But it is difficult to place a value on this labour. This is partly because the volunteers' hours are not always well recorded and partly because of the difficulty of valuing that time. The value of volunteer labour should only be included where the people could actually have earned an income in alternative use of their time. That is, the value should be included only if there is a true opportunity cost to the time.

Three case studies for community groups, who initially formed to tackle a particular weed problem, are included in this section. In each case, an *upper value* and a *more likely* value of the volunteers' work are estimated. The *upper value* is simply the total recorded volunteer hours over the life of the project, multiplied by an hourly rate of labour. The rate of $15 per hour was deemed appropriate. The *more likely* value reflects the reality that not all volunteers would be otherwise employed if they were not volunteering, and so the opportunity cost of their labour is zero. In case study 3, the group leader estimated that 65 per cent of all volunteers could have been employed if they were not volunteering, and in the other two case studies we assumed that only a quarter had an opportunity cost for their time. Values of each project are given in total dollars and on a dollars per hectare basis. The latter measure may be a useful way to estimate the overall value of community volunteering when knowledge is available on the total area of land managed by community groups.

6.6 Discussion

There are clearly many government bodies, semi-government bodies, and volunteer groups that spend considerable quantities of resources to accomplish a wide variety of weed management activities. We could document $80.775m in expenditures by various state and territory authorities and $8.252m by the Commonwealth on its range of responsibilities. But we could not begin to approximate a total for volunteer labour because the number of people involved could not be determined with the accuracy of the other activities, and the per hectare costs of weed control vary so widely between these three examples. But if there were 5000 such groups across the nation, with the same kinds of opportunity cost, their volunteer labour would be worth some $5.265m per year.

Case study: Volunteer labour at Toodyay – The Friends of the River

Project location	Avon river, Toodyay, Western Australia
Area managed	5 km (30 ha) along Avon River in Toodyay township
Project aims	Removal of Bridal Creeper, Tamarisk, Castor Oil Bush and other weeds, re-establish native plants, stabilise river banks, facilitate return of braiding in river
Demographics of volunteers	Doctor, nurses, taxi driver, chef, historian, real estate agent, and retirees (air hostess, pastoralist, prison officer, machine operator, teachers)
Volunteer time	1,698 hours from 1994 to 2003
Value of volunteer labour	*Upper value*: $25,470 or $849 per ha (assumes all labour has opportunity cost of $15/hr) *More likely value*: $6,376 or $212 per ha (assumes only 25% labour has an opportunity cost, and that was $15 per hr)
Other contributors to project	Toodyay Shire Council, Waters & Rivers Commission, LotteryWest, NHT, a local seed nursery, CSIRO, Prisoners Work Camp Scheme, Avon River Management Authority
Current status of project	Work of group is ongoing. Walkers have access to river, many weeds removed using hand pulling, biological control, fire, and herbicides.

Case study: Volunteer labour at Canberra – Mt Taylor Park Care Group

Project location	Mount Taylor, Canberra
Area managed	500 hectares
Project aims	Remove briar, hawthorn, pyracantha, cotoneaster, privets, and other exotic trees, verbascums, thistles, echium plantagium, St John's Wort and other garden escapes.
Demographics of volunteers	Professionals, public servants, scientists, manual workers, school children, university students, and retirees (a doctor and a botanist)
Amount of volunteer labour	3,575 hours (1992 to 2003)
Value of volunteer labour	*Upper value*: $53,625 or $107 per ha (assumes all labour has an opportunity cost of $15/hr) *More likely value*: $13,406 or $27 per ha (assumes only 25% of labour has an opportunity cost and that was $15 per hr)
Weeds removed	41,885 woody weeds officially recorded, about 100,000 soft weeds
Other contributors	National Australia Bank, Environment ACT, Australian Conservation Volunteers
Current status of project	Woody weeds controlled, continue removing new germinations of woody and other weeds. Monitor threat posed by weed infestations adjacent to Mount Taylor Nature Park

Case study: Volunteer labour at Perth – Clearing blackberry along Bennet Brook

Project location	Bennet Brook, East of Perth
Area managed	Initially 0.26 hectares, expanded to 0.4 hectares and growing. Encompasses 80m of brook
Project aims	Clear Bennet Brook floodplain of Blackberries, Arum lilies, Freesias, nutgrass, watercress, broadleaf weeds and grasses
Demographics of volunteers	People from inside and outside catchment area including students and full-time workers, 65% of them regarded as having an opportunity cost of labour
Volunteer time	536 hours recorded since 1999
Value of volunteer labour	*Upper value*: $8,040 or $20,100 per ha (assumes all labour has opportunity cost of $15/hr) *More likely value*: $5,226 or $13,065 per ha (assumes 65% of labour has opportunity cost of $15 per hr)
Other contributors to project	Swan Catchment Urban Landcare Program, GreenCorps, Work for the Dole, corporate groups, school groups
Current status of project	Area will expand until all blackberry and other weeds are cleared from Bennet Brook. Plans are underway for a walking trail to educate visitors on local flora, fauna, Indigenous and European history

7. Indigenous lands

We now turn to the impacts of weeds on Indigenous lands in the Northern Territory. The Territory has been selected because of the extent of current Indigenous landholdings and the significant scale and nature of weed infestations in some areas of the region.

7.1 Scope

Indigenous communities may either purchase lands, or pastoral or other leases, or acquire land through land claims. The claims can be made under either nationally-applicable legislation such as the *Native Title Act 1993* (NTA) or legislation specific to particular jurisdictions, such as the *Aboriginal Land Rights (Northern Territory) Act 1976* (ALRA) and the *Queensland Aboriginal Land Act 1991*. Indigenous lands form an increasingly extensive component of the Australian landmass and may bear a significant impact from weeds and may therefore have potentially significant impacts on weed management at a national level[1].

The most appropriate measure of impact is the change in economic welfare, but data were not available to estimate these changes. Thus, information on weed control expenditure was collected as one important part of the overall impact. This approach is also appropriate because the non-commercial management of most Indigenous properties commonly serves multiple objectives other than commercial agricultural or pastoral production[2]. Few if any products are marketed from most Indigenous land, and for this reason too, estimation of surplus measures of welfare is thus not possible[3].

7.2 Data collection

Weed control in the Territory is potentially funded from several sources, including government agencies, non-governmental organisations, statutory authorities, and the Indigenous land managers of individual holdings. For present purposes, individual weed control programs may be categorised as:

- large scale, incorporating multiple holdings and involving external funding agencies;
- small scale, limited to a single holding and involving external funding agencies; or
- small scale, limited to a single holding and involving no external funding where weed control is conducted and funded by the landholder.

Data on the costs of weed control in this last category are not readily available, and so the focus is on the first two categories which, we understand, comprise the bulk of weed control expenditure on Indigenous lands in the Territory.

Data collection primarily involved telephone discussions with personnel of relevant agencies including the:

- Central Land Council (CLC),
- Indigenous Land Corporation (ILC),
- Key Centre for Tropical Wildlife,
- National Native Title Tribunal,
- Northern Land Council (NLC),
- NT Department of Business, Industry and Resource Development (DBIRD), and
- NT Department of Infrastructure, Planning and Environment (DIPE).

Literature and web searches, and perusal of unpublished documents provided by the above agencies, supported these discussions.

7.3 Results

Area of Indigenous land

Land under Indigenous ownership in the Northern Territory which is acquired by land claim is transferred from the Crown to Indigenous interests under the provisions of either the ALRA or the NTA. In addition, pastoral leases may be purchased. The majority of current Indigenous lands in the Territory have been acquired using the ALRA. The small area successfully claimed under the NTA is in an urban setting, so lands acquired in this way are not included in the discussion that follows. The areas granted to Indigenous groups under the various provisions of the ALRA are substantial in extent (Table 7.1) and thus potentially highly significant in terms of weed control.

Table 7.1. Indigenous lands granted under the ALRA as at 31 October 2003[4]

Type of title	Granted to…	Area (m ha)
Inalienable Commonwealth freehold	an Aboriginal Land Trust in resolution of a land claim	59.373
NT freehold title	Aboriginal Corporations outside the formal land claim hearing process	1.447
Aboriginal Community Living Areas	Aboriginal Incorporated Associations for the purposes purposes of living areas	0.186
Total area		**61.006**

Source: Deborah Ford, DIPE

Other areas of Indigenous lands include:

- the areas contained within Kakadu (1.980m ha), and Uluru – Kata Tjuta (0.133m ha) National Parks[5], which are inalienable Commonwealth freehold leased back to the Australian Government by their Indigenous owners; and
- the 1.540m ha contained in six pastoral leases owned by Aboriginal Corporations (Gail McLeod, DIPE, pers. comm.).

Including these lands, the resultant area of 646 590 000 ha represents approximately 48.4 per cent of the Territory's land mass and 8.4 per cent of the land area of Australia. Resolution of current land claims would add a further 10 per cent of the terrestrial landmass of the Northern Territory to the Indigenous estate (cited in Altman and Whitehead 2003).

Management of Indigenous land

The majority of Indigenous land in the Territory is managed by either Aboriginal Land Trusts or Aboriginal Corporations (Table 7.1). These bodies are assisted in their land management activities by non-governmental organisations including the Central and Northern Land Councils and the Indigenous Land Corporation. The roles of these and related organisations are now briefly considered.

There are four land councils in the Northern Territory, which together encompass all the lands within the Territory. The two principal bodies[6] are:

- the Central Land Council (CLC), covering approximately the southern half of the Territory;
- the Northern Land Council (NLC), covering approximately the northern half of the Territory, with the exception of those areas which fall under the Anindilyakwa Land Council or the Tiwi Land Council.

Both are statutory authorities established under the ALRA, the principal functions of which include:

- meeting responsibilities in regard to land claims, as specified in the ALRA and the NTA;
- meeting responsibilities defined in other legislation such as the *Local Government Act 1993* (NT); and
- assisting Indigenous land owners with land management and economic development[7].

This last role is of direct relevance to weed control on Indigenous lands.

The NLC, through its Caring for Country Unit (CFCU), provides significant assistance to Indigenous land managers. Aside from the weed management information provided on its website[8], the Unit designs weed control programs, conducts and administers assistance to land owners. The CLC's Land Management Unit provides similar services in the southern part of the Territory, albeit at an apparently lesser level at this stage.

Weed control is a significant part of the CFCU's operations. The Unit has one staff member solely dedicated to weed control programs, and other staff also provide significant input. The Unit's website notes that weeds are considered a major threat to the values of traditional lands.

The Indigenous Land Corporation (ILC) also contributes significantly to the management of Indigenous lands in the Territory. The principal functions of the ILC, a statutory authority, are to assist Indigenous groups to buy or to manage land[9]. The organisation provides land management services which are in addition to (rather than a replacement for) those provided by other agencies (Matthew Brown, ILC, pers. comm.).

All three organisations currently work closely with government and non-government agencies to develop, implement and/or support land management programs on Indigenous lands. All have current and potentially significant future roles in assisting Indigenous land managers with weed management.

Costs of weed control activities

The present estimates focus on the major weed management programs which have been conducted on Indigenous land in the last five financial years (1998–1999 to 2002–2003). This period encompasses the WONS-based NHT funding and the impacts of the recent (August 2001) change of government in the Territory. The data collected are summarised in Table 7.2.

The data in Table 7.2 show that $15.225m has been spent on weed control programs on Indigenous lands in the Territory in the past five financial years, an average of $3.045m per annum. The actual expenditure will be greater, because data were not collected on weed control funded solely by individual landholders (that is, with no external funding). For example, the Jay Creek Land Trust sprays Buffel grass on an *ad hoc* basis, funded from its existing resources (Sandy Marty, CLC, pers. comm.). Similarly, the Tangentyere Council sprays Buffel grass when conducting revegetation projects around community areas (Peter Donohoe, CLC, pers. comm.). These and similar activities are not included in Table 7.2.

In addition, the data exclude weed control expenditure which is undertaken as part of other land management operations, but not costed as a separate entity. For example, the spraying of Athel pines in December 2002 by the Jay Creek Land Trust in association with DIPE and CLC staff, uses 6 to 10 CDEP workers over a two day period, but is not reflected in Table 7.2 (Sandy Marty, CLC, pers. comm.). Similarly, the weed control activities of the Julalikari Council Aboriginal Corporation are conducted as part of its regular outstation management and support operations on the Barkly Tableland but are not separately costed (Stewart King, Julalikari Council Aboriginal Corporation, pers. comm.). Other functions performed by the same staff over the corporation's 34m ha area include small enterprise development, management of agisted stock, plantation and horticulture work and fire management. These NHT-funded activities are conducted on a budget of $0.5m per annum, with three staff but the weed-related component cannot be readily identified.

The cost of $15.225m is therefore the minimum amount spent on weed control on Indigenous lands over the period 1998–99 to 2002–03.

7.4 Discussion

The sources consulted during the course of this work indicated a recent significant increase in collaborative, cooperative approaches to weed management on Indigenous lands by Northern Territory government agencies. This was attributed to the change of government in August 2001 and the current Labor Government's strong positive focus on Indigenous land management. The Government is also working to enhance Indigenous community governance, as is exemplified by the recent NT Indigenous Governance Conference held in Jabiru. These changes augur well for future cooperation on weed control programs on Indigenous lands. However, the uncertainties of future Northern Territory, National Heritage Trust and other funding, coupled with the absence of reliable weed distribution data and unmet needs for enhanced weed management capacity, limit the capacity of Indigenous land managers to undertake effective strategic weed control.

Endnotes to Section 7

1 *As an illustration of the potential future extent of Indigenous lands in Australia, it is useful to consider the extent and distribution of areas currently under claim under the NTA. Details of current claims can be obtained through the website of the National Native Title Tribunal (2003a and 2003b), at http://www.nntt.gov.au/. Maps which illustrate the geographic extent and distribution of current claims, can be accessed at http://www.nntt.gov.au/publications/national_maps.html.*

2 *Centre for Agricultural and Resource Economics (2000) noted only one viable Indigenous cattle property in the Top End. More recent advice from the ILC suggests a greater number of viable properties in the Territory (Matthew Brown, ILC, pers. comm.).*

3 *This situation is altering somewhat with the growing production of wildlife from Indigenous lands (noted, for example, in Altman and Whitehead 2003). Nonetheless, most wildlife harvesting is not currently commercially focussed; production uses a customary approach, with a commercial overlay (Altman and Cochrane 2003).*

4 *A further area of 12.9m ha is currently subject to claim under the ALRA (Deborah Ford, DIPE, pers. comm.), which may result in future additions to the Indigenous estate.*

5 *These data are from Kakadu Board of Management and Parks Australia (1998) and Uluru – Kata Tjuta Board of Management and Parks Australia (2000) respectively.*

6 *There are two land councils responsible for relatively small areas: the Anindilyakwa Land Council covering Groote Eylandt and the Tiwi Land Council, covering the Tiwi Islands north of Darwin.*

7 *Further details of these and related roles are detailed on the NLC website, at http://www.nlc.org.au/html/abt_res.html.*

8 *At http://www.nlc.org.au/html/care_weed.html.*

9 *Further detail on the operations of the ILC can be found at http://www.ilc.org.au.*

10 *Sources: The sources for the information in the table are personal communications, reports and press releases from the Central Land Council, Indigenous Land Corporation, Northern Land Council and Department of Infrastructure Planning and Environment.*

11 *The funding sources included Bawinga Community Council, Bushfires Council, CRCTSM, Demed Association, DEWRSB, DPIF, Gulin Gulin and Weermoll Community, Jawoyn Association, NHT, NLC, NTETA, PWC, Yugul Mangi Community Council*

12 *The figures provided here are estimates only, based on 20 schemes with (i) an average scheme duration of 3.75 years in the period 1998/9– 2002/3; (ii) an average expenditure of $80 000 each per annum from non-CDEP sources and an additional $125 000 contributed from CDEP, and (iii) about 75% of expenditure on weeds. The figures are conservative.*

Table 7.2. Funds for weed control on Indigenous lands (1998–99 to 2002–03)[10]

Project	Period	Funds ($m)	Notes
Mimosa Agreement A (between the ILC, NLC, DPIF and White Eagle Aboriginal Corporation)	17/9/1998 – 30/6/2003	3.418	funding sources included DPIF, ILC, NLC
Mimosa Agreement B (between the same as above)	17/9/1998 – 30/6/2003	0.534	funding sources included ILC, White Eagle Aboriginal Corporation
Top End Training and Employment Strategy (also known as the Top End Aboriginal Land Management Employment Scheme (TEALMES))	25/8/2000 – 24/8/2004	3.270	followed the Mimosa knockdown project described above; funding sources included several aboriginal communities, DEWRSB, DPIF, ILC, NTETA, NHT, NLC
Weed control across southern NT	1/11/2001 – 30/10/2003	0.144	funding sources included CLC, DPIF, ILC
Fire control across Bulman region of Arnhem Land	1/1/2002 – 31/12/2003	0.538	[11]
Land Management Training Program at West Wagait	30/1/2001 – 1/2/2005	0.578	funding sources included the aboriginal community, DEWRSB, DPIF, ILC, NHT, NLC, NTETA
Land Management Training Program across Upper Daly Land Trust	1/4/2002 – 1/2/2005	0.178	funding sources included DEWRSB, DPIF, ILC, NHT, NLC, NTETA, Pine Creek Aboriginal Advancement Association, PWC, RSP
Environmental Protection of the Tiwi Islands	1/5/2002 – 30/4/2004	0.591	funding sources included various NT Government agencies, Aboriginal Benefit Account, ILC, NHT, Tiwi Land Council
Management across the Garawa Land Trust	1/1/2002 – 31/12/2003	0.113	funding sources included various NT Government agencies, ILC, Mungoorbada Aboriginal Corporation, NHT
DIPE Weeds Branch operating costs (Indigenous lands)	1/7/1998 – 30/6/2003	0.200	DIPE or its predecessor agency
DIPE Weeds Branch, Jabiru position	1/7/1998 – 30/6/2003	0.350	DIPE or its predecessor agency
DIPE Weeds Branch, Borroloola position (1/2)	1/7/1998 – 30/6/2003	0.175	DIPE or its predecessor agency funded one position in the CFCU to support the TEALMES
DIPE Hymenachne survey	1/7/2001 – 30/6/2002	0.100	funding source NHT/WONS
DIPE Parkinsonia survey	1/7/2002 – 30/6/2003	0.300	funding sources included NHT/WONS, DBIRD, landholders
Control of Lion's tail, Yarralin	in period 1/7/1998 – 30/6/2003	0.090	funding sources included CDEP, DIPE
Weed control, various locations in the Katherine region	in period 1/7/1998 – 30/6/2003	0.053	funding source DIPE
Control of Bellyache bush and Mimosa, Ngukurr	in period 1/7/1998 – 30/6/2003	0.020	funding sources included DIPE, ILC
Survey and control of Devil's claw, Lantana, Mesquite and Prickly acacia; Elsey Station / Jilmikkagan	in period 1/7/1998 – 30/6/2003	0.065	funding source DIPE

Project	Period	Funds ($m)	Notes
Coffee senna, Mexican poppy, Mesquite, Rubber bush and Athel pine control; Yuendumu	1999/2000	0.022	funding source DIPE
Rubber bush and Athel pine control; Papunya	1999/2000	0.008	funding source DIPE
Athel pine control; Hermannsburg	in period 1/7/1998 – 30/6/2003	0.010	funding source DIPE
Mexican poppy and Parkinsonia control at Santa Theresa	2000/2001	0.002	funding source DIPE
Coffee senna and Athel pine control; Imanpa	in period 1/7/1998 – 30/6/2003	0.006	funding source DIPE
Athel pine, mesquite and Mexican poppy control; Amoongana	2000/2001	0.010	funding source DIPE
Aboriginal Land Management Employment Schemes, northern part of the Territory (other than TEALMES)[12]	1/7/1998 – 30/6/2003	3.280	funding sources included Aboriginal Benefit Account, CDEP, CFCU, ILC, NHT
Parkinsonia, Rubber bush, Caltrop, Khaki burr, Neem control; various locations locations in Katherine region	in period 1/7/1998 – 30/6/2003	0.125	funding sources included CFCU, DIPE
Overview of weeds on Indigenous lands in the Top End	1/7/1998 – 30/6/1999	0.035	funding sources included CRCTSM, CFCU
CFCU operations – Wetlands Officer	1/7/1998 – 30/6/2003	0.400	funding sources included CFCU, ILC, NHT
CFCU operations – Conservation and Development Planning Officer	1/7/1998 – 30/6/2003	0.250	funding sources included CFCU, ILC
Indigenous landholder weed control consultation and capacity building	1/7/1998 – 30/6/1999	0.060	funded by NHT
Total		**$15.225**	

8. Discussion and conclusions

8.1 The results and their interpretation

The results

We have estimated the separate values of the impacts of weeds in agriculture, natural environments, and on public and Indigenous lands. These annual values can be aggregated, and we use the economic surplus results for agriculture from Section 4 to do so. The results, all to the nearest million dollars per year by sectors, are as follows.

Sector	Low	Mean	High
Costs of control and losses in output			
Agriculture	3,442	3,927	4,420
Costs of control only: no losses in output			
Natural environment	20	20	20
Public authorities	81	81	81
Indigenous lands	3	3	3
Commonwealth research	8	8	8
Total	**$3,554**	**$4,039**	**$4,532**

If there were no weeds, incomes to agricultural producers and benefits to consumers of food would rise by $3,927m in the mean case and $112m of government expenditure would be released for productive investment elsewhere.

We have presented the results as a range of estimates from $3,554m to $4,532m, because of the difficulty of calculating a unique value for agriculture. But clearly this range demonstrates that the economic impact of weeds is a significant problem of land use and resource management. Weed control would generate substantial benefits on both private and public land, and research enhances those benefits.

This range is a lower bound because we:

- adopted conservative values where judgements were necessary,
- could not collect some data from the agencies and persons we contacted,
- could not estimate the impacts (losses) on the outputs of natural environments,
- only began to estimate the opportunity costs of volunteer labour, and
- did not attempt to estimate the impacts in urban areas or the impacts of pollens on human health.

We have estimated the agricultural impacts on an industry basis, yet there are winners and losers within an industry (See the case study in Section 4). Weed invasions may decrease production in an industry in one region and so allow increases in production in another. Our results say nothing about this kind of distribution of impacts within and between industries.

Impacts relative to other environmental problems

Weeds clearly lead to significant adverse impacts for the community, but so do many other issues of resource management. Consider the impact of three kinds of land degradation namely salinity, sodicity and acidity (Table 8.1). According to Hajkowicz and Young (2002), acidity and sodicity are more serious immediate problems than salinity, although salinity is much more likely to cause off-site or external effects. Further, salinity may increase more rapidly than the other forms of land degradation.

Weeds have a higher impact at the farm gate than any of these three kinds of land degradation. The lowest estimate of the *net* impact of weeds ($3,442m) is an order of magnitude higher than the *gross* estimates at farm gate given for salinity ($187m), acidity ($1,585m) or sodicity ($1,035m). When all the other possible impacts are added in, the highest cost of salinity ($3,500m) is equal to the lowest for weeds. But the salinity estimate includes the multiplier and secondary effects of lost business that are explicitly excluded from the weeds estimate because a portion of these impacts may be not be true net impacts for the community as a whole.

Allocation of resources

At the project level, the economic approach to the allocation of investment funds is to compare benefits with costs and to allocate first to the project with the highest ratio of benefits to costs, second to the project with the next highest ratio, etc, until the funds are exhausted. At the broader program or sector level, the same principles apply. We should determine the extra benefits and the extra costs of programs and allocate accordingly. The high per hectare benefits from weed control, the very high benefits to the whole agricultural sector, and the high benefits relative to other environmental problems, as indicated in the last paragraph, all suggest that weeds should be a major recipient of investment funds.

Table 8.1. Opportunity costs and financial costs of other resource management issues

Issue and Impacts	Annual Cost	Year	Sources
Dryland salinity[a]			
Lost agricultural production	$130m	undated	1
Lost agricultural production: gross, farm-gate value	$187m	1996/97	2
Lost agricultural production: net, farm-gate value	$200m	2003	3
Lost agricultural production, environmental damage	$1b	2001	4
Lost agric production, costs of control, lost business	$3.5b	2002	
Infrastructure and water quality damage	$700m	2020	6
Infrastructure damage	$100m	undated	1
Sodicity[b]			
Lost agricultural production: gross farm-gate benefit	$1035m	1996/97	2
Soil acidity[c]			
Lost agricultural production: gross farm-gate value	$300m	2001	4
Lost agricultural production: gross farm-gate benefit	$1585m	1996/97	2

Sources: 1 Fixland clearing, undated, 2 Hajkowicz and Young (2002), 3 Warnick (2003), 4 Healey (2001), 5 CRC for Plant-based Management of Dryland Salinity (2000), 6 Australian Bureau of Statistics (2002).

[a] *Salinity is a measure of the total soluble salts in a soil. A saline soil is one with a sufficient accumulation of free salts at the surface or within the profile to reduce plant growth and affect land use (Department of Primary Industries, Victoria 2003).*

[b] *Sodicity is a measure of the exchangeable sodium in the soil in relation to other exchangeable cations (Department of Primary Industries, Victoria 2003). A sodic soil contains sufficient sodium to interfere with the growth of plant, including crops.*

[c] *Acidity is a measure of the pH of the soil. In its general meaning, soils with a pH less than 7.0 are said to be acidic. Soils can become acidic over time due to their parent material, the addition of nitrogen to the soil, or leaching due to rainfall. An acidic soil has a sufficiently low pH to reduce plant growth.*

Allocation of costs

The results can assist the formation of policies to allocate the costs of weed control. We have noted that about 80 per cent of the benefits of weed control in agriculture accrue to producers and about 20 per cent to consumers. If policies follow the principle that beneficiaries pay, then farmers might be asked to pay 80 per cent of costs and consumers pay the remaining 20 per cent. But further, governments may choose to act on behalf of consumers and it may be more efficient for governments to do so. The magnitude of the loss to consumers appears to justify substantial government involvement.

8.2 Strengths and weaknesses of the results

This report naturally has its strengths and weaknesses. The main strengths include the use of:

- current comprehensive data,
- estimates of economic surplus to measure impacts on agriculture, and
- prices, costs and quantities that had been observed or expended in the market.

All these data are based on preferences revealed in the market rather than preferences that are elicited by survey. A further strength is the estimate of the monetary value that decision makers place on the biodiversity benefits from protecting a threatened species and a threatened special conservation area.

The main weaknesses include the following:

- Inevitably some data for agriculture, natural environments, public authorities and Indigenous lands are missing. We did not pursue the collection of what appeared to be ‘small’ sums and some data simply could not be provided. The results will therefore be under-estimates of the true impacts but we do not know by how much.
- Inevitably, we could not estimate welfare measures for all the impacts.
- Weeds and weed control cause further costs that were not estimated.

These further costs are largely related to external or off-site effects caused by either the weed invasion or the weed-control activities. There appears to be no information available on these costs, but some related research on these issues has been undertaken for pesticides, particularly in the United States of America. We now review these external costs associated with pesticide use and identify the types of costs that may also apply to weeds. The information is largely based on Steiner *et al*. (1995), and the external losses can be divided into three classes, administrative costs, health effects on humans, and environmental costs.

Administrative costs represent a real, current, and perhaps sizeable cost in the management of both pests and weeds. They include the costs incurred by the Environmental Protection Agencies and other state and federal agencies to draft and enforce regulations on the use of chemicals. They also includes farm work safety and training costs, which are becoming increasingly important as farmers are required to obtain certification to handle chemicals (a portion of this cost is private but it should be accounted for). We have included many of these costs but our coverage was not complete.

Health effects of herbicides on humans are difficult to measure, but they are probably low and many are avoidable. In contrast to insecticides, herbicides are safer to handle and apply despite some exceptions such as paraquat. A more important factor concerning human health would be the effect of the weeds themselves. Pollen and spores may cause hay fever, other allergies and respiratory illnesses – see page 42 for the case of Parthenium. These costs are difficult to measure because allergies can also be caused by plants that are not weeds.

Chemicals used for control of pests can affect the environment in several ways. The numbers in parentheses below indicate the percentages of pesticide that are lost into the environment.

- Spills, tank washes and storage losses (0–10)
- Losses into the air during application (0–60)
- Leaching into groundwater (< 1)
- Surface water runoff (0–0.5)
- Residues on crops (< 1).

The direct monetary costs associated with the first two items have been included in our estimates of the cost of purchasing and applying herbicides. Additional costs will occur only if these losses damage the environment. Herbicides tend to be less damaging to the environment than insecticides, but there is always the possibility of losses in environmental services if herbicides ‘escape’ into a natural environment and kill native plants. Spray drift can be an important externality also in agriculture. For example, organic producers may be situated close to intensive horticulture enterprises. Spray drift from horticulture may involve direct yield and quality losses or forced land-use changes by the organic producer to create buffer zones. The last three dot-point items are probably negligible in the context of herbicides.

The actual effects of chemicals on the environment include reductions in natural enemies, increases in pest resistance, loss of crops and trees, and loss of fish and wildlife. Of these, pest resistance and crop and tree loss may be the only important effects in some locations and for some herbicides. Most of the environmental costs of weeds are related to the weeds themselves, rather than to the control methods.

8.3 Gaps in knowledge and some suggestions

While preparing this report, we were able to gain some sense of the total set of gaps in knowledge, and those gaps that were more important to this kind of work. The following gaps seem more pertinent.

(a) There are no reliable comprehensive data on the distribution of weeds across Australia, onto which to overlay land use, land tenure and measures of inputs and outputs. If there were, we could analyse the ways in which changes in natural environments accompany changes in weed intensity and the ways in which the changes in natural environments are associated with changes in the output of goods and services.

(b) The processes involved in the analysis of data for the WONS report (Thorp and Lynch 2000) were consistent, innovative and thorough. From an economic perspective, gains are likely by allocating weed management funds across state jurisdictions to projects wherever the relative gains are highest. The data collection and the analytical processes of the WONS report could be extended to be a useful way to aggregate potential unpriced benefits where money estimates of them are unavailable.

(c) The distribution of impacts varies between producers and consumers, between producers in different regions, between consumers of different goods and services, and between different weeds. The distribution of impacts is in many ways as important as the size of the impacts, and little is known about these distributions apart from agriculture.

The question of course is, how can we address the problems that these gaps create? The problem of comprehensive data on distribution (gap a) would require a nation-wide program, but the problems of valuation and lack of data on changes in output (gap b) can perhaps be addressed. The general framework to estimate the impact of weeds revolves around the identity,

$$C = E + L$$

For natural environments we have estimated E as the expenditure on weed control, but we have not estimated L which is the value of the loss in yield. There will be several kinds of losses in ‘yield’ when weeds invade natural environments and these include changes to health, fire risk, recreation and aesthetics, herbal and medicinal uses, as well as to biodiversity protection which is probably the most important.

Case study: The health costs of Parthenium weed in Queensland

Parthenium is an annual broadleaf plant that can grow to two metres, has a deep taproot, and can tolerate drought. There are severe invasions of it in the Queensland shires of Bauhinia, Belyando, Bowen, Broadsound, Dalrymple, Duaringa, Emerald, Fitzroy, Nebo and Peak Downs.

The weed creates severe allergic reactions in humans, including hay fever and asthma, and lowers stocking rates and condition in grazing animals. These responses are caused by contact with airborne pieces of dry plant material and pollen.

The current per capita expenditure on human health, due to the weed, is $6.90 per person or $19.90 per household in affected areas (AECgroup 2000). The reduction in health expenditures, before and after the biological research and control programme, would provide an annual benefit of $6.82m and improve the health of a large section of the community.

Our application of this framework has been ‘top-down’ that is by each agricultural industry and by natural environments as a group. But consider a ‘bottom-up’ application by individual weeds, perhaps for some of the 72 weeds considered for the WONS determination. For this analysis, expert panels estimated the effect of each weed on several of these different yields using a four-step rating from nil to high. For each weed, a social value index was determined as the aggregate of the effects that the weed could cause in each kind of yield.

These estimates of changes in health or aesthetics, for example, are directly equivalent to the yield loss (Q_0 – Q_1) in Figure 2.3, which underlie the estimation of losses in economic surplus. To continue to apply this surplus model of to estimate loss, we need to estimate the prices but this is hard. We have illustrated the valuation of health effects for Parthenium, and the valuation of biodiversity effects for agricultural and forest weeds. Fire risks can perhaps be assessed as expected damage costs.

This ‘bottom-up approach’ will, of course encounter problems such as double-counting between weeds and estimation of values, but it does combine the framework with multi-attribute analysis and the established procedures of weed science.

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Appendix 1

An estimate of the value of biodiversity protection from weed control

Dr Garry Griffith undertook the basic econometric work for this analysis and we gratefully acknowledge his assistance.

The scenario

Farmers, forestry agencies, and local government authorities charged with weed management, undertake annual control programs on farms, production forests, and the associated roadsides and reserves. In 'The Determination of Weeds of National Significance', otherwise known as the WONS report, Thorp and Lynch (2000) provide estimates of the expenditures on these programs for each of 35 'primary industry weeds'.

The 35 weeds were prickly acacia, madeira vine, bitou bush, pampas grass, rubber vine, golden dodder, Scotch Broom, Patersons curse, African love grass, broom, narrow leaved cotton bush, St. Johns Wort, Hyptis, bellycache bush, lantana, African boxthorn, cats claw creeper, mimosa, serrated tussock, Onopordium, broomrape, Parkinsonia, parthenium, mesquites, blackberry, willows, ragwort, fireweed, sicklepod, silverleafed nightshade, giant paramatta grass, giant rats tail, gorse, Noogoora Burr, and Bathurst burr. These are weeds of pasture, grazing land and environmental areas.

Method

We need first to model the way in which the expenditure on control is determined. We can hypothesise that the annual expenditures to control a weed will vary with its characteristics, its current and potential spread, and the degree to which it threatens biodiversity. As a simple model:

Cost of control = f(characteristics, current and potential area spread, and quantity of threatened biodiversity). (1)

Ordinary least squares regression is the basic econometric technique to estimate equations for such models. If we can estimate an equation, we may be able to separate the influence of the various factors on the cost of control. To do so, we need data on all the variables in the model.

Data collection

The WONS report provides quantitative indices of:

- the characteristics of each weed (invasiveness, impact on the environment, and tendency to become a monoculture),
- the current area and potential area occupied,
- the number of species threatened by the weed,
- the number special conservation areas threatened, and
- the social impact of the weed.

The report also provides details of other characteristics such as level of impact and number of states in which the impact occurs. John Thorp also provided, explicitly for the present purpose, data on the actual numbers of threatened species and numbers of special conservation areas.

So we were able to define the following 20 variables, the first two of which are alternative ways to specify the cost of control in equation (1). The cost of control is of course the dependent variable in the model, and the variables on the right-hand side are the independent or explanatory variables.

Cost: total annual cost ($000) of control as a 10 year average.

Econindex: an index of total annual cost derived from **Cost** and scaled as actual costs divided by the cost for Patersons curse.

Spthreat: the proportion of plant species that are threatened by the weed across all states, as an index.

Comthreat: the proportion of special conservation areas that are threatened by the weed across all states, as an index.

Sthreat: the number of plant species that are threatened by the weed across all states.

Cthreat: the number of special conservation areas that are threatened by the weed across all states.

Socimpact: the scaled sum of impacts of the weed on human health, fire risk, recreation values, employment and economic impacts such as tourism.

Currarea: the proportion of the continent that the weed currently affects.

Potarea: the proportion of the continent that the weed could potentially affect.

DUM1: scaled as 1 if the weed has a medium to high effect on the number of threatened communities for a number of states, and 0 otherwise.

DUM2: scaled as 1 if the weed predominantly affects South Australia, and 0 otherwise.

DUM3: scaled as 1 if the weed has a medium to high effect on the number of threatened conservation areas for a number of states, and 0 otherwise.

DUM4: scaled as 1 if the weed predominantly affects the Northern Territory, and 0 otherwise.

DUM5: scaled as 1 if the weed has only low effects on the number of threatened conservation areas, and 0 otherwise.

AGRI: scaled as 1 if an agricultural weed, and 0 otherwise.

FOR: scaled as 1 if a forest weed , and 0 otherwise.

BOTH: scaled as 1 if a weed of both agriculture and forests, and 0 otherwise.

Invasive: index of invasiveness as a characteristic of the weed.

Moncult: index of expected potential to develop into a monoculture, as a characteristic of the weed.

Impact: index of impact on the environment.

These variables were applied to the model (equation 1), and the analysis proceeded as follows.

Analysis

(i) First, the two potential dependent variables (**Cost and Econindex**) and all 18 potential explanatory variables were printed out to double check for errors. Summary statistics for all variables and correlations between them were calculated to check for possible interactions.

(ii) Wherever there were alternative variables describing essentially the same effect, the relevant alternative regression equations were estimated and compared using the common diagnostic tests. Ordinary least squares regression was used in the first instance.

(iii) Thus two sets of equations were estimated, one set with actual cost (**Cost**) estimates as the dependent variable and the other set with the cost index (**Econindex**) as the dependent variable.

(iv) To start with, all possible explanatory variables were included, and then particular variables were excluded based on the diagnostic tests.

(v) Estimates were made for just 'agricultural' weeds and for all weeds, with dummy variables for **FOR** and **BOTH**. The latter form was chosen because selecting just agricultural weeds gave inappropriate signs almost all the time.

(vi) Generally, the 'species' measures (**Spthreat** and **Sthreat**) and 'communities' measures (**Comthreat** and **Cthreat**) are quite closely related and so it was not possible to include both in the same equation and obtain significant coefficients.

(vii) Generally, there was no significant effect of the area of the weed, the characteristics of the weed or the impact of the weed, apart from impact on species or communities threatened.

(viii) Generally, replacing the indexes of species and communities threatened by actual counts of species and communities threatened increased the explanatory power of the equations and provided more significant coefficient estimates.

(ix) There was a general problem of heteroscedastic errors in those equations which had actual costs as the dependent variable. All equations were re-estimated to correct for this problem. The re-estimated equations are now presented and the monetary values interpreted from them.

Results

Application of econometric techniques provided the following four useful models, two for threatened individual species and two for threatened special conservation areas. The t-statistics are in parentheses.

Models for threatened individual species

Equation	2 Cost	3 Econindex
Sthreat	68.712 (1.5)	0.00247 (2.1)
DUM1	4058.19 (1.2)	0.262 (1.9)
FOR	-3456.62 (1.9)	-0.251 (3.8)
BOTH	-3190.43 (0.69)	0.237 (1.6)
Constant	1041.04	0.1481
Adjusted R2	0.602	0.684

Models for threatened special conservation areas

Equation	4 Cost	5 Econindex
Cthreat	5.987 (2.9)	0.00015 (2.7)
DUM3	-3958.25 (1.4)	0.140 (0.8)
FOR	-807.34 (1.3)	-0.144 (2.8)
BOTH	-3299.35 (1.7)	0.411 (2.1)
Constant	448.17	0.1196
Adjusted R2	0.860	0.769

The mean values for the variables in the models were as follows: Cost $2.032m, Econindex 0.205, Sthreat 20.0, Cthreat 357.6, DUM1 0.14, DUM3 0.17, FOR 0.20, and BOTH 0.09.

Discussion: values for biodiversity

The coefficients in equations (2) and (4) indicate the change in cost for a one-unit change in Sthreat or Cthreat respectively. So an increase of one threatened species is associated with an increase in expenditure of $68,700 per year and an increase of one special conservation area is associated with an increase of $6,000. That is, each extra species that is threatened brings forth an increase in expenditure of $68,700. Economic theory assumes that managers are balancing the benefits of control with the costs, and so each threatened species that is saved has a benefit of $68,700 per year. In practice, this amount is limited by the resources available to managers of public lands.

Appendix 2

Expenditure by public land managers and public authorities in each state and territory

The total expenditures in each state and territory were summarised in Table 6.1 and discussed in Section 6. The details for each state, together with some explanation for each, are presented here.

New South Wales

The NSW State Government provided almost $7m in noxious weed grants in 2001–02. The grants are managed by NSW Agriculture and are divided between Operational Programs, Education Training and Extension, Administration of Counties, Weed Control Coordination and Cooperative Arrangements. Shire councils, or groupings of councils known as Local Control Authorities, are the main recipients of these grants. NSW Agriculture undertakes additional expenditure on research and direct salaries (Table A).

The Department of Lands undertakes weed control on Crown Land using grant money from NSW Agriculture and matched funding, for a total of $375,000 in 2001–02. Funding is then allocated through a competitive application process to the various groups that manage areas of Crown Land.

There are also many State government agencies in New South Wales that manage weeds on their own land. Weed expenditure data were collected from State Forests and the Sydney Water Catchment Authority, and were estimated for the State Council of Rural Lands Protection Boards. This estimate was based on a sample of expenditure patterns by Boards on the Coast, in the Tablelands and in the Western division.

Other State Government Agencies with a responsibility for weed management on public land are the Roads and Traffic Authority of NSW and the Rail Infrastructure Corporation. Unfortunately no data could be obtained from these organisations and so their expenditure on weed control is not included in Table A.

Table A. Expenditure on weeds by New South Wales public authorities and public land managers, 2001–02

	Coordination, inspections, surveys, treatments ($m)	Education, training, extension & research	Salaries, admin, other indirect costs & in-kind contributions ($m)	Total ($m)
State Government Departments [a]	6,221,195	2,326,000	4,169,511	12,716,706
State Government Agencies [b]	934,669			934,669
Local Government [c]	5,766,195		447,511	6,213,706
Total				**$19,865,081**

[a] *Included in this category are NSW Agriculture and the Department of Lands.*
[b] *Included in this category are State Forests of NSW and the NSW Rural Lands Protection Boards.*
[c] *This is the required matching of State Government Funding by Local Control Authorities.*

Queensland

All three levels of government in Queensland allocate significant amounts of resources on weed control (Table B).

The Queensland Department of Natural Resources and Mines (QDNRM) spend money on research, extension and policy, as well as controlling weeds on public land. The Queensland Department of Primary Industries (QDPI) undertakes research and extension into minimising the impacts of weeds in Queensland agriculture. The data for QDPI includes costs of weed control in state forests and the cost of attending to stock poisoning that results from noxious plants.

The Queensland Department of Main Roads control weeds on the portion of state roads for which they have a responsibility. The remainder of roadside weed control is the responsibility of local governments. Local government expenditure on weed control on roads and other land is reported in Table B and includes the amounts contributed to the QDNRM as precept payments. The precept payments are legislated amounts that local councils must contribute to the Department, who in turn undertake weed (and pest) control on their behalf.

Table B. Expenditure on weeds by Queensland public authorities and public land managers, 2001–02

	Coordination, inspections, surveys, treatments ($m)	Education, training, extension & research	Salaries, admin, other indirect costs & in-kind contributions ($m)	Total ($m)
State Government Departments [a]				15,577,358
State Government Agencies [b]	1,300,000		1,000,000	2,300,000
Local Government [c]	8,933,333			8,933,333
Total				**$26,810,691**

[a] *Included in this category are the Queensland Department of Natural Resources and Mines, the Queensland Department of Primary Industries and the Queensland Department of Main Roads. Information was not provided in a disaggregated form for all organisations so only a total figure has been given here.*

[b] *Queensland Rail is included in this category.*

[c] *This amount includes Local Government budget and precept payments.*

South Australia

South Australian Government Departments contributing to weed management on public and private land are the Animal and Plant Control Commission within the Department of Water, Land and Biodiversity Conservation, and the Department of Primary Industries and Resources of South Australia. The Commission manage weeds on crown land and undertake research. They spend a significant amount of money on the Branched Broom Rape Eradication Program, which also attracts funds from all Australian states, the Commonwealth, the CRC for Australian Weed Management and several Research and Development Corporations.

Weed management expenditure for SA Water, Forestry SA and Transport SA are included in Table C. Data from SA Water include the costs of making firebreaks, slashing and boom spraying. They do not include expenditure on their biological control program because its cost is mostly borne by partnerships between land managers and community groups. Forestry SA spend money on plantation weed research, plantation weed control and noxious weed control. Transport SA were only able to estimate expenditure for weed spraying in their Road Maintenance program, but a significant amount of expenditure on weed control is part of road construction, Expenditures on environmental programs and property management are not included in Table C.

Table C. Expenditure on weeds by South Australian public authorities and public land managers, 2001–02

	Coordination, inspections, surveys, treatments ($m)	Education, training, extension & research	Salaries, admin, other indirect costs & in-kind contributions ($m)	Total ($m)
State Government Departments [a]	3,280,408	412,347	770,178	4,462,933
State Government Agencies [b]	2,857,986	250,000		3,107,986
Local Government [c]	1,840,000			1,840,000
Private rail managers [d]	315,000			315,000
Total				**$9,725,919**

[a] *Included in this category are the Animal and Plant Control Commission, part of the Department of Water, Land and Biodiversity Conservation. Data from the Department of Primary Industries and Resources of South Australia were not available the time of writing.*

[b] *Included in this category are Transport SA, South Australian Forestry Corporation (Forestry SA), and South Australian Water Corporation (SA Water).*

[c] *Local shire councils contribute to Animal and Plant Control Boards.*

[d] *Included in this category is the Australian Rail Track Corporation.*

Tasmania

The main organisations undertaking weed management activities on public land in Tasmania are the Department of Primary Industries, Water and Environment, the Department of Infrastructure Energy and Resources, Parks and Wildlife Service, Hydro Tasmania, Forestry Tasmania and Local shire councils. Their expenditure is summarised in Table D. Expenditure for weed control on crown lands is included in Section 5 with other Parks and Wildlife expenditure.

The Department of Primary Industries, Water and Environment is responsible for the administration of Tasmania's Weed Management Act 1999, and its expenditure on weed management is largely for policy formulation, extension and provision of an operating framework for other weed managers. This department does not undertake any on-ground control of weeds.

Management of weeds in the road corridors is the combined responsibility of Department of Infrastructure, Energy and Resources and local councils. An estimate of annual average expenditure on weed control on roads in the north and north west of Tasmania over recent years by the Department has been included in the table. However, data on weed management by the Department in southern Tasmania are not included. Another notable omission is expenditure on weed control by the 29 local councils in Tasmania. Details of weed management expenditure by each council are not readily available in one central location and time constraints did not allow for collection of the data from individual councils.

Forestry Tasmania manages 41 per cent of Tasmania's forests and spends large amounts of money on weed control in these areas. Weed management expenditure in the remaining forest areas of Tasmania is not included in the table. Another important agency that has a role in managing weeds on public land is Hydro Tasmania but their weed control costs were not available at the time of writing.

The Tasmanian Institute for Agricultural Research, a joint venture between the Department of Primary Industries, Water and Environment and the University of Tasmania, undertakes research into weeds in Tasmanian agriculture. Institute data in the table includes only the expenditure on the biological control of weeds, the main focus of their weeds research.

Victoria

In 2001–02, the former Department of Natural Resources and the Environment (DNRE) spent approximately $12m on weed management. The majority of this was spent on private land, in extension programs and ensuring compliance with relevant legislation. The remainder was spent through the Good Neighbour Program. An additional $5m was available for private land initiatives through Landcare, however the exact figure for these projects was not available because all projects were multi-resource projects. In 2001–02 the DNRE also managed weeds on Crown Lands and in Victorian State Forests, but this information was not available.

Weed expenditure figures for management of Victorian rail and road networks by state government agencies are included in the Table E (see page 54). Local governments also undertake significant weed control on roads in Victoria, but these data could not be collected from each of the 79 Local Governments that exist in the state. Private rail managers spend significant amounts on weed control on land leased from the VicTrack, and these amounts are reported in the table. Victorian water authorities were not contacted for their weed management data.

Table D. Expenditure on weeds by Tasmanian public authorities and public land managers, 2001–02

	Coordination, inspections, surveys, treatments ($m)	Education, training, extension & research	Salaries, admin, other indirect costs & in-kind contributions ($m)	Total ($m)
State Government Departments [a]				1,195,000
State Government Agencies [b]	770,051		26,280	796,331
Local Government				nc
Total				**$1,991,331**

nc: data not collected

[a] *lIncluded in this category are the Department of Primary Industries, Water and Environment, the Department of Infrastructure Energy and Resources. Expenditure was not allocated to individual categories by all departments.*

[b] *lIncluded in this category are Hydro Tasmania and Forestry Tasmania.*

Table E. Expenditure on weeds by Victorian public authorities and public land managers, 2001–02

	Coordination, inspections, surveys, treatments ($m)	Education, training, extension & research	Salaries, admin, other indirect costs & in-kind contributions ($m)	Total ($m)
State Government Departments [a]	10,700,000	1,300,000		12,000,000
State Government Agencies [b]	1,319,000			1,319,000
Victorian Local Governments				nc
Private rail managers [c]	1,250,000			1,250,000
Total				**$14,569,000**

nc: data not collected

[a] *IIncluded in this category is information from the former Department of Natural Resources and Environment, which has since become the Department of Sustainablity and Environment and the Department of Primary Industries.*

[b] *IIncluded in this category are VicRoads and VicTrack.*

[c] *IIncluded in this category are Freight Australia and the Australian Rail Track Corporation.*

Western Australia

Weed control by public authorities in Western Australia occurs on both public and private land. Almost half of the total expenditure by WA public authorities in 2001–02 went on the Skeleton Weed Eradication Program. The Program commenced in 1974 and aimed to detect and eradicate skeleton weed infestations from agricultural land in WA, and prevent new infestations.

The Skeleton Weed Eradication Program was funded mainly from a levy on all grain sold in the state (35c per tonne since 2001–02) with approximately 89 per cent of program funding coming from the grain growers. The levy was paid into the Skeleton Weed Trust Fund, which was then managed by the WA Department of Agriculture (AgWest). This department allocated the money to surveillance, detection and implementation of quarantine procedures while individual grain producers are responsible for the cost of treating the weed on their farms (these costs are included within the agricultural costs of Section 3).

Ag West also spends a significant amount of money on treatment of other noxious weeds and undertakes research into determining economically efficient methods to reduce the impact of declared weeds. Ag West undertakes control of declared weeds on crown lands using revenue collected from the Department of Land Administration.

The Department of Main Roads and local shire councils manage the road network in Western Australia. While an estimate of expenditure on noxious weed control was obtained from the Department of Main Roads we did not collect expenditure on weed management from all the 142 local governments.

The cost of weed control on regional rail lines was collected from the Australian Railroad Group and the Australian Rail Track Corporation. Weed expenditure by the Public Transport Association, the metropolitan rail manager and another regional rail manager, are not included in Table F. Data were not collected on weed control expenditure undertaken by the Water Corporation.

Table F. Expenditure on weeds by Western Australian public authorities and public land managers, 2001–02

	Skeleton weed eradication program ($)	Coordination, inspections, surveys, treatments ($m)	Education, training, extension & research ($m)	Salaries, admin, other indirect costs & in-kind contributions ($m)	Total ($m)
State Government Departments [a]	3,406,200	2,779,193	302,850	470,000	6,958,243
State Government Agencies [b]					nc
Local Government					nc
Private rail managers [c]		63,000			63,000
Total					**$7,021,243**

nc: data not collected

[a] *Included in this category are the WA Department of Agriculture (Ag West), the Department of Land Administration and Main Roads Western Australia. Ag West manages funds from the Department of Land Administration and the Skeleton Weed Trust Fund.*

[b] *Included in this category is the Water Corporation.*

[c] *Included in this category are the Australian Rail Group and the Australian Rail Track Corporation.*

Australian Capital Territory

Table G. Expenditure on weeds by Australian Capital Territory public authorities and public land managers, 2001–02

	Coordination, inspections, surveys, treatments ($m)	Education, training, extension & research	Salaries, admin, other indirect costs & in-kind contributions [b] ($m)	Total ($m)
Territory Government Departments [a]	662,986		21,471	684,457
Total				**$684,457**

[a] Included in this category is the ACT Department of Urban Services. Units within this department who have weed management responsibilities are ACT Forests, Land and Property, and Urban Parks and Places.
[b] The ACT Weed Control Program Report for 2000–2001 reports Indirect Costs as including revegetation and assistance to Landcare and Park Care Groups.

Northern Territory

The Northern Territory government expenditure reported in Table H is for weed control on crown lands and roads by the Department of Infrastructure, Planning and the Environment. Data on the additional expenditure by the Department on agricultural research programs, where weed control is the primary focus, were not available. Data on weed control expenditure by local government in the Northern Territory was not collected from the many individual councils.

Table H. Expenditure on weeds by Northern Territory public authorities and public land managers, 2001–02

	Coordination, inspections, surveys, treatments ($m)	Education, training, extension & research	Salaries, admin, other indirect costs & in-kind contributions ($m)	Total ($m)
State Government Departments [a]	94,645		13,000	107,645
NT Local Government				nc
Total				**$107,645**

nc: data not collected.
[a] Included in this category are the Department of Infrastructure, Planning and the Environment.

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