ECONOMIC ISSUES RELATING TO WEED MANAGEMENT IN NATURAL ECOSYSTEMS: THE CASE OF SCOTCH BROOM ON BARRINGTON TOPS, NSW

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Abstract

The area of the imported weed Scotch Broom (*Cytisus scoparius*) is steadily expanding and eliminating natural ecosystems and their habitats of rare and endangered species in Barrington Tops National Park. A research project, funded by the CRC for Weeds Management Systems, has commenced to provide economic information to assist the management of this problem. To provide a focus for the project, the economic issues surrounding the broom problem are explored in this paper.

The general economic characteristics of weeds in natural ecosystems are discussed first, and include externalities and public goods. The economic issues in weed management are addressed next, and include the problems of government management, choice of control measure, and sources of funding.

In the case of broom on Barrington Tops, specific economic issues include the allocation of funds to protect rare and endangered species, and difficulties of guaranteed continuous funding. Other issues include; common boundaries and interactions with private landholders and with State Forests, the spread of broom through recreation activities, severe topography and landscape which restricts the range of possible control measures, the persistence of seed banks, and growth habits of broom that limit growth of natural species.

The major questions to be resolved appear to include the specification of the utility functions of decision makers; the allocation of funds between containment of broom, preservation of biodiversity, and management of new forest areas; the estimation of a damage function (to show how the spread of broom and loss of habitats is affected by management and biophysical factors); and the choice of economically-efficient versus technically-effective methods of control.

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1. Introduction

Weeds may be broadly defined as plants growing where they are not wanted, that is, ”out of place”, and they may be either native or exotic species. However, in an ecological sense they are plants usually very much “in place”, being well adapted to the prevailing conditions (Tisdell, 1988).

In parks and gardens, any species which has not been deliberately planted or retained is usually regarded as a weed. In natural ecosystems, any species of exotic origin is usually considered to be a weed. It is difficult to place a monetary value on the impact of weeds in these situations because the services provided by parks, gardens and natural ecosystems are rarely priced and marketed.

An “ecosystem” has been defined as a recognisable ecological system, comprising both living organisms and the non-living environment interacting with one another, and defined over a particular area such as a forest, grassland or lake (Diesendorf and Hamilton, 1997). A natural ecosystem is one, which has not been (substantially) disturbed by humans.

A research project funded by the CRC for Weeds Management Systems has commenced to provide economic information to assist the management of problems caused by the imported weed Scotch Broom (*Cytisus scoparius*) in Barrington Tops National Park. The broad aim of the project is to develop strategies to assess the economic impacts of, and make decisions on, the management of weeds invading natural ecosystems. The assessment will recognise the maintenance of biological diversity, the prevention of degradation of natural habitats, the promotion of sustainable management, and the uncertainties involved, in the context of this particular weed and ecosystem.

A natural inclination is to use a formal welfare economics framework to assist in such an assessment. This paper explores the economic problems of weed management which may lead to modifications to the standard welfare framework. These include the problems of government management of weeds in natural ecosystems, choice of control measures and sources of funding between natural ecosystems and commercial agriculture production systems. Different characteristics of the two environments require different approaches. The objective of this paper is to review the economic issues relevant to this problem, to indicate the data requirements and problems, and to provide a focus for what might be feasible research areas in following phases of the project.

2. Economic characteristics of the weeds problem in natural ecosystems

2.1 Externalities or spillovers

If weeds are not controlled in natural ecosystems, they may impose external costs on other landholders by their spread. They can spread to agricultural land, commercial forest, and to irrigation and drainage channels. They can therefore reduce water yield to cities downstream.

If weeds are well controlled in natural ecosystems, external benefits may flow to individuals who are not making direct use of the areas. These benefits might include spillover effects on production and returns to commercial enterprises, as well as various "intangible" benefits to non-users. Some of the more tangible spillover benefits of control of weeds in natural ecosystems are as follows.

- Invasion or reinvasion of agricultural land by weed dispersal may be reduced. Hence, there are improvements in agricultural productivity and lower costs of weed control on agricultural land, both of which lead to higher farm returns.

- Similar benefits may accrue for commercial forests, and even in the case of non-commercial forests spillover benefits may be present. For example, there may be lower costs of control of weeds because of reduced invasion.

- Fishing outside the natural ecosystems may be improved because of increased stocks of fish due to control of aquatic weeds.

- The quantity of water may be increased and the quality of water improved by the control of aquatic weeds, and this may benefit water-users downstream. In some cases, there may be less invasion of aquatic weeds in irrigation and drainage channels, and navigation of waterways may be improved (Crafts, 1975).

- The risk of fires spreading to neighbouring properties can sometimes be reduced (Tisdell, 1988).

In general, external benefits of weed control in natural ecosystems may be reflected in;

(a) reduced costs of weed control on non-public conservation and recreation land, as well as on other public land, and

(b) greater productivity or improved services from such land. For example the use of biological weed control.

However, sometimes control techniques themselves can give rise to adverse externalities or spillovers. For instance, drift from herbicide application can damage crops on nearby properties or pose health risks to nearby population (Tisdell, 1985).

2.2 Public goods and government intervention

A pure public good (or its negative, a pure public bad) has extreme externality characteristics. Once a pure public good is provided, it is available to everyone in society at no cost, irrespective of whether they have contributed economically to its provision. The same is the case for a pure public bad.

Biological control of weeds has the characteristics of a pure public good. Once the biocontrol is successful, it spreads to other properties irrespective of whether their holders have contributed to the costs of introducing the control agent.

A pure public bad may exist in relation to the importation of potentially serious weeds. While the importer may, for example, hope to gain an interesting garden plant from the import and desire to import the plant out of his own self-interest, his potential gain may be small in relation to the potential damage to agriculturalists from its introduction. The loss of the agriculturalists is external to the gardener and will not be taken into account by him. Hence, there is a need for the government to control the importation of plants (Tisdell, 1985).

2.3 Unpriced benefits and under (or over) investment

In general, it is much more difficult to assess the benefit of controlling weeds in natural ecosystems than on private land because the services or outputs of natural ecosystems are unpriced, unmarketed, or underpriced. In contrast, the outputs of weed control on private land are normally sold commercially and market prices can usually be used to determine the economic value of controlling weeds. Indeed, because so many unpriced values are involved in weeds in natural ecosystems, there are few, if any, empirical estimates of the true costs or benefits of control.

Nevertheless, economists have suggested a number of methods for assessing the value of unmarketed or unpriced goods and these can be applied to help determine the value of controlling weeds on public conservation and recreational land (Sinden and Worrell, 1979 and Tisdell, 1988).

The unpriced benefits of weed control to users of public conservation and recreational land include:

- reduces discomfort or injury due to thorns, burns, prickles, pollen and so on,
- improves access for walking or reduced impediment for recreational use,
- reduces the replacement of desired native species by introduced weeds, and in turn preserves suitable habitat, increases plant diversity, and helps to conserve native animal populations,
- improves scenic beauty in urban parks as well as in conservation areas,
- lowers available fuel and lowers the danger of fire, and
- control of aquatic weeds in conservation areas may improve swimming and other water-based recreational opportunities, and increase fish catches.

The methods to assess these benefits include contingent valuation, travel-cost method and hedonic pricing.

The lack of market prices leads to problems of estimating efficient levels and kinds of investment.

2.4 Dynamics and uncertainty

Recent Australian research has shown that the greatest economic benefits in weed management are provided by management actions that aim to minimise weed seed bank populations. Weed management in natural ecosystems is often a very labour-intensive undertaking and the costs of weed control per unit area can escalate rapidly with increases in weed density. Control efforts are arguably most cost-effective during the earliest stages of weed invasion. Management effort should be focused on this stage, given that particular weeds are considered sufficiently serious to warrant intervention (and the natural area considered sufficiently important to warrant protection).

An understanding of weed population dynamics may allow the definition of maintenance levels, where a low annual or biennial control commitment would be sufficient to prevent substantial population increase. Better information on the cost (and effectiveness) of control efforts at different stages of weed invasions should assist in defining such levels, which could function as triggers for weed control (Panetta and James 1999). The dynamics of weed populations, specific to broom, are detailed in section 4.

The uncertainties associated with variations in demographic traits, weed impacts and efficacy of weed control methods that apply to weeds in agro-ecosystems are just as relevant in natural ecosystems. From a practical perspective, however, there remain sources of unpredictable variation in demographic traits, such as the multiplicity of factors affecting seed production, dispersal and persistence (management practices, climate, natural disasters, feral animal populations, rare and endangered species and other site characteristics) as well as variations in weed recruitment and survival. Population rates of increase may therefore vary considerably from year to year.

Moreover, recruitment of weeds in natural ecosystems can be highly episodic. The associated risk is that rapid increases in density could make effective control much more difficult leading to uncertainty of funds. In addition, uncertainty of occurrence of species and uncertainty of the spread of weeds may result to irreversible loss of species.

3. Economic issues in weed management in natural ecosystems

The following economic issues, as well as the previous economic characteristics, are summarised in table 1.

3.1 Government intervention in management

The economic characteristics of the weeds problem, as discussed in the previous section, invite government intervention to achieve optimal levels of control and management. However, economic theory suggests that the most efficient allocation of resources occurs in a competitive market without Government intervention, and that intervention in these circumstances can only reduce total social welfare. There is a need, therefore, to consider what market conditions need to exist before intervention may be justified. That is, when is there "market failure"?

The classical case of market failure is the existence of externalities (Menz and Auld, 1977). An individual imposing external costs, (such as through herbicide drift,) will tend to invest in more weed control than would be socially optimal. Conversely, a farmer producing external benefits by preventing weed spread onto neighbouring properties is likely to under-invest in control. From the broad social view, the prevention of weed spread or re-invasion is a commonly cited justification for government involvement in weed control (Auld *et al.* 1978 /79, 1982, and 1987).

Government intervention can also be justified by the existence of public goods. Most biological control agents are able to spread well beyond the boundaries of the properties where they are introduced and provide public goods (Menz *et al*. 1984, Tisdell *et al*. 1984). The economics of actual or potential biological control programs have been assessed for skeleton weed. As a result of the biological control act of 1984, release of future control agents may be subject to economic evaluation (Tisdell, 1987). The public good characteristics of information are often put forward as justification for government involvement in weeds research.

Apart from the existence of externalities and public goods, the main justifications for government intervention in weed control are to overcome perceived ignorance, to take advantage of economies of scale (Menz and Auld 1977) and to overcome differences between public and private attitudes to risk.

3.2 The political nature of decisions

National park services manage most of the nations natural ecosystems. In the Australian states, national parks and wildlife services are funded from general government revenue and any income which they receive is paid into that revenue. They are therefore, dependent entirely on the political process for funds.

Given the non-commercial nature of public conservation and recreational land, political factors play a much greater role in determining effort and methods used to control weeds on public land than on private land.

Given the public conservation and recreational land is under the control of government bodies, it is clear that the main, and in many cases only, avenue for the community to exert an influence is through the political process. However, while the political process is influenced by the community benefits to be had, it reflects these imperfectly (Buchanan and Tullock, 1962; Downs, 1957; Hartley and Tisdell, 1981).

Because of deficiencies in political mechanisms, weed control and management on public conservation and recreational land is unlikely to be optimal from an economic viewpoint. On conservation lands in particular, there may be insufficient control of weeds because of lack of funding.

Conservation pressure groups in Australia in recent years seem to have concentrated political action on increasing the area set aside for national parks but have not exerted as much pressure for increased funding of park management.

3.3 How does government management affect weeds?

- **Are there different control measures for National Parks vs Private lands?**

Different control measures can be applied on private lands as against National parks. On the private property "Tomalla" which is mainly pasture, several control measures are used to control scotch broom. These include using herbicides (Garlon & Tordon) which are applied through tractors & spray tanks, trucks & spray tanks, air spraying with helicopters and manual cutting of bushes and spraying stumps with Tordon. Other control measures include; biological control of which the results have not been seen yet, the use of fire, and livestocks, where goats, sheep and cattle are used to eat the smaller plants and ring barking the larger ones (Scotch Broom Management Committee, State Forests, 1998).

In National Parks, scotch broom is controlled mainly by using herbicides which are sprayed by vehicle mounted spray units, manual pulling along the trails, and biological control which is yet to work.

- **Is control more costly in National Parks?**

The costs of controlling weeds in National Parks are usually greater than in agricultural or commercially used land, given similar weed densities. This basically because; (a) the choice of acceptable control techniques in National Parks is more restricted because of environmental or political considerations, and (b) the natural environment in which control has to take place in National Parks prevents or restricts the use of more efficient techniques frequently used in the flatter, more accessible agricultural land (Tisdell, 1988).

Most National Park authorities allow some use of herbicides despite the fact that chemical control is often the cheapest and most effective method available. The use of fire is not allowed. Thus restrictions on socially acceptable methods of weed control in National Parks can add to control costs. It is, however, important to take into account the possible side effect of alternative techniques in controlling weeds in National Parks. For example special attention needs to be given to the possible impact of fire and herbicides on native animals, plants and nature generally.

In National Parks and similar areas, even mechanical means of weed control may be unacceptable because of accelerated soil erosion and unwanted impact on desired vegetation. Like wise, livestock control can not be used due to the topography and difficulties in controlling them.

4. Scotch Broom on the Barrington Tops

Barrington Tops National Park (BTNP) conserves about 80,000 hectares of rugged landscapes varying in altitude from 1585 metres on the Barrington Plateau down to 170 metres at the Chichester Dam. This large altitudinal range combined with a mosaic of geology, soils, rainfall and aspects provide a diversity of vegetation communities and fauna habitats. Vegetation communities grade from subtropical rainforest and tall open forests in the valleys through to cool temperate rainforests and sub alpine woodlands and wetlands on the plateau. The rainforests of the BTNP are the southern limit of the world heritage listed rainforests of eastern Australia. The diverse vegetation communities found in the park provide habitat for over 60 rare or threatened plant species.

Scotch Broom (*Cytisus scoparius*) has become a major weed in the Barrington Tops since it was first introduced as a garden plant at a property known as ”Tomalla” at the Northern end of the plateau in the 1840’s. It spread throughout the plateau area in association with grazing, fire and logging trails (Waterhouse, 1986). Scotch Broom was recognised as a major weed by 1964.

Scotch Broom infests an estimated 10,000 hectares (this could now include an additional 4000-5000ha, (personal observation C. Howard, NPWS, 1999) of the Barrington Tops National Park and is having a major impact on the natural ecology of the sub-alpine environment (Waterhouse, 1988; Smith 1994). The weed has become established in woodlands and open forest dominated by *Eucalyptus pauciflora*, and occurrs in woodlands of other species such as *E.stellualata* and *E.dalrympleana* (NSW National Parks and Wildlife Service, 1989).

Since the 1980’s Scotch Broom has also infested both the edge of sub-alpine wetlands and the open grassland plains (pers observations M. Newton, NPWS, 1998) of the plateau. Vegetation communities below the Barrington plateau within the National Park are dominated by sub-tropical rainforest, warm temperate rainforest, beech forest and wet and dry sclerophyll forests. Whilst rainforests do not provide conditions suitable for the establishment of Scotch Broom, large disturbed areas and drainage lines within rainforests where there is more light, may provide suitable conditions. Dry sclerophyll forests at high altitude also provide suitable open conditions for establishment.

Broom produces between 30-360 seeds per square metre below a eucalypt canopy and 7700-8900 seeds per square metre in the open away from overstorey trees. Indeed, broom soil seedbanks in Australia have been measured at values ranging from 190 to 50,000 seeds per square metre, values comparable to those found within the plant's native range (Hosking *et al.* 1996, 1998). These numbers are greatly in excess of the minimum necessary for stand replacement, and are supported by the presence of abundant seedlings which appear within broom stands every year. Broom plants live to a maximum of about 35 years, and all regeneration is by seed rather than by vegetative means (Hosking *et al*. 1998).

Broom plants are easy to kill with herbicides, burning, slashing or pulling. They resprout poorly from stumps, and in small numbers they can be controlled by grazing. But the large reservoir of dormant seeds accumulating in the soil, beneath and near broom stands, is undoubtedly the principal factor making broom control so intractable.

However, any disturbance which exposes surface soil to the temperature variations, from direct sunlight and nocturnal cooling, leads to partial germination of the soil seedbank. If they are adequately lit and do not experience drought, seedlings establish well, and broom thicket quickly returns to the site usually at higher density than previously. This regrowth must be killed within four years of the original disturbance, before it produces further seeds. But even if this were achieved, seeds from the original seedbank will continue to germinate for many more years, requiring repeated treatment.

Most broom seeds are dormant at the time of their explosive release from the pods, which flings them up to five metres. They may then be collected by ants and carried up to at least one metre (Smith and Harlen, 1991). Dispersal on this scale, together with growth and lean of shrubs within the stands, leads to stand expansion into surrounding, previously uncolonised habitat.

At a local scale, jump dispersal commonly leads to establishment of individuals tens or hundreds of metres from seedling stands, due to seed dispersal by mammals (pigs, horses, and possibly macropods, which ingest seeds and pass them in faeces in viable condition), by streams, or by humans or their vehicles and equipment

(Smith and Harlen 1991). Disturbance accelerates the process by increasing rates of seed germination and seedling establishment, so that after fire, herbicide treatment or physical disturbance, regrowth stands may be both denser and larger than before the disturbance (Moodie 1985, Robertson *et al*. Unpublished).

The strategy for broom management in Barrington Tops National Park was originally elimination. Due to the costs and difficulties of controlling broom the containment program was introduced which involves; containment & protection of endangered habitats, and control within the infested area by moving inwards from the perimeter.

The process whereby broom regenerates, and thereby persists at a site after the initial invasion, is relevant to management, especially in places of conservation significance. In these places, attempted control measures such as heavy grazing, herbicides, fire or other large disturbances are inappropriate or difficult to apply.

With widening recognition of broom's importance, and in order to curb its spread, control measures have been more vigorously adopted in recent years, particularly herbicide application to small, isolated populations. There is an annual program to locate and destroy regenerating broom at known, marked sites. If such measures are not maintained, regeneration is likely to lead within a few years to further accessions to the soil seedbank. For example roadside broom plants were flowering again in 1998 at Glencoe and Ebor in northern New South Wales despite their eradication from those sites about four years earlier (Hosking *et al*. 1998).

The major impacts of the infestation of broom on Barrington Tops are the loss of natural vegetation, restriction of recreational access to streams and tracks, and provision of harbour for feral pigs which subsequently cause further damage to the vegetation (Waterhouse, 1986). Invasion by broom is causing major and possibly permanent changes to the vegetation of the Barrington Tops plateau. Vegetation change after death of
the present broom generation is not clear, but three alternative scenarios are suggested (Waterhouse, 1986):

- Large areas previously dominated by eucalypt may now be dominated indefinitely by broom with few eucalypts present.
- Expansion of broom into all available habitats on the plateau may be followed by a decline in its population so that it remains a permanent but not dominant member of the local flora.

- The infestation may eventually be supplanted by shade-tolerant native vegetation.

5. Economic issues of broom on Barrington Tops

5.1 Influence of Park status

There are some questions to resolve which might assist in specifying the objectives of the park management.

- What are the effects of regulations and park status on management practices?

- What a park service can and can't do?

- Can the problem be handled differently to present practices?

5.2 Issues of social costs

- What are the costs of management strategies and the probability of success?
- How do the several classes of cost compare?
  - (a) direct offsite money costs of control (contractors, supervision etc.)
  - (b) direct offsite costs (salaries, research costs, other NPWS costs, and survey costs)
  - (c) social costs (the above, valued as opportunity cost, other opportunity costs such as lost timber output, and external costs)

The community should and will recognise all the social costs, NPWS should and will not recognise them all.

- Comparison of direct money costs and full social costs, including loss of biodiversity, unpriced costs, costs of salaries, and any extra costs for Park management.
- There is always the uncertainty of future funding of a government agency.

- How would they spend extra money if provided? The extra money will be used for biodiversity protection through targeting areas with rare species and introducing new biological control.

5.3 Is biological control more attractive?

In Barrington Tops, the terrain and vegetation can make it costly and difficult to gain access to weeds and to operate machinery so adding to costs in comparison to control costs on agricultural land. It may also be that there are a greater range of environments on public conservation and recreational land than on adjacent agricultural land and a greater variety of weed species present in more scattered communities. This can result in greater costs of weed control because of the diversity of weed species to be controlled and loss of economies of scale in control. Because of such problems, classical biological control is an attractive possibility for control of exotic species in this area, as Tisdell and Auld (1988) argue for public conservation areas in general.

But the following question remains. Are the benefits of preventing the loss of habitats and species worth more than the cost of biocontrol ? If the benefits are higher then its worthwhile doing it.

5.4 Does the value of biodiversity exceed the costs of protection?

Funds are spent to contain the infestation of broom and to reduce the danger that the weed will eliminate the habitats of rare and endangered species. The obvious economic issue is, does the value of biodiversity protection exceed this expenditure? (Abdalla,1994; Freeman, 1994). This value may be estimated as follows;

$$\text{Value of biodiversity} = \underset{\text{discounted to present}}{\text{market value of benefit}} \times \underset{\text{benefit}}{\text{Probability of obtaining}}$$

The probability that any given species will provide a market benefit is unknown and the time that it will be discovered is unknown. Further, there are difficulties in estimating the market value of the benefit. However, there are several possibilities for estimating the value.

- A government agency may buy land in the open market for the purposes of preserving it. In principle, the payment is one measure of the value of biodiversity.

- A land owner may make expenditures on inputs to protect biodiversity on the land such as treatment of broom. These are called "defensive expenditures" to defend the existing level of biodiversity.

  This expenditure is a minimum value of biodiversity. For example, suppose the owner spends $60,000 per year to protect, successfully, the habitats of 12 rare and endangered species. Assuming an economically rational decision, the value of this protection must be at least $60,000 per year or the expenditure would not have been undertaken.

- The government may transfer land from commercial use, with a state forest service, to preservation use with a park service. The opportunity cost of the foregone output, is a minimum measure of the value of protection. For example, suppose that a hectare of forest land will yield $1,000 this year and then $1,000 every 40 years thereafter. At a 5 per cent rate of interest, we calculate the opportunity cost as follows.

$$
\begin{aligned}
\text{Opportunity Cost} &= \$1000 + \left[1000 \div [(1.05)^{40} - 1]\right] \\
&= \$\,1000 + \left[1000 \div 6.04\right] \\
&= \$\,1166
\end{aligned}
$$

The minimum value placed on biodiversity protection is $1166 per hectare.

6. Discussion and Conclusions

We can now identify the economic approach that we would like to apply concerning management of scotch broom in natural ecosystems at Barrington Tops (table 2).

(a) **Identify the welfare optimum (the overall framework).** The pareto-optimal allocation of resources will be achieved when the price ratios for outputs equal the marginal cost ratios for production which in turn equal the marginal utility ratios for consumption. To estimate this ideal set of outputs and inputs over time, we obviously require the complete set of market prices for goods and the utility functions of both consumers and producers. When markets are competitive the welfare optimum is met at the equilibrium of demand and supply. Beal and Harrison (1997) apply this wisdom to a set of regional national parks with both fragile and robust ecosystems and both little and adequate infrastructure.

(b) **Minimise costs of producing park services for a multi-product firm (an operational model of the framework).** Natural ecosystems and National Parks are of course, part of a multi-product firm. The wide range of inputs must be combined to produce a wide range of outputs including biodiversity protection, recreation, water, and soil conservation. If all of these outputs were priced, the optimal set of quantities can be chosen relatively straight forwardly through programming techniques providing the technical input-output coefficients are known too (Wear & Hoffman, 1982).

(c) **Achieve given levels of biodiversity protection at least costs (a restricted operational model).** Park managers apply labour and capital inputs to their natural ecosystems to protect their biodiversity. They can also achieve given levels of biodiversity protection by acquiring new land, or restricting recreation activity in existing parklands. They face the "standard" isoquant problem of combining all these many kinds of input and control measure to protect given levels of biodiversity at least cost (Miller, 1978). The analysis must recognise the uncertainties of funding through time, the levels of rarity and endangement, the different kinds of biological risk, and the choice of input measure (Koskela and Ollikainen, 1999).

(d) **Estimate damage functions (a possible starting point).** A damage function, in terms of a natural ecosystem, relates environmental and management inputs to the "final" output of loss of species and habitats. There are two stages in the estimation of such a function, the first is to model the spread of broom and the second is to relate spread to loss of species. The "output" from broom spread is damage to the natural ecosystem, in the form of loss of species and habitat. The "inputs" to the spread include the natural environment (defined by several characteristics), management measures, the weather, human activity, and weed density. Panetta and James (1999) postulate damage functions of the (conventional) sigmoid form to relate weed density (plants per square metre) as the input to species density (loss of number of species or number of plants of a given species) as the output.

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Table 1. Economic issues relating to weeds in natural ecosystems

Economic and management issues	General effects	Specific effect in BTNP
1. Externalities	• Spread of weed, • Spillover benefits and costs	• Spread into and from other land • Costs to the external water supply
2. Public goods	Justifies: • government management of ecosystems, • government control of weeds	• Management given to NPWS • Largely dependent on government funds • Need for biocontrol in BTNP
3. Unpriced benefits	Difficulties in: • justification of funds, and • decisions on allocation.	• Insufficient funds for control, • Questions over future funding.
4. Public Policies	• Mixed objectives, • Sub-optimal allocation of funds.	• Pressure to include state forest in park
5. Public management	• Choice of control measure is constrained • Private methods of control inappropriate.	• Biocontrol yet to fully work • Control more costly in Park • Chemical use limited

Table 2. A Summary of an Economic Approach

Framework or level	Application	Particular data needs
1. Optimise welfare	Identify optimal outputs and inputs over time.	Values of all benefits and costs, estimates of demand and supply functions (competitive markets)
2. Cost minimisation of multi-product firm	Identify optimal trade offs between outputs and inputs for a park.	Costs of all goods and services including, biodiversity protection, recreation, and water conservation.
3. Cost minimisation for a single product	Identify least cost ways to preserve given levels of biodiversity.	Levels of funds, comparative values of rare and endangered species, riskiness of future budgets and effectiveness of protection measures
4. Production function	Estimate damage functions for broom.	Output is loss of species and habitats, inputs are characteristics of broom spread, natural environment, and effects of management inputs.