The role of resource economics in the control of invasive alien plants in South Africa

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The recognition of the economic consequences of alien invasive plants in terms of water-supply costs was pivotal in the establishment of the Working for Water programme, which has spent over R3 billion in dealing with the problem while simultaneously addressing poverty relief. Given competition from other social development projects for future funding, however, there is a need to justify further alien control programmes and to maximize efficiency within the programme. This requires valuing the biodiversity benefits of alien control and improving of the evaluation methods used. The concept of ecological goods and services has been a useful political tool, but the resource-economics concept of the Total Economic Value of biodiversity forms a more useful analytical framework. Studies on the impacts of alien invasive plants in South Africa initially concentrated on water losses, but more recently have included values of direct consumptive and non-consumptive use, option and existence value, and other indirect measures. Secondary effects such as downstream changes in aquatic ecosystem functions have not been assessed. Studies have varied in their scale and scope, as well as in the 'currency' of evaluation (such as financial or economic). Several approaches have been used for valuing water losses, with initial estimates having been the most conservative. Estimates of non-water benefits have frequently involved extrapolation from site-specific investigations within the study area, or been estimated from estimates at the regional level. None of the contingent valuation studies used has been applied following internationally accepted guidelines. In water-yielding catchments, alien control programmes are easy to justify in economic terms. In other areas, this may be more difficult. Cost–benefit analyses to date have tended to include the full financial costs of clearing, whereas, in reality, the opportunity cost of labour is close to zero, and economic costs are therefore much smaller. Benefits, which accrue later, tend to be underestimated from lack of information on biodiversity values and by high discount rates. A revised approach would favour the outlook for control programmes. If this fails to secure funding, what alternatives are there? New regulations are considered suboptimal and likely to fail. Opportunities for creating incentives to clear aliens from private lands are extremely limited, and there are no incentives that can reduce future invasions. Government-funded control programmes are thus the most efficient option. Future studies will need to address the right questions using the appropriate methods, incorporate both ecological and economic dynamics, express values in the right 'currency', and use a discount rate that reflects the rights of future generations. The quality of this research will depend on relevant ecological enquiry.

Introduction

This account provides a critical overview of the role that resource economics has played in the establishment of South Africa's alien plant control programme, known as the Working for Water programme. It shows how many of the approaches used to date have failed to evaluate the total economic value of biodiversity, or to use shadow prices correctly, and also that most studies have used high discount rates. These shortcomings have meant that the economic benefits of alien plant clearing programmes have been underestimated. Further ecological research will be needed to underpin reliable economic analyses of the problem.

Over 160 of the approximately 8750 plants that have been introduced to South Africa are known to be seriously invasive.[1,2] By 1997, 180 woody aliens were estimated to have invaded about 10 million hectares country-wide.[3,4] The fynbos biome (fynbos vegetation being a highly diverse shrubland) is the most heavily invaded, with invasions mainly by acacia and pine species that affect both mountainous and lowland terrestrial areas as well as river courses.[2] Grassland and savanna are also extensively invaded, but mostly in the moister regions and particularly along river courses. The semi-arid Nama and succulent karoo biomes (semi-arid low shrublands) are invaded by mesquite trees (*Prosopis* species), cacti (*Opuntia* species) and saltbushes (*Atriplex* species). Forests are heavily invaded by alien species, although the extent is unknown.[5] In addition, aquatic alien plants have made similarly serious incursions into bodies of fresh water.[6]

The proliferation of alien plants in these biomes has had a profound effect on biodiversity and ecosystem functioning. While the impacts of invasive aliens on biodiversity has been a concern for some time,[2] it was the demonstration of their effects on water resources that resulted in the problem being recognized as one that had serious economic consequences.[2,7–9] This led to the establishment of the Working for Water programme.[2] Initially set up to clear alien invasives from mountain catchments, the programme has since expanded to include lowlands and wetlands. This programme is the only major response the problem of aliens, since the high costs of clearing discourage private efforts[10] and are usually unaffordable in other conservation management budgets of state departments.[11] Nevertheless, current funding of the Working for Water programme is insufficient to tackle the problem with equal urgency in all parts of the country. It is faced with a problem of setting priorities for action, and maximizing the efficiency of its efforts. Such efforts are not only directed at clearing aliens *per se,* but also involve research programmes, with particular emphasis on the development of methods of biological control.

To date, the Working for Water programme has spent some R3.163 billion (in 2003 rands, past figures being adjusted using the production price index) on alien clearing and satellite programmes. A total of 171 000 ha was cleared, with follow-up weeding on 183 000 ha,[12] and some 24 000 people were employed in 2000.[13] The programme has also led to new weeds legislation and stimulated research on biological control. Indeed, the Working for Water programme has been hailed as an important success under South Africa's new political dispensation. The political success of the programme has, however, largely stemmed from its emphasis on poverty relief and social development, rather than on its environmental benefits. Now, almost a decade since its inception, the Working for Water

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programme has to compete with other government initiatives for funding, and its future is uncertain. The proposals that it will compete with will be developmental, rather than environmental.

The future funding of this programme will depend on the demonstration of its full socio-economic worth, which, in turn, will depend on how efficiently its resources have been allocated. Until now, the entire economic benefits of the programme's actions have not been adequately described in economic terms, nor has there been any prioritization strategy in place to ensure that the benefits of the programme's current activities are maximized.

The Working for Water programme's resource and development economics research agenda has two main priorities at present. These are to elucidate the full economic costs and benefits of the associated projects, and to develop methods for prioritizing future projects so that the returns to society as a whole are maximized. This paper reviews the state of our understanding of these issues, identifies current stumbling blocks, considers alternative methodological approaches, and makes recommendations for the future role of resource economics in this arena.

Understanding the value of biodiversity

Putting a monetary value to the impacts of alien invasive plants on biodiversity requires a clear and common understanding of the meaning of biodiversity and its economic worth. Although the term biodiversity is often used in the sense of species richness, it strictly should encompass ecosystem functioning as well, and is synonymous with natural systems or nature. Semantics aside, it is the role of the resource economist to estimate the economic values associated with biodiversity or natural systems, and to estimate how these values would change if these systems were to be altered in any way.

In ecological-economics parlance, natural systems represent the 'natural capital' that, together with man-made capital and human capital, produce goods and services which are consumed by households in the economy. Thus, while the traditional view of the circular economy portrays the production of goods and services by firms (man-made and human capital), ecological economics recognizes the important contribution made by ecosystems. Following the publication of Costanza *et al.*'s article in *Nature*,[14] ecosystem functions that scientists have been grappling with for years have been catapulted into the public arena, repackaged as valuable 'goods and services'. The main merit of that paper is that it has significantly influenced the thinking of policy- and decision-makers around the globe.

The classification of ecosystem characteristics in terms of economic commodities (goods and services) may be thought of as follows (Table 1). Goods are the tangible products provided by ecosystems, such as timber, and services encompass benefits such as those associated with ecosystem functioning, for example, water purification. Natural systems also have economic attributes, such as biological diversity, which contribute to their potential, such as ecotourism value, or sense of place, adding to overall quality of life.

This characterization of 'goods and services' (the phrase implicitly includes 'attributes'), while being useful in communicating the idea that ecosystems have economic value, has led to much confusion and needless debate in the scientific arena, particularly when it comes to their quantification and valuation. There is sometimes confusion in defining ecosystem goods and services, which are ecosystem components or functions that are consumed at present, but do not include all such components and functions. However, it can be argued that the remaining elements of biodiversity have potential future value. This future asset is recognized by the resource-economics concept of Total Economic Value of biodiversity, which is probably a more useful framework for the analysis of the economic impacts of aliens. This framework has been devised to simplify the description and measurement of value (Fig. 1). The Total Economic Value framework has not caught on with ecologists as much as the concept of goods and services, possibly because its connections with biodiversity have been vague, but is more popular in the resource-economics literature.

Table 1. A comparison of ecological and economic characteristics of ecosystems (adapted from Aylward and Barbier[45]).

System characteristics	Ecosystem characteristics	Economic characteristics
Stocks	Structural components	Goods
Flows	Environmental functions	Services
Organization	Biological and cultural diversity	Attributes

The structural components and organization of biodiversity, akin to the popular interpretation of biodiversity, underpins ecosystem functioning. In particular, it is thought to play an important role in determining the resilience of ecosystems, or their capacity to withstand major perturbations, by ensuring the continuity of ecosystem functioning (or provision of ecosystem services) over a range of environmental conditions.[15] While certain species have more important roles than others under one set of environmental conditions, others become important when those circumstances change. The loss of species, for example owing to alien invasions, is thought to undermine the buffering role played by ecological redundancy.[16] Indeed, the maintenance of structural diversity and organization within ecosystems (these characteristics are used as indicators of 'ecosystem health') is important for the maintenance and stability of primary production, which ultimately gives rise to the direct consumptive use value of ecosystems (Fig. 1). These are the values derived from local activities such as livestock grazing or resource harvesting. However, ecosystem functioning is also important in that it contributes to economic processes at a broader scale. Water regulation and purification, and carbon sequestration are processes which provide value at a broad scale. In addition, genetic diversity and organization contribute non-consumptive recreational value as well as option and existence value. Option value is a measure of potential future

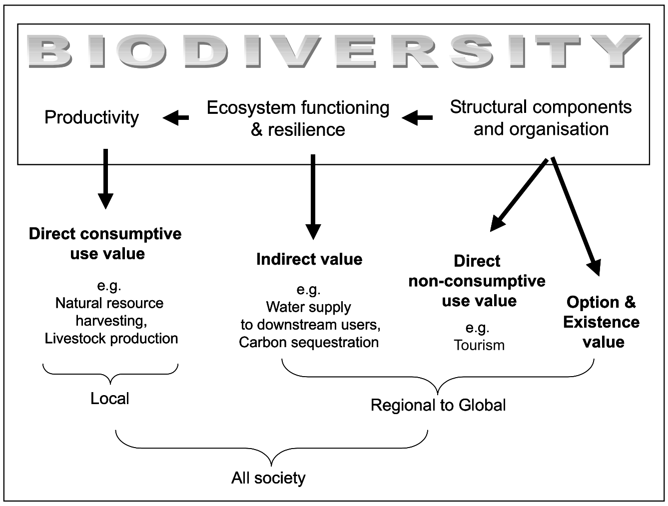

Fig. 1. A modified view of the elements of biodiversity that contribute to Total Economic Value.

use of biodiversity. For example, most cultivated crops contain genetic material that is recently incorporated from related wild species,[16] and this includes the cultivation of fynbos species in South Africa. It has been estimated that at least half the increase in agricultural productivity in the last century is attributable to inputs from wild plants.[16,17] Existence value is a measure of the satisfaction that people gain from the simple knowledge of the fact of certain aspects of biodiversity.

The invasion of ecosystems by aliens changes the structural make-up, genetic diversity and organization of biodiversity, effectively eroding the foundations of ecosystems. In so doing, these plants affect ecosystem functioning and resilience, and ecosystem productivity. They thus have an influence on all the values described above. While the impact of aliens on biodiversity is often referred to, the full implications of these influences are not generally understood, even in concept, by many policy- and decision-makers. Total economic value encompasses all the measures that affect human welfare. Nevertheless, it is currently only those values that are relatively tangible (direct and indirect use values, akin to goods and services) that carry any weight in the political arena.

Estimating the economic effects of alien invasive plants: how far have we come?

It is increasingly recognized that conservation and restoration efforts need to be justified in economic terms. This has led to attempts to estimate the value of biodiversity.[18] The economic consequences of alien invasive plants have been studied in South Africa largely to justify continued funding of clearing, biocontrol and research programmes, as well as to examine the costs of alien invasion to different stakeholders under different types of land tenure.[10,19]

There have been numerous recent attempts to estimate the economic costs of alien invasive plants, as well as their control.[16,20,21] Studies on the economic consequences of alien invasion in South Africa began with attempts to value the water losses incurred.[7–9,22] Later investigations also considered the losses in natural resource harvests, tourism, pollination services, and option and existence values.[10,23,24] More recently, the cost of increased fire risk has also been taken into consideration.[25] There has been no attempt to estimate the overall economic costs of aliens in South Africa, mainly because existing studies use different approaches, making aggregation difficult.[2] These studies variously concentrate on particular species, localities, catchments or biomes, and the values included and the way in which they are measured or presented differ from study to study. Indeed, there have been very few attempts to aggregate the economic costs of invasions at a regional or national level anywhere in the world,[26] though it is questionable whether this would be relevant to future policy decisions.[27] Why are so many different approaches used, and what is the right approach to estimating the economic consequences of invasions?

The various scales of analysis have ranged from multi-species assessments at a local to a biome level, to single-species analyses at a national scale, and result from the variety of questions being addressed. Most, if not all, studies have targeted terrestrial or riparian invaders, rather than aquatic plants. In most cases, multi-species analyses, whether at a local or regional scale, have aimed at highlighting the damage done by invasions or demonstrating the value of clearing. Single-species studies have generally analysed the costs and benefits of biological control programmes. The latter have been presented in terms of cost–benefit ratios, while the former have also been given in terms of annual values before and after invasion, net present values with or without clearing programmes (cost–benefit analysis), and the rates of return to investments in clearing. The actual values presented are a mixture of financial measures (accounting costs and farm-gate benefits), and economic criteria (total value added to national income), though shadow pricing (adjusting prices to reflect the true value of commodities or inputs) has not been properly applied in any study to date (see later).

Studies hitherto have also varied considerably in terms of the types of impacts considered. Even in the more comprehensive analyses, researchers have concentrated on the primary effects of invasive alien plants, such as water, species and diversity losses, and the increased costs of prevention or fire-fighting associated with enhanced fire risk. The direct changes in ecosystem structure and functioning due to alien plants also have knock-on effects, some of which are felt in distant ecosystems. Secondary impacts that have not yet been considered in any study are the influence on biodiversity and associated changes in economic value due to changed functioning of downstream aquatic habitats. This includes the functions of estuaries as nurseries that support inshore marine fisheries. Ironically, reductions in flow, amongst other factors, also render aquatic systems more susceptible to invasion by aquatic invasive alien plants, which have further effects on biodiversity and disease vectors. In addition, these species are capable of transpiring significant quantities of water, far exceeding natural rates of surface evaporation.[6] These highly tangible effects need to be taken into account.

Perhaps the most daunting challenge is to improve the dynamic dimension of these studies. Static analyses in which the current situation is used to estimate the value that has been lost, or the cost of further invasion, rely heavily on assumption. Dynamic studies, in which invasion processes are simulated, are only dynamic in that respect. None has explored possible changes in the demand for ecosystem goods and services in relation to changing supply and socio-economic circumstances. Moreover, none of the studies to date has considered how the economic impacts of invasive alien plants might be exacerbated in areas subject to climate change.

Valuing water losses: what is the correct approach?

One of the main differences between studies is the way in which valuation of the biophysical consequences has been applied, particularly in the valuation of water losses. At least two approaches have been used for the latter in South Africa: replacement cost and opportunity cost. Replacement cost entails the valuation of water or water losses in terms of the costs of buying water from national water supply schemes (average bulk water costs[22]), or in relation to the enhanced expense of supplying that water from planned future supply schemes in the area.[9,10,28,34] Opportunity cost entails valuing water or water losses in terms of the opportunity cost of water forgone to downstream uses, or the value that use of this water could have added to national income. This could be in terms of direct use, such as by agriculture or indirectly through provision of goods and services by downstream aquatic systems. The added value forgone in irrigated agriculture was used as a proxy for the full social cost of water losses due to plantation forestry.[29] This approach implied that irrigation agriculture was the next best user of water (generating the highest social returns) compared to alternative uses (such as environmental), and was considered to be a lower bound estimate.

Water has also been assessed using the average value added to the economy per unit of water used, multiplied by the proportion of total available water consumed.[25,30–33] This approach is the outcome of Natural Resource Accounting,[30,31] which is increasingly recognized as a standardized and defensible technique for water valuation anywhere[30,31,33] and the valuation of water losses due to changes in catchment vegetation.[25,32] This method links water use and supply data to established national accounting methods, by estimating the value added per unit volume of water to recognized economic sectors.[31,32]

All these estimates use average, not marginal, values of water. It is assumed that the average value is a close approximation of the marginal value, since the marginal value of water is unknown.[30]

All of the above methods yield very different values for the water losses incurred, and it is worth noting that the first studies, which led to the inception of the Working for Water programme, were among the most conservative. The different approaches have all been accepted in the past because they are all valid measures of value. The differences lie in the question of 'value to whom?'. Replacement costs represent a financial assessment, suitable to some extent for comparison with the costs of clearing, although different groups would bear these costs. These studies inherently assume that water *per se* is not limiting, just the supply of dams. Now that the environment is recognized as a legitimate user of water under the National Water Act of 1998, water available for impoundment is scarcer, and this should be taken into account. Opportunity cost measures follow an economic approach and represent the cost to society as a whole. There needs to be debate about whether to consider the value of water in terms of regional or national value added, though given the abundance of inter-basin water transfer schemes, the latter is probably more apt. It is important that the type of value used be compatible with the rest of the values in the study of concern and suitable for the purpose.

Valuing non-water benefits of alien clearing

Few attempts have been made to estimate the impacts of aliens on ecosystem values other than water supply. The few studies that have been conducted tend to be used in other investigations for extrapolation to different areas.

Direct consumptive use values (for example, for harvesting products from natural vegetation) are probably the most straightforward to estimate. Thus, the direct consumptive use value of fynbos based on interviews with farmers and information on the product industries (mostly export industries) has been estimated,[24] and this was used in conjunction with spatial data on alien cover to estimate the differences in value of pristine fynbos versus areas of different degrees of invasion.[10] The data provided were accurate at the scale of the Agulhas Plain, but when generalized to the fynbos biome, became rather inaccurate. Accurate estimation of direct consumptive use values is relatively easy, but ideally requires field work at the scale of the analysis. Where direct consumptive use values are considered, the corresponding uses of the invasive species are also generally taken into account.

In the resource economics literature, recreational value is typically estimated using the travel-cost method. Using travel costs to derive a demand curve leads to an estimate of value which includes both expenditure and consumers' surplus, and is particularly apt when recreational use of environmental amenities does not incur major costs or entrance fees. However, travel-cost analyses are usually specific to a particular amenity, such as a nature reserve. It is difficult to apply at the level of a catchment or beyond. Thus, two approaches have been taken in the estimation of recreational value at a regional level: a bottom-up one in which the results of travel-cost analyses for localities within the study area are extrapolated to the whole area,[10] and a top-down approach in which provincial or national estimates of value added by tourism are apportioned to the study area.[19] Both approaches have their problems, and ideally need to be replaced by studies that target the study area as a whole. Moreover, no studies have yet determined the effect of alien invasive plants on recreational value; these have been estimated from assumed non-linear relationships between the extent of invasion and recreational use.

Option value, the potential future use value of biodiversity, is impossible to estimate, though some attempts have been made by extrapolating from studies of the pharmaceutical worth of species,[10] or by using the expenditure on *ex situ* species preservation as a proxy.[34] Only quasi-option value can be measured, which is society's willingness to pay to retain the option for future use. This and existence value are typically measured using stated-preference valuation techniques such as the contingent valuation method. No studies using the contingent valuation method, that follow internationally accepted guidelines, have been carried out to assess the economic impact of aliens in South Africa. As for recreational value, site-specific values have been extrapolated (using conservative assumptions) to a regional level as a rough estimation.[10] A recent contingent valuation method study to estimate the existence value of South African biodiversity at a provincial scale suggests that the value of natural habitats, while high in aggregate, is actually fairly small at the per hectare scale.[35]

Apart from water supply, the other indirect values associated with natural systems have proved more difficult to estimate, possibly because of the prerequisite requirement of sound ecological research and modelling in the relevant areas. One of the better-researched consequences of alien invasion is the effect on fire. With invasions, the deleterious results of fires are increased,[36] making them more difficult to control and enhancing risk of damage. More intense fires damage soils,[37] leading to soil loss.[38] Both prevention costs[39] and damage costs[38] have been estimated. Other values include the range of services provided by downstream aquatic ecosystems whose functioning depends on this water supply. The value of fynbos was considered in terms of its support of bees that pollinate commercial fruit orchards and form the basis of a honey industry.[19] The latter is complicated by the fact that alien species contribute to this service to some extent. The issue of carbon cycling has not been addressed. Does invasion by alien plants, especially where this leads to increased fires, contribute to additional releases of carbon into the atmosphere, or does the enhanced biomass confer a sequestration benefit?

In general, economic impact studies need to be better informed by scientific research and modelling, and by case-specific resource-valuation studies. This includes the use of methods which are designed to measure changes in the characteristics or quality of environmental amenities, such as conjoint or choice modelling methods.[40]

Evaluating and prioritizing control projects against aliens

A programme to bring invasions under control through clearing would cost an estimated R650 million per year for the next 20 years.[21] This is considerably more than the amount currently being spent. As long as we continue to under-spend, so the problem continues to increase exponentially, and the costs of any future action are raised considerably. Of course, the costs of clearing vary with habitat and species.

The most comprehensive study to date[21] modelled the spread of invasives in four catchment areas in which river flow has been reduced by 6–22%. It was shown that, without action, these reductions would eventually be 22–95%, and that the costs to prevent this spread (some R80 million to R2000 million per catchment) were justified compared to potential impacts of alien invasion. Indeed, water is a key constraint to economic growth in South Africa, and in productive catchment areas, these costs are usually easy to justify in terms of stemming water losses.[10,28,34]

In other areas, the benefits of clearing are more difficult to quantify in monetary terms. For example, alien control programmes on lowland fynbos areas are beneficial to biodiversity but yield very little in the way of water benefits. Even where estimates of direct use value, indirect use value and existence value have been made, there will never be a way to measure the future use value of biodiversity with any certainty.

In many cases the costs of clearing may not be justified. Indeed, valuation of natural resources should not be seen as a panacea for conservation problems. For one, natural resources may not always carry a particularly high economic value, and secondly, there remains severe competition for government funds among a number of worthy causes. With this in mind, it is important to examine what costs and benefits are being compared. With a few exceptions,[23,34] most studies that calculated costs of alien invasion concentrated on estimates of costs and benefits without developing decision models or theoretical analyses.[16]

The lack of shadow pricing in the analysis of costs and benefits is a particularly contentious issue. Shadow pricing involves the adjustment of prices of commodities or factors of production in the analysis so as to reflect their true scarcity at a national level. In well-functioning markets, such adjustments would not be necessary, but where markets are distorted, for example through subsidies or price control, adjustments should be made if the analysis is to reflect the true benefits to society. This is particularly relevant when evaluating clearing costs. At face value, or in financial terms, the costs are extremely high. However, a large proportion of the expense of clearing is the cost of labour, and this labour comprises formerly unemployed people in poor communities. The shadow price of labour in these communities, where employment opportunities are scarce, would be close to zero. In any event, as a poverty relief initiative, this labour should not be included as a cost. Taking this into account, it would be interesting to take a fresh look at the returns to investment in clearing, which would undoubtedly become far more favourable. The Working for Water programme is not nearly as costly as it appears when its social benefits are taken into account.

Cost–benefit analysis may also have a different outcome if one examines alternative means of control. For example, it has been shown[6] that integrated biocontrol and herbicidal control are the cheapest ways to deal with water hyacinth. The benefit–cost ratios for biological control programmes were estimated to be high.[32] However, the consequences of delayed effects and delayed benefits were not taken into account. Clearing and biocontrol costs vary among species and habitats, and the most efficient strategy can be expected to be different for each. More research is needed to decide the most efficient combination and the optimal effort for biological control. In Australia, for example, research has indicated the marginal value of extra funds for weed control,[41] and where and how additional releases of biocontrol agents are economically justified to speed up control.[42]

Cost–benefit analysis is further complicated by the fact that some invasives also provide valued goods and services. On the benefit side, no study has yet considered dynamic changes in the value of ecosystem goods and services. As these (including water) become scarcer in general, they will become more valuable. Whether this has any effect on the results of a cost–benefit analysis will be strongly determined by the choice of discount rate. Currently there is no agreement on the appropriate discount rate to use. Projects have typically been evaluated using a rate of 8%.[33] At this rate, any benefits accruing in 25 to 30 years' time or beyond are reduced to a present value of close to zero. For example, a project that incurs costs of R338 000 over ten years, and yields benefits of R3 332 000 over 50 years, will have net present values of R338 000, R313 648 and R267 595 for costs, and net present values of R3 322 000, R1 320 532 and R228 649 for benefits at discount rates of 0%, 3% and 10%, respectively (Fig. 2). These translate into cost–benefit ratios of 1:9.8, 1:4.2 and 1:0.85, respectively. Since costs are borne upfront, the long-term benefits of the alien control programmes are undervalued in conventional cost–benefit analysis. Since investment in alien control is a contribution by society, future benefits that accrue to future generations should not be so severely discounted. With a social discount rate of 3%, many more control programmes would be seen as justifiable than when using a typical project discount rate of 8%.

Thus in general, costs have been overestimated, and benefits have been underestimated and heavily discounted. Our approach needs to be revised. Though more research is needed to quantify the costs and benefits of alien clearing in South Africa, alien control is probably largely justifiable from a societal perspective if the above considerations are taken into account. Nevertheless, there is pressure on the programme to perform with maximal efficiency. Efficiency should be achieved both in the cost-effectiveness of control programmes in general, and in terms of prioritization of areas to be attended to.

A start has been made within Working for Water to develop a system to prioritize quaternary catchments for the implementation of clearing programmes. This is currently based on a cost–benefit model in which the returns to investment in the competing areas will be compared, taking the social benefits of the programme into account. The actual decision process stands to be delayed because of the immense task of populating the models, especially in terms of the biodiversity values involved. Instead of delay, however, action should be based on existing knowledge and should be refined over time as our understanding of the value of biodiversity and the marginal costs of invasion grows. Delaying decisions in the hope of acquiring perfect information can only be less efficient.

What other options are there?

If we cannot justify current alien control programmes sufficiently to attract enough funding to make them more effective, what other alternatives are there? The options include regulatory approaches and incentive measures. Indeed, regulation regarding alien invaders has been intensified with the recent listing of harmful invasives and legal requirements to remove these plants from private and other lands. However, economic analysis of the consequences of these new regulatory mechanisms shows that they are neither socially optimal nor likely to be effective.[19] They have the potential to bankrupt landowners and may even act as a perverse incentive, discouraging farmers from conserving natural vegetation in areas susceptible to invasion. While there is an incentive for the state to control aliens, private landowners currently have little inducement to do so, even when faced with a legal obligation. The benefits of clearing are largely advantages to society as a whole, with a very small reward to landowners.

Where local direct use values of uninvaded lands are high

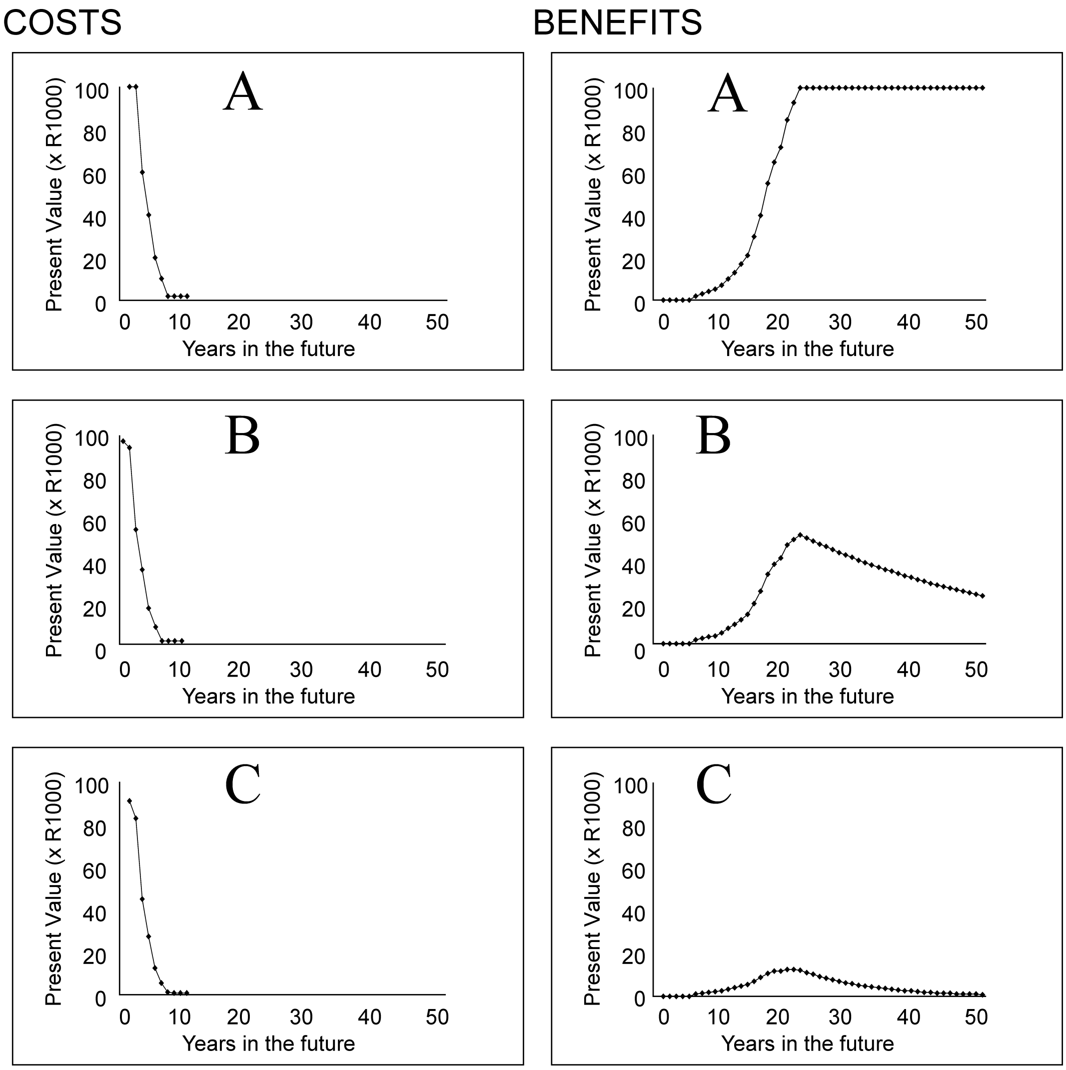

Fig. 2. Net present values for the costs and benefits associated with the same project at different rates of discounting. The rates used are: A = 0%, B = 3% and C = 10%. The total present value is the area below the curve. Lower discount rates will yield higher benefit:cost ratios.

relative to invaded lands, there may be an incentive to clear. This would be more prevalent if the costs of clearing were reduced. Thus, if the Working for Water programme generates entrepreneurial groups that undertake clearing, the associated costs might be reduced, in turn creating greater incentives for clearing on private lands. The only other way is to change the benefits, perceived or real, of uninvaded natural vegetation to landowners, for example through marketing programmes such as eco-labelling to raise the demand for natural products, or by enhancing the appeal of ecotourism on private lands. Incentives such as rate rebates[43] are unlikely to be effective given the ratios of costs and benefits involved. In the end, government-sponsored integrated control programmes involving both clearing and biological control are probably the optimal solution over the long term.

As an inevitable consequence of the growth in global trade, there will be more invasives to deal with in future. We need to understand and predict invasions,[16] and to this end new situations will need intensive monitoring. To some extent, our increased understanding of the ecological and economic consequences of past invasions will spur us into more timely action in future. Though ideal in theory as a long-term solution, the prevention of introductions is almost impossible. Unlike other environmental externalities (costs imposed by economic activity on others and which are not compensated for), invasions as externalities of trade are self-perpetuating, which means that conventional regulatory or incentive mechanisms to discourage the production of externalities are unlikely to be effective in stemming alien invasions.[16] It is thus also vital that control programmes include research and monitoring of new and potential invasives.

Conclusions: How can we get the best out of resource economics in future?

The recognition of the existence and value of ecosystem goods and services has been pivotal in the establishment of conservation measures such as the Working for Water programme. However, surprisingly little is known about the relative costs and benefits of alien control projects, mainly due to the paucity of data on the value of biodiversity. There is now sufficient capacity in this country for valuation studies to be carried out using the proper application of valuation methods. The naïve belief that resource economists can produce values for biodiversity out of nowhere must be quashed, and sufficient funding needs to be allocated to conduct studies to international standards. Nevertheless, it will be necessary to note the trade-offs involved in terms of research effort and quality of outputs forming the basis of decision-making, especially concerning issues of scale and intensity.

The way in which studies are pursued should be revised and standardized approaches to the valuation of impacts and of alien control projects would be desirable in many respects. We need a route by which to apply valuation methods, as well as to recognize the scope and limits of the valuation and information needs, including geographical scale and time frame, and the data collection methods and valuation techniques. Valuation for the sake of it is a wasted effort, especially of static studies that describe only the status quo. Future studies need to address the right questions using the appropriate methods, incorporate both ecological and economic dynamics, express values in the right 'currency', and use a discount rate that reflects the rights of future generations.

Finally, it cannot be emphasized enough that the quality of resource economics research depends on the quality of biophysical information available.[44] Ecological research is a prerequisite to making good decisions in a resource economics framework.

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