Nature's Services

Societal Dependence on Natural Ecosystems

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Chapter 19

SERVICES SUPPLIED BY SOUTH AFRICAN FYNBOS ECOSYSTEMS

Richard M. Cowling, Robert Costanza, and Steven I. Higgins

Perched at the southwestern tip of Africa is the world's smallest and, for its size, richest floral kingdom, the Cape Floristic Region. This tiny area, occupying a mere 90,000 km^2, supports 8,500 plant species (of which 68 percent are endemic), 193 endemic genera, and 6 endemic families (Bond and Goldblatt 1984). Because of the many threats to this region's spectacular flora, it has earned the distinction of being the world's "hottest" hot spot of biodiversity (Myers 1990).

The predominant vegetation in the Cape Floristic Region is fynbos (figure 19.1), a hard-leafed and fire-prone shrubland that grows on the highly infertile soils associated with the ancient, quartzitic mountains (mountain fynbos) and the windblown sands of the coastal margin (lowland fynbos) (Cowling 1992). Owing to the prevalent climate of cool, wet winters and warm, dry summers, fynbos is superficially similar to California chaparral and other Mediterranean-climate shrublands of the world (Hobbs et al. 1995). Fynbos landscapes are extremely rich in plant species (the Cape Peninsula has 2,554 species in 470 km^2), and narrow endemism ranks among the highest in the world (Cowling et al. 1992).

What services do these species-rich fynbos ecosystems provide and what is their value to society? The valuation of ecosystem services is fraught with problems (see chapters 3 and 4), and very few studies provide a comprehensive economic valuation. We know of no ecological-economic studies from unusually species-rich ecosystems. Here we review recent research in the fynbos that demonstrates unequivocally the substantial economic value

Figure 19.1. Fynbos (foreground) with invasive alien plants (*Pinus* spp. from the Mediterranean Basin and *Acacia* spp. from southwestern Australia) in the background. Note the greater height, and hence biomass, of the aliens. *Photo:* R.M. Cowling.

of ecosystem services such as sustained supply of clean water, wildflowers, recreational opportunities, and biodiversity storage. These studies provide convincing economic incentives for management interventions aimed at conserving and restoring biodiversity. We hope that this review will be useful to researchers and policy makers working in other species-rich ecosystems that are threatened by extensive transformations.

Our chapter is divided into four parts. First, we outline the nature and value of ecosystem services provided by fynbos. Then we briefly discuss the major threat to fynbos ecosystems and the biodiversity they harbor. The next section reviews static and dynamic models that quantify the economic value of fynbos ecosystems under different management scenarios. Finally, we discuss the policy implications of these studies.

Fynbos Ecosystem Services: Their Nature and Value

Fynbos ecosystems provide a diverse array of services (Cowling and Richardson 1995). However, only recently have there been explicit attempts to provide an economic valuation of these (Burgers et al. 1995, van Wilgen et al. 1996, Higgins et al. 1996a; table 19.1). The major services are derived from consumptive use (wildflower harvesting), nonconsumptive use (hiker and ecotourist visitation), indirect use (water runoff), future use or option value (plant biodiversity), and the existence value of fynbos landscapes (see also chapters 3 and 4). We describe the nature and value of these services below.

Wildflowers

The fynbos flora is widely harvested for cut and dried flowers (van Wilgen et al. 1992). The combined value for 1993 of these enterprises, much of which was made up of export earnings, was US$18–19.5 million and provided a livelihood for twenty to thirty thousand people in an otherwise agriculturally marginal zone (Cowling and Richardson 1995). Most wildflowers are harvested on the lowlands and lower mountain slopes of the southern fynbos region (Greyling and Davis 1989). The unit value of wildflowers varies considerably but may exceed US$10,000/km^2 in certain areas (Higgins et al. 1996a; table 19.1).

Hiker and Ecotourist Visitation

The fynbos region includes a comprehensive network of nature reserves and wilderness areas (Rebelo 1992) with an excellent infrastructure of hiking trails and overnight facilities. At present, the use of most of these facilities is considerably lower than potential visitation limits of 2.8 hikers/km^2/month and one ecotourist/km^2/month (Higgins et al. 1996a). However, tourism is

Table 19.1. Nature and unit value of services provided by South African mountain fynbos ecosystems

Service	Value[a]
Native plant species maintenance ($/sp)	55–5,500
Endemic plant species maintenance ($/sp)	27,400–274,000
Hiking opportunities ($/visitor/day)	3.5–7.0
Ecotourism opportunities ($/visitor/day)	22–274
Unit value wildflowers ($/km^2)	543–11,415
Unit value water ($/m^3)	0.04–0.12

[a] Figures represent the lower and upper limits of attempts at valuation.
Source: Higgins et al. 1996a.

a major growth industry in the fynbos region, and improved marketing of its beautiful landscapes and exceptional biota is likely to result in an upsurge in ecotourism.

Water

Fynbos-clad mountain watersheds yield about two-thirds of the region's water requirements (Burgers et al. 1995). Runoff from these watersheds is very high, owing to the generally high rainfall in the mountains, the porous, sandy soils, and the low water use by fynbos plants (Le Maitre et al. 1996). Furthermore, water quality is excellent and minimal treatment for domestic use is required (Burgers et al. 1995). Mountain-derived water plays a crucial role in the fynbos region's economy, which is centered in the semi-arid lowlands; in 1992 it generated a gross domestic product of US$15.3 billion (Bridgeman et al. 1992). For example, the deciduous fruit industry, which is entirely dependent on water derived from adjoining mountain watersheds, generated a gross export earning of US$560 million in 1993 and provided employment for about 250,000 people (van Wilgen et al. 1996). The minimum unit value of water to society is normally taken as the tariff for bulk untreated water from state supply schemes (Burgers et al. 1995; table 19.1).

The fynbos region is also home to large and rapidly growing numbers of economically marginalized people who live in informal settlements on the periphery of urban centers. Most of these communities do not have access to reliable sources of clean water. The Reconstruction and Development Programme (RDP) of South Africa's government of national unity endorses the principle that all South Africans have a right to "convenient access to clean water" (African National Congress 1994). This right will be realized only if watersheds are optimally managed to ensure the delivery of this ecosystem service in a cost-effective manner.

Biodiversity

Fynbos landscapes are exceptionally rich in plant species and typically include many narrow endemics (Cowling et al. 1992). Many fynbos plants have been developed as food and drug plants (e.g., rooibos tea—*Aspalathus linearis;* honeybush tea—*Cyclopia* spp.; buchu oil—*Agathosma crenulata*) (Donaldson and Scott 1994), and numerous others, including proteas, pelargoniums (geraniums), heaths, gladioli, freesias, and restios, have been developed as horticultural crops (Cowling and Richardson 1995). There are undoubtedly many as yet undiscovered plants that have economic potential or option value.

Fynbos ecosystems provide a storage service for this plant biodiversity. Higgins et al. (1996a) estimated the value of this biodiversity storage service as the cost of maintaining indigenous plant gene banks (the two values in table 19.1 reflect the cost of two South African schemes). The value of a narrow endemic species was estimated as the cost of producing a new floricultural variety (i.e., the cost of creating a novel combination of genes).

Existence Value

The existence value to society of fynbos ecosystems is very difficult to quantify in economic terms (see chapter 3). Nonetheless, the exquisite beauty of fynbos plants and the grandeur of fynbos landscapes are of considerable aesthetic and cultural value to the people of the southwestern Cape and, increasingly, elsewhere in South Africa and the world (Cowling and Richardson 1995).

Human-Induced Disruptions of Fynbos Ecosystem Services

Alien invasive plants, all shrubs and trees from other fire-prone Mediterranean-climate ecosystems (Richardson et al. 1992), are the major human-induced threat to fynbos biodiversity and ecosystem services. These weeds invade rapidly after fires and soon displace the fynbos flora (Richardson et al. 1992; figure 19.1). Alien plants increase the biomass of fynbos ecosystems by between 50 and 1,000 percent (Versfeld and van Wilgen 1986), resulting in a decrease in runoff from watersheds of between 30 and 80 percent (van Wilgen et al. 1992, Le Maitre et al. 1996; figure 19.2). Despite the obvious economic costs of a lack of effective management to counter the threats posed by alien plants (Burgers et al. 1995, Le Maitre et al. 1996), funding for fynbos watershed and reserve management, which is largely absorbed by clearing alien plant infestations, has been inadequate for several years. Recent estimates are that 31 percent of the area of proclaimed mountain fynbos watersheds is invaded by alien plants (Burgers et al. 1995); the situation is much worse in the lowlands (Richardson et al. 1992). Rates of invasion are exceptionally rapid, and models have predicted that without management, pristine watersheds will have alien plant cover of between 80 and 100 percent after one hundred years (Le Maitre et al. 1996; Richardson et al. 1996; figure 19.3).

In conclusion, invasive alien plants eliminate native plant biodiversity and reduce substantially water production from fynbos ecosystems. Therefore,

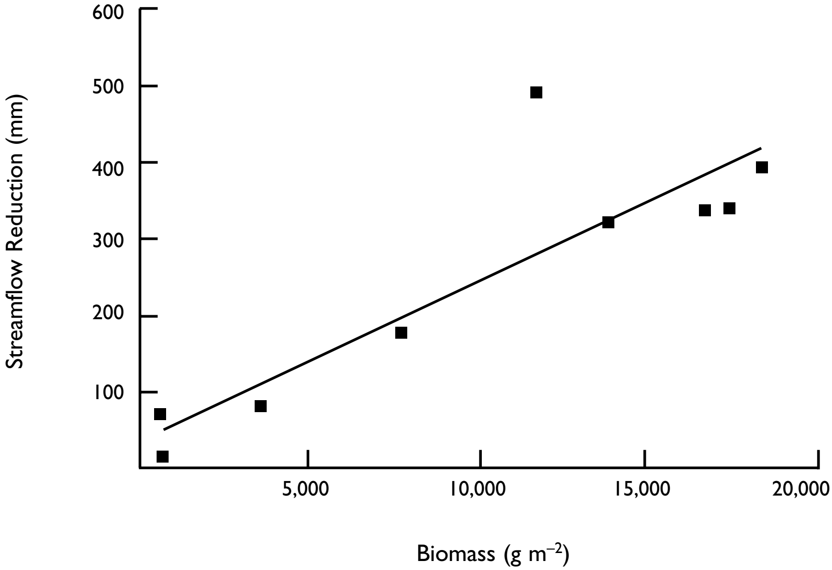

Figure 19.2. Relationship between biomass and reduction in streamflow from nine gauged watersheds in the southwestern Cape with varying degrees of invasion by alien plants.
Source: From Le Maitre et al. (1996), reproduced with permission from Blackwell Science Ltd.

they pose a direct and serious threat to all of the services provided by these ecosystems.

A Lack of Management

Most studies that have attempted ecosystem valuation adopt a static approach (e.g., Costanza et al. 1989; but see Krysanova and Kaganovich 1994). However, there is a growing recognition that effective articulation of ecosystem services will require a dynamic approach that combines, in integrative models, both ecological and economic processes (Costanza et al. 1993, Bockstael et al. 1995), and assesses the marginal costs and benefits of policy interventions (see chapter 3). In this section we discuss static and dynamic models that evaluate the economic consequences of a lack of management (chiefly alien plant control) in mountain fynbos ecosystems.

Van Wilgen et al.'s (1996) static model compared the costs of developing water supply schemes, water yield, and unit cost of water in two identical fynbos watersheds, with and without the management of alien plants (table 19.2). Both watersheds cover an area of 10,000 ha and have a mean annual

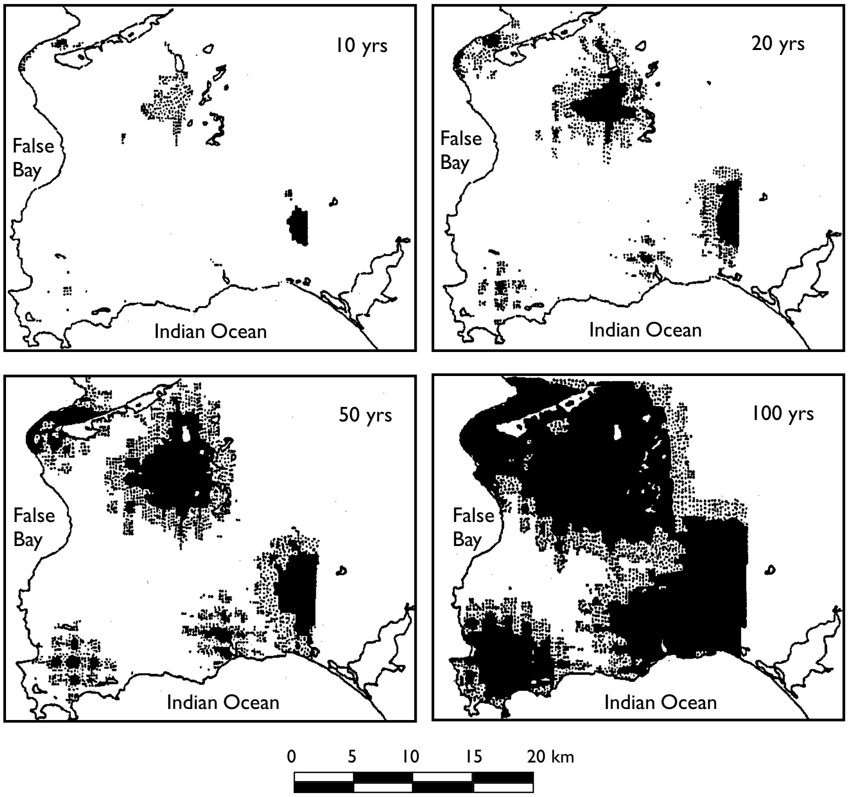

Figure 19.3. Maps showing the extent of infestation by alien plants in the Kogelberg mountain watershed (which supplies the city of Cape Town) in the southwestern Cape at various stages after the start of simulations of spread. Solid areas represent dense infestations; shaded areas represent lower-density classes, while unshaded areas are free of alien plants. If alien plant invasions are left unchecked, 86 million cubic meters of water could be lost annually. This represents 34 percent of the present annual water use by the city.
Source: From Le Maitre et al. (1996), reproduced with permission from Blackwell Science Ltd.

rainfall of 1,500 mm. At a post-fire age of fifteen years, the managed watershed supports about 3,800 gm^{-2} of fynbos vegetation; the same watershed, if fully invaded by alien trees, supports a biomass of about 11,000 gm^{-2} at the same stage (Le Maitre et al. 1996). Runoff from the invaded catchment would be reduced by approximately 30 percent.

The unit cost of water for the two hypothetical watersheds was calculated by assuming an annual interest cost on capital outlays (the building of a water supply scheme in both cases, and the initial clearing of alien plants in one) and combining this with the annual operating costs (table 19.2). Although total annual costs are 11 percent higher for the watershed where alien trees are cleared and managed, the unit cost of water production is 14 percent lower, owing to the larger volumes of water that would be produced from a watershed where alien trees are controlled. Furthermore, such a watershed would yield an additional 14.1 million m^3yr^{-1}. This last point is particularly important in view of the limited opportunities for establishing new water supply schemes in the fynbos region (Little 1995).

Higgins et al. (1996a) developed a dynamic simulation model that integrated ecological and economic processes in a hypothetical 4 km^2 fynbos watershed. The model was developed in an interdisciplinary workshop set-

Table 19.2. Assumptions for the parameters and costs and water yields associated with two identical, hypothetical watersheds in the mountains of the fynbos region, with and without the management of invasive alien plants

	With Management of Alien Plants	Without Management of Alien Plants
Aboveground biomass (gm^{-2})	3,867	10,964
Reduction in streamflow due to plant biomass at 15-yr post-fire (mm rainfall equivalent)	114	256
Capital cost of clearing initial infestation (US$ ha^{-1})	830	0
Annual cost of alien plant management (US$ ha^{-1})	8	0
Capital cost of developing water supply scheme and initial clearing of aliens (US$ $\times 10^6$)	76	67.7
Annual interest on capital cost at 8% (US$ $\times 10^6$)	6.1	5.4
Operating costs (US$ $\times 10^6$ yr^{-1})	1.36	1.27
Total annual costs (interest plus operating) (US$ $\times 10^6$ yr^{-1})	7.46	6.67
Water yield ($m^3 \times 10^6$ yr^{-1})	62.7	48.6
Unit cost of water (cents m^{-3})	11.8	13.7

Sources: Biomass and streamflow reductions were calculated from relationships given in Le Maitre et al. (1996). Table adapted from van Wilgen et al. (1996).

ting using STELLA (1993, High Performance Systems, Inc.), an icon-based simulation language that facilitates collaborative model construction. A monthly time step was selected in order to simulate the seasonal and fire-related dynamics of the fynbos watershed ecosystem over a fifty-year period. The model comprises five interactive submodels, namely hydrological, fire, plant, management, and economic valuation (figure 19.4). Parameter estimates for each submodel were either derived from the published literature or established by workshop participants and consultants (they are described in detail in Higgins et al. 1996a). The plant submodel included both native and alien plants. Simulation provided a realistic description of alien plant invasions and their impacts on river flow and runoff (figure 19.5). Our discussion below will focus mainly on the output of the economic submodel in relation to different alien plant management scenarios (table 19.3). The model enabled us to quantify the marginal costs and benefits to society as a result of different management policies (scenarios). It is important to note that the model does not provide a realistic estimate of the total value of the watershed, since we lack information on what society would be willing to pay for ecosystem management as a function of alien plant invasion (see chapter 3). The nature and unit value of ecosystem services quantified in the model are given in table 19.1.

Under management scenario M1 (present management, table 19.3), inadequate clearing of aliens had a major negative impact on the ecosystem services provided by the hypothetical watershed (Higgins et al. 1996a). The

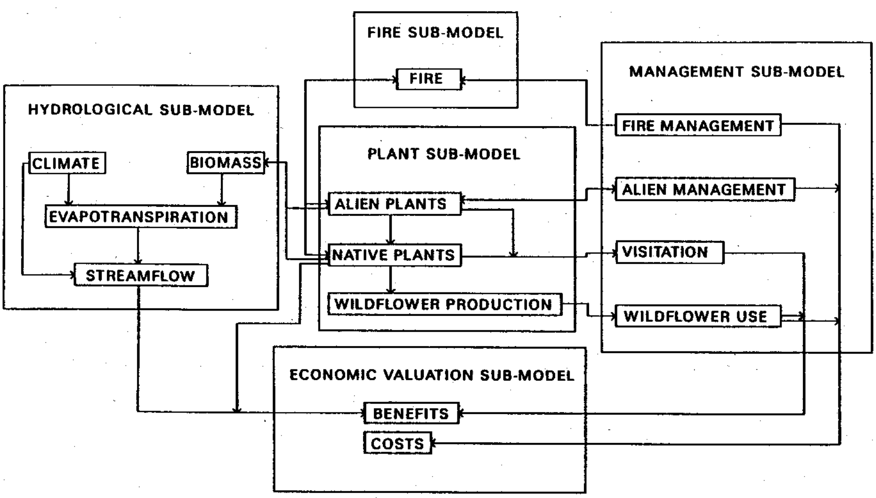

Figure 19.4. Conceptual diagram of the dynamic ecological-economic model of the fynbos mountain watershed model.

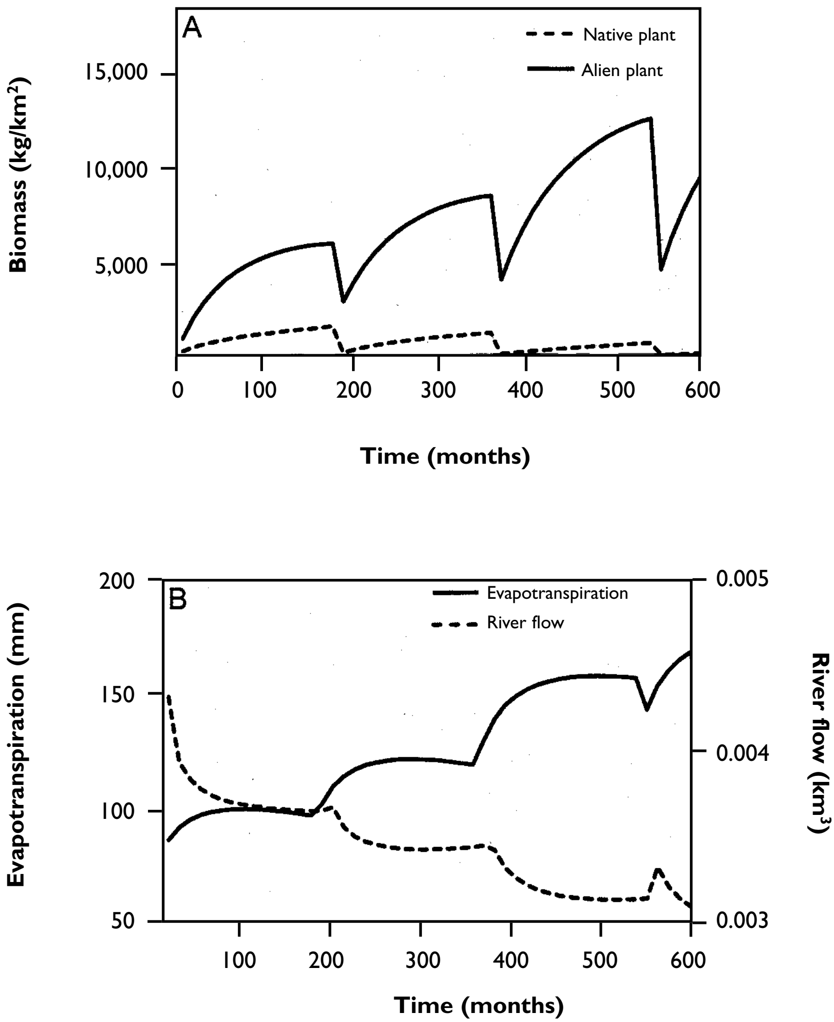

Figure 19.5. Output of the plant and hydrological submodels showing changes in: (A) alien and native plant biomass and (B) evapotranspiration and river flow over time (including four fire cycles) for an invaded catchment.

model predicts a steady decrease over the simulation period in water yield and, owing to the competitive superiority of alien versus native plants (Richardson et al. 1992), a reduction in wildflower production and a decline in the biodiversity storage service. As the watershed is invaded, it is avoided first by ecotourists and later by hikers, thereby diminishing revenues from recreational activities. When this scenario was combined with the low end of the range of unit value estimates for the four main categories of ecosystem

Table 19.3. Management scenarios used for modeling the economic outputs from the fynbos model[a]

Code	Description
M1	Present management: 50% invaded by aliens; inadequate clearing (0.003 km^2 mo^{-1}).
M2	Proactive management: 50% invaded by aliens; adequate clearing (0.01 km^2 mo^{-1}).
M3	Pristine management: uninvaded; no clearing required.

[a]Codes appear in the text as well as in figures 19.6 and 19.7, where they are combined with two levels of economic valuation of ecosystem services: E1 (lower limit of unit values in table 19.1) and E2 (upper limit of unit values).

Source: Higgins et al. 1996a.

services considered (E1; see table 19.3), the net value (i.e., with management costs deducted and discounted at 3 percent over fifty years) of the watershed was US$5.2 million (figure 19.6). At the high end of the range of unit values (E2) the value estimates totaled US$29.3 million.

When the management strategy involves the eradication of aliens from an invaded watershed (scenario M2 in table 19.3), the net value over the simulation period increased to US$7.1 million under low-end valuation, to US$55.3 million under high-end valuation (figure 19.6). This occurs in spite of increased management costs associated with a greater effort at clearing aliens (see also van Wilgen et al. 1996).

Pristine watersheds are free of alien plants and require little management other than controlled burns and hiking trail maintenance (scenario M3 in table 19.3). Under this scenario, the net value of the watershed under low-end valuation (E1) was US$7.7 million (figure 19.6). This was only marginally higher than under the proactive management scenario (M2,E1) and demonstrates that alien clearing can restore the value of key ecosystem services, especially water production (see also Burgers et al. 1995). Predictably, the highest net value (US$82.5 million) was recorded for the pristine management (M3) and high-end valuation (E2) combination.

Water dominates the value of the watershed under low-end valuation (E1), whereas the biodiversity storage service has the greatest value under high-end valuation (E2) (figure 19.7). Endemic plants contribute little to this service, owing to the small size of the watershed; the empirical relationship between watershed area (4 km^2) and species richness predicts a value 465 plant species and only 1.46 endemics (Higgins et al. 1996a). In relative terms, recreational activities (hiking and ecotourism) contribute little to the gross value of the watershed, but absolute values are substantial in well-managed situations: the derived revenues could make an important contri-

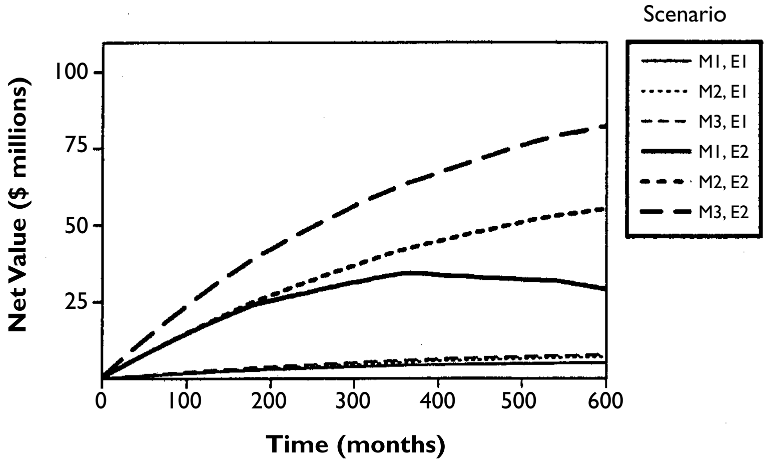

Figure 19.6. Changes in net value with time for three management scenarios (M1–M3) and two economic valuations (E1 and E2) for a 4 km^2 fynbos mountain watershed. Scenarios are described in table 19.3.

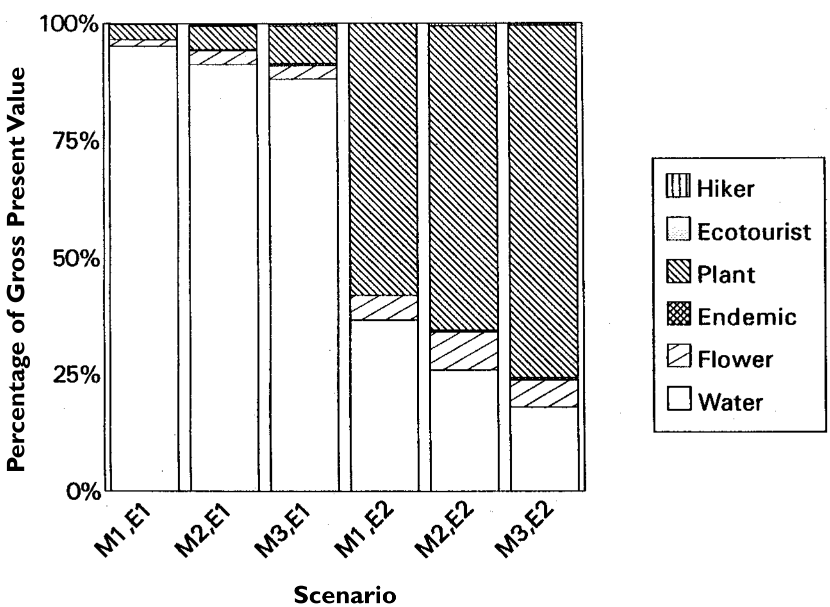

Figure 19.7. The proportional contribution of ecosystem services to gross present value of a 4 km^2 fynbos mountain watershed under three different management scenarios (M1–M3) and two economic valuations (E1 and E2). Scenarios are described in table 19.3.

bution to management costs. In this respect it is important to note that the costs of proactive management (principally alien clearance) amount to only 0.6 percent (high-end valuation, E2) and 4.8 percent (low-end valuation, E1) of the value to society of the ecosystem services supplied by the watershed.

Policy Implications

This chapter has shown that species-rich fynbos ecosystems provide a wide array of services that are of considerable economic value to society. We have also shown that the costs of optimal ecosystem management, aimed largely at eradicating and preventing invasions by alien shrubs and trees, are minuscule when compared to the benefits provided by pristine ecosystems. Our chapter raises several important implications for policy formulation. We discuss some of these in this section.

The deleterious impact of alien trees and shrubs on native plant biodiversity has been known to fynbos ecologists for several decades (e.g., see Richardson et al. 1992 and van Wilgen et al. 1992). Indeed, an appreciation of the importance of fynbos-clad watersheds for the economic development of the southwestern Cape resulted in the proclamation in the early 1970s of most of the mountains of the region as protected watersheds. Management plans were drawn up for each watershed, and alien plants were vigorously combated. However, the past five years have seen a substantial decline in funding for watershed management, and this has resulted in an alarming increase in the extent and density of alien plant infestations (Burgers et al. 1995). Given the considerable economic value to all sectors of society of the services supplied by pristine watersheds, these budgetary shortfalls make little sense. The benefits of optimal watershed management in terms of increased water yield—water being a critical limiting resource in the fynbos region—is a sufficiently persuasive argument for a policy that would provide sufficient funds for the eradication and prevention of alien plant invasions.

With this in mind, a group of fynbos ecologists, under the auspices of the Foundation for Research Development's Fynbos Forum, developed an audio-visual "road show" that described the economics of water and watershed management. The road show was presented to the minister of water affairs and forestry in May 1995. So impressed was the minister that he declared alien plant removal from watersheds as a project within the Reconstruction and Development Programme (RDP). The RDP is aimed at kick-starting socioeconomic development in post-apartheid South Africa. The watershed project is envisaged to run for twenty years (the time estimated for complete restoration) and, in the process, will create thousands of jobs, involve numerous training programs, stimulate scientific research, and safeguard many thousands of plant and animal species. The project was launched in late 1995 at several sites in the fynbos region.

With that battle apparently won, we need to turn our attention to lowland fynbos, where water is not a significant ecosystem service. There are three issues here that are important for policy development. First, lowland fynbos ecosystems have better wildflower resources than the mountains and are also more accessible. It is not surprising, therefore, that they support the bulk of the wildflower industry (Greyling and Davis 1989). Alien plants pose a major threat to wildflower resources throughout the lowlands (Cowling 1990). Although alien plants are an economically valuable fuelwood resource for the subsistence sector in lowland areas adjacent to urban centers, Higgins et al. (1996b) have shown that wildflower harvesting is more important economically and more sustainable in the longer term. Landowners and policy makers need to be apprised of the long-term economic benefits of controlling alien plant invasions for the benefit of the rapidly growing wildflower trade in the fynbos lowlands.

Second, tourism is the fastest-growing industry in the fynbos region, and there is enormous potential to market the fynbos as an ecotourist resource of international significance (Cowling and Richardson 1995). As a result of their spectacular flora, accessibility, scenic qualities, and proximity to the ocean, lowland fynbos ecosystems are prime ecotourist destinations. Alien plant invasions, which degrade scenery and eliminate native plant and animal biodiversity, represent a major threat to the ecotourism industry. There are no realistic estimates of the contribution of ecotourism to the economy of fynbos lowland regions. Entry fees charged by nature reserves (table 19.1) are not good indicators of this contribution, since users actually pay much more (e.g., transportation, time, and accommodation costs) to visit these facilities (see chapter 3). Techniques such as the travel cost method (chapter 3) urgently need to be employed to provide a realistic assessment of the contribution of ecotourism to the economies of lowland fynbos regions.

Finally, lowland fynbos ecosystems provide a storage service for many thousands of fynbos plants and animals, including numerous threatened taxa and local endemics (Cowling et al. 1992, Rebelo 1992). Many lowland species have been developed as horticultural crops, medicinal plants, and foodstuffs (Donaldson and Scott 1994). The option value of the remaining species represents a considerable economic resource. Policy makers must be made aware of the valuable service provided by these ecosystems and allocate funds to counter threats that may disrupt it.

Ecological economics is a rapidly developing discipline. However, it already provides the concepts, theories, and tools to explore the economic implications of habitat destruction and biodiversity loss (e.g., Jansson et al. 1994). The explicit economic valuation of the services provided by mountain fynbos ecosystems has resolved conflicts regarding the allocation of limited funds and provided the incentives for policies aimed at ecosystem restoration and optimal management. The fynbos model developed by Higgins et al. (1996a), which has a user-friendly interface and can be played as an interactive game by a wide range of interested parties with no prior modeling experience, could be used to communicate the value of lowland fynbos ecosystems in terms of wildflowers, ecotourism, and biodiversity storage, and thereby contribute to the resolution of management and land-use conflicts. We are confident that such initiatives will lead to improved conservation and utilization of lowland fynbos ecosystems. Such interventions will be to the benefit of all South Africans and indeed to citizens of the entire planet.

Summary

The species-rich fynbos ecosystems of South Africa represent the world's foremost hot spot of plant diversity and endemism. These ecosystems provide a diverse array of services to society, such as wildflowers, ecotourism opportunities, water supplies, biodiversity storage (including many actually and potentially valuable horticultural, food, and drug plant species), and, owing to their beauty, immense existence value. Fynbos ecosystems are severely threatened by alien plant invasions, which substantially reduce the quantity and quality of the services they provide. This chapter reviews recent research that evaluates the impact on the economic value of fynbos ecosystem services of a lack of alien plant control. Results show that the marginal costs of management to remove alien plants range between 0.6 percent (high-end valuation) and 4.8 percent (low-end valuation) of the marginal value to society of the services provided by a fynbos mountain watershed. Although water dominates the value under low-end valuation, the biodiversity storage function has the greatest value under high-end valuation. This emphasizes the importance of providing a realistic value of the latter service. The economic impact of reduced water supplies from fynbos mountain watersheds invaded with alien plants has provided the incentives for a development project aimed at restoring these ecosystems. We discuss potential policy interventions for restoring and maintaining native plant biodiversity in lowland fynbos regions, where water supply is not a major ecosystem service.

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