
The role and value of water in natural capital restoration on the Agulhas Plain

HELANYA FOURIE, MARTIN DE WIT AND ALBERT VAN DER MERWE

Stellenbosch Economic Working Papers: 03/11

KEYWORDS: COST-BENEFIT ANALYSIS, INVASIVE VEGETATION, NATURAL
CAPITAL RESTORATION, WATER
JEL: Q56

HELANYA FOURIE
MACRO AND RESOURCE
ECONOMICS
WESTERN CAPE DEPARTMENT
OF AGRICULTURE
MULDERSVLEI ROAD, 7607
ELSENBURG, SOUTH AFRICA
E-MAIL:
HELANYAV@ELSENBURG.COM

MARTIN DE WIT
SCHOOL OF PUBLIC LEADERSHIP
UNIVERSITY OF STELLENBOSCH
PO BOX 610, 7535
BELLVILLE SOUTH AFRICA
E-MAIL:
MARTIN@SUSTAINABLEOPTIONS.
CO.ZA

ALBERT VAN DER MERWE
DEPARTMENT OF ECONOMICS
UNIVERSITY OF STELLENBOSCH
PRIVATE BAG X1, 7602
MATIELAND, SOUTH AFRICA
E-MAIL: AVDM2@SUN.AC.ZA



UNIVERSITEIT
STELLENBOSCH
UNIVERSITY



A WORKING PAPER OF THE DEPARTMENT OF ECONOMICS AND THE
BUREAU FOR ECONOMIC RESEARCH AT THE UNIVERSITY OF STELLENBOSCH

The role and value of water in natural capital restoration on the Agulhas Plain¹

HELANYA FOURIE², MARTIN DE WIT AND ALBERT VAN DER MERWE

ABSTRACT

The Agulhas Plain is a low-lying coastal area within the Cape Floristic Region classified as one of the six plant kingdoms of the world. The area is heavily invaded by alien vegetation that infringes upon the sustainable supply of ecosystem goods and services provided by the native fynbos vegetation. Natural capital restoration is expected to recover the supply of ecosystem goods and services, and in particular to increase the amount of water available for consumption. The study conducts cost-benefit analyses to assess whether alien clearing and restoration would add value to the Agulhas Plain. The analyses indicate that the cost of alien clearing and restoration in the area cannot be justified if the additional water released holds no benefit to the Plain. A brief assessment shows that the actual average value of water on the Agulhas Plain, as estimated by other studies, is higher than the economic cost of making the water available through alien clearing and restoration. Thus this would make alien clearing and restoration economically justified.

Keywords: Cost-benefit analysis, Invasive vegetation, Natural capital restoration, Water

JEL codes: Q56

¹Study coordinated by ASSET Research and funded by the Water Research Commission (Project K5/1803).

² Corresponding author

Acknowledgements

We are grateful to the Water Research Commission (WRC) – Key Strategic Area, Water Utilisation in Agriculture (KSA4) who funded and commissioned this study. This work forms part of the broader WRC project entitled, ‘The impact of re-establishing indigenous plants and restoring the natural landscape on sustainable rural employment and land productivity through payment for environmental services’. We are also grateful to Africa's Search for Sound Economic Trajectories (ASSET Research), who provided a bursary and supervisory input to this work.

1. Introduction

The demand for ecosystem goods and services is increasing precipitously as economies and the human population continues to grow (Millennium Ecosystem Assessment 2005). The supply of such goods and services on which society is dependent is placed under pressure and often consumed at levels above that which ensures sustainable yield. By reducing the resilience of ecosystems and indigenous biodiversity, invasive vegetation further threatens the sustainable supply of ecosystem goods and services. A report prepared for the Global Invasive Species Programme found that invasive species impact on 33% of threatened birds, 16% of threatened mammals, and 28% of threatened amphibians (Butchart, Chanson & Hoffmann 2009). The costs associated with invasive species depend on the ecosystem in question and the ecosystem goods and services included in the analysis (Perrings, Mooney & Williamson 2010). Cost estimates vary, but Pimentel *et al.* (2005) estimate damage costs induced by invasive vegetation of between 80 and 110 per cent of South Africa's agricultural GDP.

Climate change is expected to hasten the spread and damage caused by invasive species and to increase the cost of controlling invasion accordingly (Thuiller, Richardson & Midgley 2007). This will in turn exacerbate the impact that climate change may have on health, food security, and biodiversity (Global Invasive Species Programme 2009). Restoring natural capital by eradicating invasive species and limiting their spread can provide a means of adapting to climate change, even if it does not mitigate the phenomenon in itself.

Invasive vegetation is as much an economic as a biological phenomenon: it occurs as a result of economic activity; requires economic principles to assess its impact; and needs economic incentives to control its spread. Valuing the impacts of invasive vegetation requires an interdisciplinary approach, drawing from the ecological and hydrological processes that drive and are in turn influenced by invasive vegetation, and incorporating this into economic methodology. This study draws from different disciplines to assess the change in economic value that will occur as a result of alien removal and natural capital restoration on the Agulhas Plain, South Africa.

Efficient outcomes of clearing and restoration projects depend on the value of the damage inflicted by invasive vegetation and how this value compares to project costs. Valuation studies of ecosystem goods and services have become custom (van Wilgen, Cowling & Burgers 1996; Loomis *et al.* 2000; Ricketts *et al.* 2004), with the study by Costanza *et al.*

(1997) on “The value of the world’s ecosystem services and natural capital” published in *Nature* best known. A number of studies have related ecosystem valuation to the damage and costs inflicted by alien vegetation (De Wit, Crookes & Van Wilgen 2001; Marais & Wannenburg 2008), as is also done here.

The hypothesis is advanced that by impacting on ecosystem goods and services invasive vegetation leads to a reduction in the economic value of natural capital on a micro level. It is further hypothesised that by investing in alien clearing and the restoration of indigenous vegetation, value can be restored or added to an area. The study employs a cost-benefit analysis to evaluate the change in value brought about by alien removal and restoration. To this end the report is arranged as follow: Section 2 provides an overview of the literature on natural capital, the occurrence and management of invasive vegetation, economic complexities and market creation. Section 3 introduces the study area on the Agulhas Plain. Section 4 provides an explanation of the model, and in section 5 model results are discussed. Section 6 concludes and provided some policy recommendations.

2. Natural capital, invasive vegetation and associated economics

A popular definition of natural capital is that of Daly (1994) in which he states that “*natural capital (is) the stock which produces the flux of natural resources: the population of fishes in the ocean generating the flux of fish going to the market; the forest gathering timber; the oil reserves whose exploitation provide petrol*”. Daly is correct in regarding natural capital as those features of the environment that support human life, but his definition can be augmented to include ecological systems such as photosynthesis processes, the atmosphere and water cycles (Chiesura & De Groot 2003; Blignaut & De Wit 2004), without which the stocks to which Daly refers cannot be maintained.

Ecosystem goods and services are particular features of natural capital on which humans rely for survival. Consumption of ecosystem goods and services below or equal to a level of sustainable yield per definition implies stable supply. The supply of many ecosystem goods and services has come under pressure as a result of imprudent use and the demands of a growing global population (Arrow et al. 1995). Ecosystem goods and services are often characterised by open access and lack of property rights, and individuals are reluctant to invest in goods or services from which other users cannot be barred. This results in an absence of markets and leads to pricing which is often below the actual value of the good or service. Markets aid efficient allocation of resources and a lack of markets encourage

consumption of ecosystem goods and services beyond a level of sustainable yield. Ecosystem goods and services are increasingly placed under pressure as natural resources are exploited commercially. Deforestation provides an example: as the demand for timber and fuel wood increases, carbon sequestration as one of the ecosystem services provided by trees is affected with detrimental effects to the climate of the planet.

Additional to consumption above sustainable yield, invasive vegetation has been identified as a threat to the sustainable production of ecosystem goods and services. Initial research on the subject was driven by the impact of alien vegetation on agriculture, but more recently loss in biodiversity and the disturbance of ecosystem services such as water supply have attracted the attention of researchers (Le Maitre et al. 1996; Le Maitre, Versveld & Chapman 2000; Wilcove et al. 1998; Mooney & Cleland 2001; Carey 2007).

Biological invasion results from economic activity (Perrings 2001), through the deliberate introduction of alien species or their unintentional displacement by the movement of goods and people (Perrings et al. 2002). Global trade has been closely linked to the increase in the occurrence of invasive vegetation (Turpie 2004; Levine and D'Antonio 2003), and Bright (1999) has gone so far as to label invasive vegetation as a disease caused by globalisation.

The spread of invasive vegetation can be *mitigated* through passive or active restoration practices. Passive restoration refers to removing invasive vegetation and leaving the veld to fend for itself thereafter, while active restoration entails first hand participation in the recovery of the area. Successful restoration often requires active participation, for instance in cases where indigenous vegetation types are unable to outcompete re-sprouting alien plants, or where they need to be reintroduced to the area. Restoration is always a time consuming and costly exercise.

Evaluating whether alien removal and natural capital restoration is a value adding endeavour depends on the direct financial costs and benefits incurred by the investing agent, as well as on costs and benefits external to the agent. This requires a valuation of the ecosystem goods and services affected by alien vegetation best described as an attempt to determine the relationship between the underlying ecosystem and the overarching economy (Aylward & Barbier 1992). Because markets for ecosystem goods and services are often absent, there is seldom an efficient price whereby changes in the quantity or quality of ecosystem goods and services can be valued. When this is the case or when prices are affected by market distortions, *shadow prices* or direct or indirect proxies are used to estimate the value of an

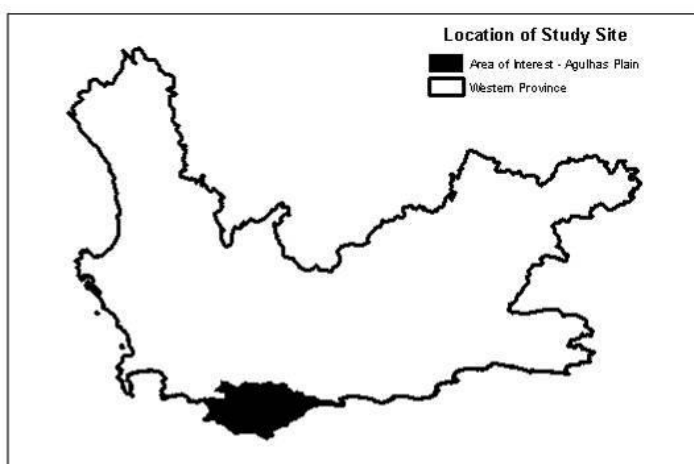
ecosystem goods and services (Blignaut & Lumby 2004). A shadow price is “*the opportunity cost of products and services when the market price ... does not reflect these costs in full*” (Mullins et al. 2007). Where a market for ecosystem goods and services *does* exist but the mechanism responsible for setting the price is influenced by distortive taxes, subsidies, quotas or tariffs, the price will not reflect the efficient price and will need to be adjusted for these distortions.

In order to determine and compare the desirability of alternative project outcomes it is necessary to assess the per annum benefit and cost streams that will occur if an alien clearing and restoration project is implemented. Cost-benefit analyses can be applied to this end.

3. Study area: The Agulhas Plain, Western Cape

The Cape Floristic Region (CFR) spans approximately 94 000 km² across the southern tip of the African continent. It is home to such a variety of fynbos species that it has been classified as “one of the hottest” global biodiversity hotspots (Myers 1990). 68.2% of the approximately 8 500 fynbos species are endemic, causing Cape Flora to be acclaimed one of the six plant kingdoms of the world (Higgins et al. 1997). The Agulhas Plain is a low coastal region and comprises 2 160 km² within the CFR (see figure 1). It is home to fynbos and renosterveld vegetation types that thrive in the Mediterranean climate of the area (Cowling & Holmes 1992). Fynbos is fire prone, shrubland vegetation found on the nutrient poor soils of the mountain areas (Rouget 2003; Cowling 1992).

Figure 1: Location of the Agulhas Plain, Western Cape (Nowell 2010)



The use-value of the fynbos biome is made up of a supply of ecosystem goods and services including fynbos flowers and other fynbos products, marine resource harvesting, ecotourism,

water cycling from mountain catchments, etc. Turpie, Heydenrych and Lamberth (2003) estimate the value of the terrestrial and marine biodiversity of the CFR to amount to R10 000 million per annum, approximately 10% of the gross geographic product of the Western Cape Province in which it is situated.

The fynbos biome is the most heavily invaded biome in South Africa (Richardson et al. 1997; Henderson 2007). Cole et al. (2000) estimate that almost 40% of the natural vegetation in the Agulhas Plain has been invaded by alien species. The high degree of plant endemism, the limited water supply and the prevalence of invasive species render the Plain a priority area for restoration.

The Agulhas Plain is covered by twelve predominant vegetation types, all of which are invaded to a greater or lesser extent. These are Strandveld, Southern coastal, seasonal wetlands, sand dune, rivers and floodplains, Restioid fynbos, Mountain fynbos, Lime fynbos, estuaries, Ericaceous, Elim fynbos and Afromontane fynbos. As expected, invasive vegetation has occupied natural veld to a greater extent than veld under different land use.

Invasive vegetation can affect the life history of fynbos by preventing it from reaching different growth phases or by causing changes in the cycles and intensity of fires. Common invaders include *Acacia*, *Eucalyptus*, *Pinus*, *Hakea* and *Leptospermum* spp. (Higgins et al. 1999; van Wilgen et al. 2001). This study considers the three most dominant invasive tree species on the Plain: *Acacia*, *Eucalyptus* and *Pinus*. *Acacia* trees were initially planted as dune stabilisers and to provide protection, while *Eucalyptus* was introduced in the 1940s with the purpose of providing timber. *Pinus* became established through plantations and was also planted to provide tree cover in the shrubland vegetation of the Western Cape (Richardson 1998). The lack of foresight with which alien species are sometimes introduced is evident in a letter to the Agricultural Journal of 1908, advocating the beneficial properties of the Port Jackson Willow (*Acacia salinga*) (Benke 1908). See insert below.

Port Jackson Willow as a Sluit Stopper.

To the Editor, AGRICULTURAL JOURNAL.

SIR,—Be so kind as to publish these few lines in your widely read paper about the Port Jackson tree. If you have seed of this tree and throw a handful of it at the upper end of the “sluit,” your “sluit” is largely changed in a few years’ time. It is a quick grower, and has hard wood, a pole as good as olive wood. Although there does not grow a single tree at the upper end of the “sluit,” it will give sufficient seed in a few years’ time to have the “sluit” filled by trees. No animal eats it, and it does not wither. I put the seed in the walls of sluits and on heights. It is a fine tree for protection, and strong. I can receive orders for seed in November, 1s. 6d. per lb., without postage; no order without money. The seed should be placed in warm water, when it will soon germinate. Once germinated, it goes on well. The seed is ripe from December and January.—Yours, etc.,

J. D. BENCKE.

P.O. Ruitersbosch, Mossel Bay.

Most of the land on the Agulhas Plain is under private ownership and used for commercial agricultural purposes (Heydenrych 1999). When land-use is categorised according to activities from which more than 50% of farm income is derived, livestock farming covers almost half of the area followed by fynbos flower farms (28%). Mixed farming and conservation takes place on the remaining areas. Flower farms prove more productive per hectare than livestock grazing (Heydenrych 1999). Agriculture related work provides 10.5% of employment in the area (Municipal Demarcation Board 2006; own calculations).

Flower farms on the Agulhas Plain can be divided into those that rely on harvesting flowers from the wild, those that focus on flower cultivation, and a final small group of farms on which a combination of the two methods are employed. The market composition of wild and cultivated flowers changed dramatically as flower farming became a profitable enterprise. The majority of flowers are now cultivated (Conradie and Knoesen 2009). The fynbos flower industry supports a number of spin-off industries of which the value is not reflected in the market for flowers. These include Honeybush tea, thatching reed, honey production and beekeeping. Non-landowners draw benefit from sour fig harvesting, beekeeping and firewood provided by fynbos as well as by invasive vegetation.

Individuals will carry the burden of restoration either directly or indirectly and will change their behaviour as a result of changes in the supply of ecosystem goods and services. A large share of the population on the Agulhas Plain live in rural areas and are dependent on alien vegetation as a source of energy for heating and cooking. They will become poorer in real terms if this source of fuel is removed.

2. Method and approach

Economically efficient outcomes occur when the marginal benefits of a project or service outweigh the marginal costs thereof (Pearce 1998). In the context of alien removal and natural capital restoration, efficiency implies that the value of ecosystem goods and services replaced by restoration equals the costs incurred in doing so. Environmental change is neither smooth nor predictable, but cost-benefit analysis methodology provides an instrument that can be used to assess the efficiency of alien removal and restoration under varying assumptions.

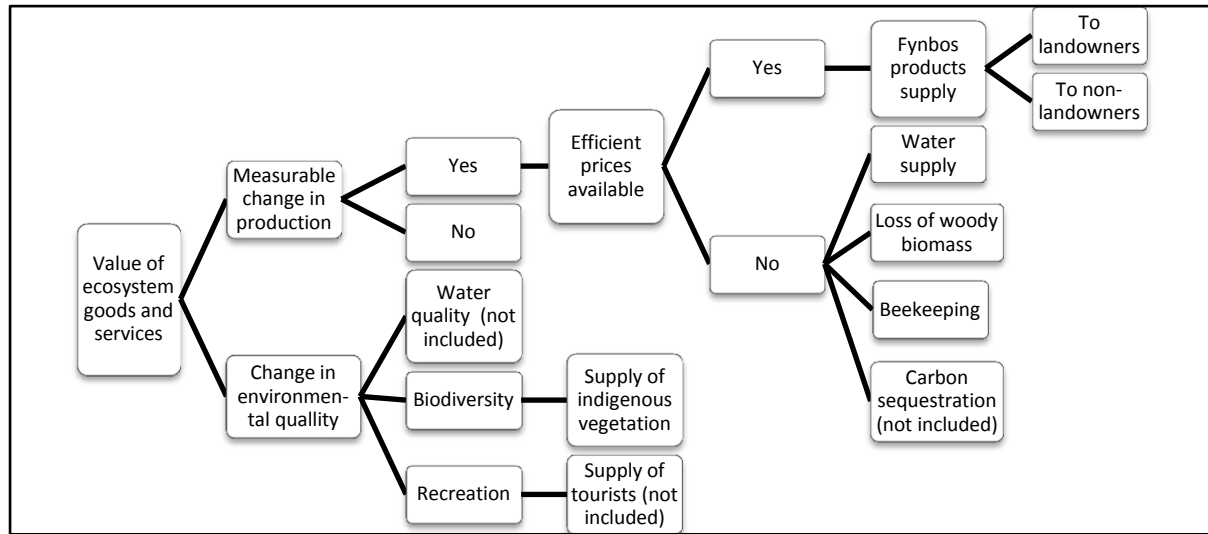
The project adopts a timeframe of twenty years, based on the assumption that this allows sufficient time for change within the ecosystem to occur, while simultaneously providing a realistic timeframe under which landowners can plan and be held accountable for land use.

This study assumes post-restoration land-use activities that will ensure a stable supply of ecosystem goods and services through the sustainable harvesting of wildflowers. Stable supply over a long period of time suggests that a low yet positive discount rate should be assumed. Through increasing the future value of ecosystem goods and services a negative discount rate would inappropriately imply scarcity, while a discount rate of zero would imply no value loss and an overly confident commitment to future generations. The results are tested for the impact of varying positive discount rates as derived from the literature, but a market related rate is expected in accordance with the investment of private funds by the individuals involved.

Ecosystem goods and services included in the model are selected according to the expected influence of alien removal and restoration and the accuracy with which changes can be valued. These include additional net income from wildflowers and fynbos products, the increase in water supply resulting from reduced evapotranspiration, beekeeping, and the opportunity cost of woody biomass. Figure 2 provides a schematic representation of the ecosystem goods and services affected by alien removal and restoration.

Figure 1: Ecosystem goods and services affected by alien removal and restoration

(Adapted from Blignaut & Lumby 2004)



Changes in ecotourism are not included in the model due to the supposition that additional fynbos vegetation will have a negligible impact on the number of visitors to the area. The net impact of alien removal and fynbos restoration on carbon sequestration is also disregarded owing to lack of accurate data and the assumption that the change in carbon sequestered will be insufficient to allow for cost-effective carbon trading. Finally, the change in water quality is not included due to an absence of hydrological data. The water released is assumed to be of adequate quality for consumption.

2.1. Model

The annual value of alien clearing and restoration in year t (V_t) is a function of net income to landowners (L_t) and non-landowners (N_t), water supply (W_t), net impact on beekeeping (B_t), the opportunity cost of woody biomass (M_t), and clearing and restoration costs (C_t). In turn, net income to landowners and non-landowners is a function of fynbos vegetation type (f); water supply is a function of yield (y) and the composition of alien trees (a); net impact on beekeeping is a function of fynbos vegetation type and alien trees; and the opportunity cost of biomass and clearing and restoration costs are a function of the composition of alien trees. The systems value of alien removal and fynbos restoration for year t is illustrated below:

$$V_t = f(L_t(f), N_t(f), W_t(y, a), B_t(v, a), M_t(a), C_t(a)) \quad (1)$$

Restoration is assumed to allow sustainable wildflower harvesting from n fynbos vegetation types on all invaded land except land that has not been transformed by agriculture or development. Such land may be classified as protected or public areas from which no harvesting is allowed. The study assumes that clusters of restored fynbos replace invasive vegetation on veld that is under different land use, such as marginal land on agricultural areas from which farmers receive no rent due to invasion.

The value of wildflowers and fynbos products is estimated using net income at farm gate for each fynbos vegetation type (Turpie et al. 2002). Farmers in South Africa are not supported by formal subsidies. It is consequently assumed that net income at farm gate provides an efficient price. Fynbos products such as thatching reed and Honeybush tea harvested by landowners are sold in formal markets and included in the estimates of net income per hectare of fynbos vegetation. It is assumed that income from wildflower and fynbos product harvests will be comparable to that of harvests from pristine veld ten years after restoration. Mountain fynbos provides the highest net income per hectare and Elim fynbos the lowest. Annual net income to landowners equals the product of net income derived from vegetation type (δ_s) and the condensed hectares of transformed land invaded by alien species (ha_s^n):

$$L_t = \sum_{s=1}^n (\delta_s ha_s^n) \quad (2)$$

Non-landowners also obtain benefits from fynbos products, in particular by harvesting sourfigs from Dune fynbos to produce sourfig jam. Most sourfig harvesting takes place without the consent of landowners and does not necessarily heed to public and private boundaries. The study assumes that sourfig harvesting could take place on all restored areas of Dune fynbos. Heydenrych (1999) estimates net income of R3.75/kg of sourfigs (1997 prices). Annual net income to non-landowners equals the product of net income from harvests per vegetation type (θ_s) and total hectares of corresponding condensed invasion (ha_s).

$$N_t = \sum_{s=1}^n (\theta_s ha_s) \quad (3)$$

Although fynbos vegetation holds foraging value for bees, *Eucalyptus* spp. provides pollination services that will be foregone if the trees are cleared. Foraging and pollination services are valued according to the net income at farm gate received from honey production and beekeeping. Fynbos vegetation types vary with regard to the foraging benefits they provide, resulting in varying net incomes per hectare. The difference between the benefits derived from fynbos (x_s) and *Eucalyptus* spp. (E) is regarded as the impact of alien clearing

and restoration on beekeeping and honey production as an ecosystem service. If $B_t > 0$ clearing and restoration will add value to beekeeping, but if $B_t < 0$ an opportunity cost is implied. Bees do not restrict their behaviour to farm boundaries and estimates are based on the total number of condensed invaded hectares on the Plain.

$$B_t = \sum_{s=1}^n (x_s h a_s) - E \quad (4)$$

A decrease in the incidence of invasive vegetation leads to a decrease in evapotranspiration and ultimately to an increase in the supply of groundwater and surface water. Vegetation interferes with aquifers by making demands on groundwater and through precipitation decreases the amount of rainwater available to replenish the water table (Le Maitre, Scott & Colvin 1999). In the Western Cape, alien species account for using 15.82% of the mean annual water runoff (Le Maitre, Versveld and Chapman 2000).

Alien clearing and restoration on the Agulhas Plain will release an estimate of 82 264 MI water into the hydrological system (Nowell, 2010). The entire amount will not be made available as yield, but the study assumes a demand for the yield that is made available. The value of additional water released through alien clearing (W_t) is determined by the value estimate (φ) per unit of water and the proportion of additional water converted to yield (y). The analysis tests the efficiency of the project based on different assumptions about average water value and yield.

$$W_t = \varphi y (82\,264 \text{ MI}) \quad (5)$$

Invasive plants provide many rural households on the Agulhas Plain with a source of fuel for heating and cooking. Invasion by *Acacia Cyclops* (also known as Rooikrans) in Strandveld fynbos and Lime fynbos provides the most prevalent source of firewood (Turpie, Heydenrych & Lamberth 2003). Based on the assumption that farmers receive no rent from invaded land, an opportunity cost associated with the removal of invasive vegetation befalls these rural inhabitants. The opportunity cost is calculated as the loss in average net income obtained by harvesting firewood from densely invaded fynbos vegetation types (π_s).

$$M_t = \sum_{s=1}^n (\pi_s h a_s) \quad (6)$$

Direct project costs incurred by alien clearing and natural capital restoration is composed of the cost of initial clearing (I), restoration treatment through sowing indigenous fynbos species (R), and the cost of five follow-up clearings (F_m). It is assumed that initial clearing

and restoration treatment is completed during the first year, and that the follow-up clearings are completed in five subsequent consecutive years.

The model is based on cost estimates of high density invasion in accordance with the number of condensed invaded hectares. A hypothetical cost per hectare is calculated based on the fraction of total invasion (a_j) of each invasive species included in the study. The hypothetical cost per hectare is multiplied by the total number of condensed hectares invaded.

$$C_0 = ha \sum_{j=1}^3 [a_j (I + R)] \quad (7.1)$$

$$C_t = ha \sum_{j=1}^3 (a_j F_m) \quad (7.2)$$

where $\sum_{j=1}^3 a_j = 1$ and $m = t \in N_1 \{1 \dots 5\}$.

The impact of clearing and restoration can be divided between private and social benefits and costs. Harvests of wildflowers and other fynbos products will translate into private pecuniary benefits, while society at large will benefit from an increase in water supply. Similarly, costs associated with clearing and restoration and losses to beekeeping will pertain to individual landowners, while the loss of woody biomass as a source of energy will affect broader society.

The financial net present value (NPV^f) includes income to landowners and non-landowners from fynbos flowers and other fynbos products, net impact of beekeeping and honey production, and clearing and restoration costs. A discount rate of r is assumed:

$$NPV^f = \sum_{t=0}^{20} \frac{(L_{t+10} + N_{t+10} + B_{t+1} - C_{t+1})}{(1+r)^t} - C_0 \quad (8.1)$$

The economic net present value (NPV^e) incorporates the impact of alien removal and restoration on beekeeping and honey production, water, and the opportunity cost of firewood into the analysis:

$$NPV^e = \sum_{t=0}^{20} \frac{(L_{t+10} + N_{t+10} + B_{t+1} - M_{t+1} + W_{t+1} - C_{t+1})}{(1+r)^t} - C_0 \quad (8.2)$$

To obtain estimates of water yield (y) and water value (φ) scenarios that would justify alien clearing and restoration, equation (9) needs to hold. At these estimates the discounted benefits and costs on the left hand side of equation (9) is equal to the discounted value of

water made available through clearing and restoration, as illustrated on the right side of the equation.

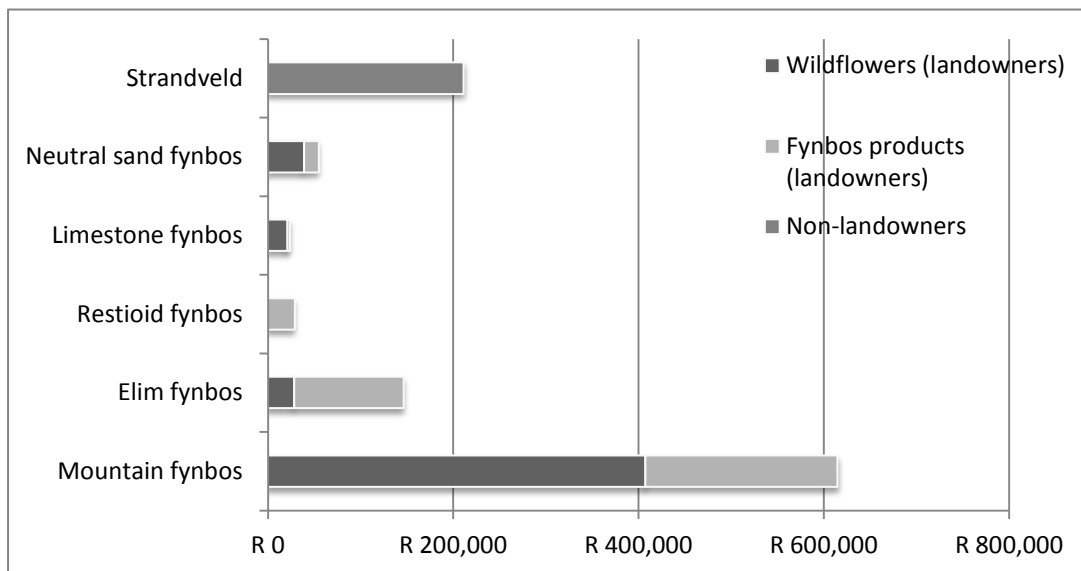
$$C_0 - \sum_{t=0}^{20} \frac{L_{t+10} + N_{t+10} + B_{t+1} - M_{t+1} - C_{t+1}}{(1+r)^t} = \sum_{t=0}^{20} \frac{y\varphi(82\,264\text{Ml})}{(1+r)^t} \quad (9)$$

3. Results

3.1. Ecosystem goods and services

Figure 3 illustrates net income derived from wildflowers and other fynbos products harvested from restored areas for the whole of the Agulhas Plain. Total additional net income from wildflowers and other fynbos products amount to R1.08 million.

Figure 2: Total private income from harvesting

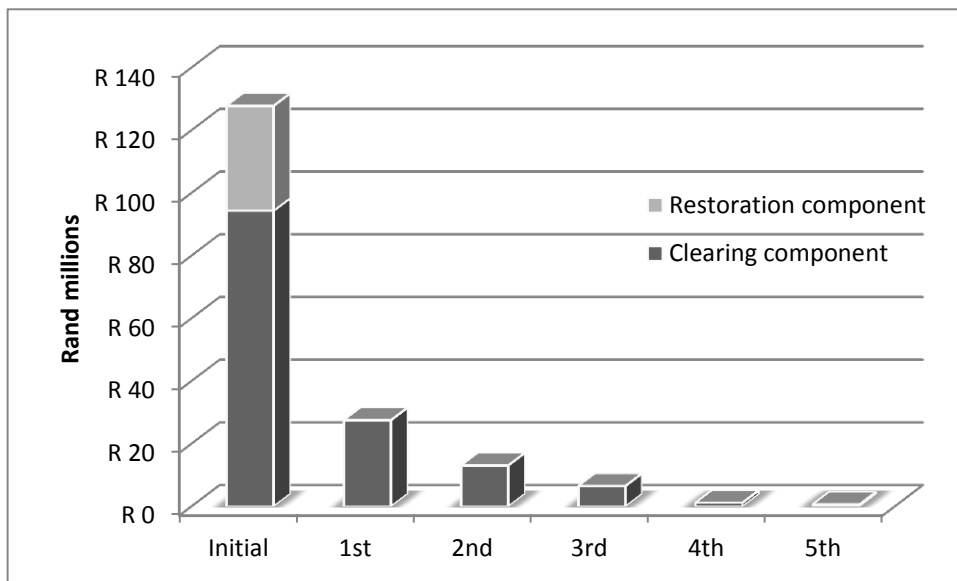


The benefits that *Eucalyptus* spp. provide for beekeeping through pollination services are higher than the foraging value provided by indigenous fynbos vegetation. An associated opportunity cost of R1.19 million for beekeeping will occur on the whole Plain if *Eucalyptus* spp. are removed.

The opportunity cost of fuelwood lost from heavily invested Lime and Strandveld fynbos amounts to R3.95 million.

Total clearing and restoration costs amount to R176 million as illustrated in figure 4. The initial costs incurred in clearing and restoration account for 72% of total direct costs.

Figure 3: Clearing and restoration cost for the entire Agulhas Plain



3.2. Cost-benefit analyses

The financial net present value of alien clearing and restoration on the Agulhas Plain indicates that clearing and restoration costs are too great to allow income from wildflowers and fynbos products to justify investment, even when the opportunity cost associated with beekeeping is excluded (as illustrated in figure 5). The annual income obtained from year ten onward does not compensate for the high costs incurred during the first five years. Private financial benefits can consequently not be used as an argument for clearing. Sensitivity tests assuming a 25% increase in income and a 25% decrease in costs provide a somewhat improved outcome, but still do not render clearing and restoration efficient.

Figure 4: Private NPV per annum over 20 years

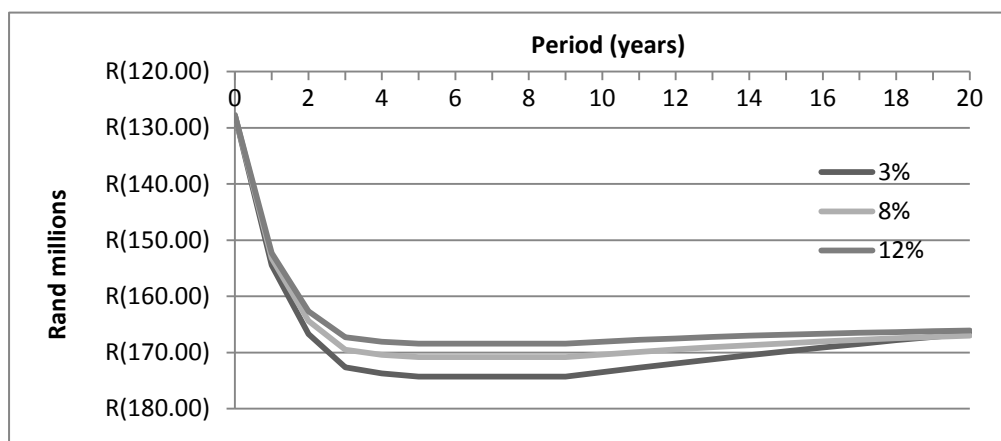


Table 1 compares the magnitude of different cost and benefit components. The results suggest that the water released through clearing and restoration needs to be a valued commodity in order to ensure an efficient outcome.

Table 1 Discounted total costs and benefits; Rand millions

Benefit/ Cost component	Annual average over 20 year period	Discount value		
		3%	8%	12%
Benefits from harvesting	R 0.54	R 9.22	R 7.25	R 6.11
Direct project costs	(R 8.83)	(R 174.28)	(R 170.85)	(R 168.43)
Opportunity cost of woody biomass	(R 3.85)	(R 57.34)	(R 37.84)	(R 28.79)
Opportunity cost of beekeeping and honey production	(R 1.19)	(R 17.70)	(R 11.68)	(R 8.89)

The Cape Agulhas Local Municipality, in which the Agulhas Plain is primarily located, purchases excess raw water from the Klein Sanddrift dam at a rate of 12.5c/kl during March to April, and 20c/kl from September to February. Total allocation from the dam amounts to 515 Ml per annum (Cape Agulhas Municipality 2009), equal to 0.6% of the water that can be made available through alien clearing and restoration. Assuming that the cost of raw water from the Sanddrift dam is representative of the value of raw water for the entire Plain, the internal rate of return (IRR) under an assumption of 100% yield is 0.8%. This suggests that raw water is not valued highly enough to justify restoration under the discount rates assumed in this study. However, the required average value of water under different discounts rates and yields can be compared with other estimates of water value in comparable areas to judge the likelihood that the actual average value of water supersedes the value required to render restoration efficient, as listed in Table 2.

Table 2: Required average value per kilolitre of water

Discount rate	10% yield	25% yield	50% yield	100% yield
3%	196c	78c	39c	19c
8%	263c	105c	52c	26c
12%	325c	130c	65c	32c

In South Africa, the National Resource Accounts are increasingly regarded as one of the more accurate means of calculating the average value of water (Turpie 2004). These accounts provide the average value of water for every unit of use per economic sector or industry within the Water Management Areas. Unless specific studies have been carried out marginal

values of water are generally unknown. Although this study assumes that the average values estimated by the Resource Accounts provide the best available estimates, it should be noted that the Agulhas Plain only comprises a small section of the Breede Water Management Area and that water value estimates may differ from the rest of the area.

Table 3: Average water values per water use in the Breede Water Management Area (WMA)

Water use in the Breede WMA	Average value/kl
Irrigation water (non-purchased)	460c
Dryland crops	60c
Municipal water sold	471c

Assuming that the average values for water use in the Breede Water Management Area also holds for the Agulhas Plain, alien clearing and restoration at water yields of 50% and above should translate into value-adding outcomes irrespective of the type of water use. However, under low levels of yield the required value of water is higher than the average value that water contributes towards dryland crop production. Due to its low-lying nature the latter accounts for a large proportion of water use on the Agulhas Plain. This suggests that the cost of making water available through alien clearing might be too high relative to the average use values of water, and that further investigation into the actual value of water in the area is needed before recommendations can be made.

Burger et al. (1995) estimate the average capital and operational costs for water supply schemes in the Western Cape at R1.59/kl (2008 value), providing an alternative preliminary assessment. If this is assumed to be an accurate estimate of the replacement cost of water in the Agulhas Plain, our results suggest that (irrespective of the discount rate assumed) at a water yield of more than 25% alien clearing and restoration will provide a lower-cost alternative for obtaining water supply.

The study advocates that, depending on the water yield, the cost of making water available through alien removal and restoration on the Agulhas Plain is likely to be lower than the average use-value of water in the area or than costs associated with alternative supply schemes. As a preliminary assessment this study suggests that alien removal and restoration can be expected to add value to the Agulhas Plain.

4. Conclusions and recommendations

Growing human societies and impending climate change is threatening the sustainable supply of ecosystem goods and services. Invasive vegetation poses an additional threat to the goods and services supplied by indigenous biodiversity and ecosystems. This study presented the hypothesis that alien removal and natural capital restoration may add value to invaded areas through recovering the ecosystem goods and services supplied by indigenous vegetation. The study drew from ecological, hydrological and economic observations to assess the net impact that alien removal and restoration could have in the Agulhas Plain. A cost-benefit analysis were conducted to assess whether the value of recovered ecosystem goods and services outweigh the costs associated with alien clearing and restoration. The impact that using different discount factors and unit values for valuing ecosystem goods and services has on the results was tested to ensure robust conclusions and recommendations.

When the potential private financial benefits obtained from clearing and restoration are compared with the costs incurred, the income obtained from harvesting wildflowers and fynbos products fails to compensate the costs of clearing and restoration within the specified period of 20 years. The economic analysis incorporates the loss of woody biomass and net impact of beekeeping into the results and uses the model to calculate the average unit value of water required to justify clearing and restoration. Alien clearing cannot be justified in the absence of water as a valued commodity. The required average value of water ranges between R0.19 and R3.25, depending on the yield and discount rate assumed. When compared to the average value of water within the Breede Water Management Area, as well as to the average capital and operational costs associated with water supply schemes in the Western Cape, the study suggests that making water available through alien clearing and restoration is an efficient alternative to increasing water supply.

The results indicate that alien clearing and restoration is likely to add value to the Agulhas Plain. However, further studies regarding where water will be made available and what yield can be expected, as well as a study focused on calculating the marginal value of water in the area, would add value to the results. These uncertainties need to be addressed before final recommendations for clearing and restoration can be made.

Alien removal and sustainable farming practices can be regarded as activities for which users of ecosystem services may be willing to pay. On the Agulhas Plain, users of ecosystem services that are measurably improved by active restoration include wildflowers producers

and water consumers. The market for sustainably harvested wildflowers could encourage landowners to restore invaded land and adopt sustainable land-use practices, but benefits from alternative land-use such as flower cultivation often outweigh the benefits from wildflower harvesting (Leiman 1996). Ecosystem services can be bundled to attain a value that is high enough to encourage alien clearing and restoration, as indicated by the economic analysis. For instance, a municipality can augment farmers' income from sustainable wildflower harvesting by offering landowners a payment to restore their land. This simultaneously provides the municipality with a lower cost alternative of attaining water supply than through investment in new supply. The payment must compensate the gap between direct project costs and improved land use. In this way farming income can be augmented to the extent that alien clearing and restoration becomes feasible. Alternatively, municipalities can decide to clear the land themselves in return for a proportion of the water made available. Finally, payments need to be designed in a way that ensures that landowners will continue to keep their land free of invasive vegetation after clearing. Designing such a system for the payment of ecosystem services requires careful consideration. Accurate estimates about the water yield made available through restoration are needed, and will vary between locations and by density and type of invasion. The location of the yield that is made available also needs to be specified carefully.

Alien clearing and natural capital restoration on the Agulhas Plain is likely to add value to the area, but is fully reliant on the value of additional water supply. Water shortages in South Africa are expected to increase as a result of increasing demand and climatic changes, suggesting that the value of water will increase correspondingly. With the rising economic value of water, alien clearing and restoration of ecosystems will increasingly become an economically viable land and ecosystems management strategy.

5. References

- Arrow, K., R. Costanza, P. Dasgupta, C. Folke, C.S. Holling, B. Jansson, S. Levin, K. Maler, C. Perrings & D. Pimentel (1995). Economic growth, carrying capacity and the environment. *Ecological Economics*, 15. 91-95.
- Aylward, B. & E.B. Barbier (1992). Valuing environmental functions in developing countries. *Biodiversity and Conservation*, 1. 34-50.
- Bencke, J.D. (1908). Port Jackson Willow as a Sluit Stopper. *The Agricultural Journal*. 32. 652.
- Blignaut, J. N. & A. Lumby (2004). Economic valuation. In: J. Blignaut, M. de Wit (Eds.) *Sustainable Options*. Cape Town: UCT Press. Chapter 4.
- Bright, C (1999). Invasive species: Pathogens of globalization. *Foreign Policy*, 116. 50-64.
- Bromley, D.W (1982). Land and water problems: an institutional perspective. *American Journal of Agricultural Economics*, 64(5). 834-844.
- Butchart, S.H.M., J. Chanson & M. Hoffmann (2009). *Red List Indices for invasive species' impacts. Technical Report for the Global Invasive Species Programme*. Birdlife International, Cambridge and IUCN, Washington DC, USA.
- Cape Agulhas Municipality (2009). *Cape Agulhas Municipality Water Services Development Plan 2007/8-2011/12*. 1-170.
- Carey, A. (2007). Restoring and maintaining natural capital in the Pacific Northwest, USA. In J. Aronson, S.J. Milton & J.N. Blignaut (eds.) *Restoring Natural Capital: Science, Business and Practice*. Washington D.C.: Island Press. Chapter 11.
- Chiesura, A. & R. De Groot (2003). Critical natural capital: a socio-cultural perspective. *Ecological Economics*. 44. 219-231.
- Cole, N. S., A.T. Lombard, R.M. Cowling, D. Euston-Brown, D.M. Richardson, & C.E. Hejnis (2000). Framework for a conservation plan for the Agulhas Plain, Cape Floristic Region, South Africa. *Institute for Plant Conservation Report*. 00/01. University of Cape Town.

- Conradie, B. & H. Knoesen (2009). A survey of cultivation and wildflower harvesting of fynbos flowers in South Africa. *PPSA Nuusbrieff*. July.
- Costanza, R., R. D'arce, R. De Groot, S. Fraser, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton, P. & M. Van Den Belt (1997). The value of the world's ecosystem services and natural capital. *Nature*. 387. 253-260.
- Cowling, R.M. & P.M. Holmes (1992). Flora and vegetation. In R.M. Cowling (ed.) *The Ecology of Fynbos: Nutrients, Fire and Diversity*. Cape Town: Oxford University Press. 23-61.
- Daly, H. (1994). Operationalising sustainable development by investing in natural capital. In: A. M. Jansson, M. Hammer, C. Folke, R. Costanza (Eds.) *Investing in natural capital: the ecological economics approach to sustainability*. Washington DC: Island Press. 22-27.
- De Wit, M.P., D.J. Crookes, B.W. & Van Wilgen (2001). Conflicts of interest in environmental management: estimating the costs and benefits of a tree invasion. *Biological Invasions*. 3. 167-178.
- Global Invasive Species Programme (2009). *Global Invasive Species Programme Annual Report*. Available online: www.gisp.org.
- Groves, R.H. (1989). Ecological control of invasive terrestrial plants. In J.A. Drake *et al.* (eds.) *Biological Invasions: a Global Perspective*. John Wiley & Sons Ltd. Chapter 20.
- Henderson, L. (2007). Invasive, naturalized and casual alien plants in southern Africa: a summary based on the Southern African Plant Invaders Atlas (SAPIA). *Bothalia*, 37(2). 215-248.
- Heydenrych, B.J. (1999). Historical background of land use on the Agulhas Plain. *Hard Copy: Flower Valley Farm*.
- Higgins, S. I., D.M. Richardson, R.M. Cowling & T.H. Trinder-Smith (1999). Predicting the landscape-scale distribution of alien plants and their threat to plant diversity. *Conservation Biology*. 13(2). 303-313.
- Higgins, S. I., J.K. Turpie, R. Costanza, R.M. Cowling, D.C. Le Maitre, C. Marais, C. & G.F. Midgley (1997). An ecological economic simulation model of mountain fynbos ecosystems: Dynamics, valuation and management. *Ecological Economics*. 22. 155-169.

Koenig, R. (2009). Unleashing an army to repair alien-ravaged ecosystems. *Science*, 325. July. 562-563.

Le Maitre, D. C., D.F. Scott & C. Colvin (1999). A review of interaction between vegetation and groundwater. *Water SA*. 25(2). 137-152.

Le Maitre, D. C., B.W. Van Wilgen, R.A. Chapman, & D.H. Mckelly (1996). Invasive plants and water resources in the Western Cape Province: modeling the consequences of a lack of management. *Journal of Applied Ecology*. 33(1). 161-172.

Le Maitre, D.C., D.B. Versfeld & R.A. Chapman (2000). The impact of alien plants on surface water resources in South Africa: a preliminary assessment. *Water SA*, 26(3). July. 397-408.

Leiman, A. (1996). The economics of conserving land. In B.J. Heydenrych, C.J. Burgers & J.H. Oberholzer (Eds.) *The sustainable use of the Western Cape Lowlands: can this be achieved?* FCC Report 96/2. Botanical Society of South Africa, Kirstenbosch.

Levine, J.M. & C.M. D'Antonio (2003). Forecasting biological invasions with increasing international trade. *Conservation Biology*, 17(1). 322-326.

Loomis, J., P. Kent, L. Strange, K. Fraser & A. Covich (2000). Measuring the total economics value of restoring ecosystem services in an impaired river basin: results from a contingent valuation survey. *Ecological Economics*. 33. 103-117.

Millennium Ecosystem Assessment (2005). *Ecosystems and human well-being: synthesis*. Washington: Island Press.

Mooney, H.A. & E.E. Cleland (2001). The evolutionary impact of invasive species. *PNAS*, 98(10). 5446-5451.

Mullins, D., D.D. Mosaka, A.B. Green, R. Downing & P.G. Mapekula (2007). A Manual for Cost Benefit Analysis in South Africa with specific reference to water resource development. *WRC Report No. TT 305/07*. Second Edition.

Municipal Demarcation Board South Africa (2006). *Municipal Profiles*. Available online: <http://www.demarcation.org.za/municprofileonline/websiterouter.aspx?http://www.demarcation.org.za/municprofileonline/index.aspx>. Accessed September 14, 2009.

- Myers, N. (1990). The biodiversity challenge: expanded hotspot analysis. *The Environmentalist*. 10. 243-255.
- Nowell, M. (2010). Determining the hydrological benefits of clearing invasive alien plants on the Agulhas Plain. *MSc Dissertation, Stellenbosch University*.
- Pearce, D.W. (1998). Cost benefit analysis and environmental policy. *Oxford Review of Economic Policy*. 14(4).
- Perrings, C. (2001). The economics of biological invasions. *Land Use and Water Resources Research*, 1(3). 1-9.
- Perrings, C., H.A. Mooney & M.H. Williamson (2010). The problem of biological invasion In C Perrings, H.A. Mooney & M.H. Williamson (eds.) *Bioinvasions and Globalization: ecology, economics, management and policy*. New York: Oxford University Press.
- Perrings, C., M. Williamson, E.B. Barbier, D. Delfino, D. Silvana, J. Shogren, P. Simmons, & A. Watkinson (2002). Biological invasion risks and the public good: an economic perspective. *Conservation Ecology*. 6(1).
- Rees, W.E., J. Farley, E. Vesely & R. De Groot (2007). Valuing natural capital and the costs and benefits of restoration. In J. Aronson, S.J. Milton & J.N. Blignaut (eds.) *Restoring Natural Capital: Science, Business and Practice*. Washington D.C.: Island Press. Chapter 26.
- Richardson, D.M., I.A.W. Macdonald, J.H. Hoffman & L. Henderson (1997). Alien plant invasions. In R.M. Cowling, D.M. Richardson & S.M. Pearce (eds.) *Vegetation of Southern Africa*. Cambridge: Cambridge University Press. 535-570.
- Richardson, D.M. 1998. *Ecology and Biogeography of Pinus*. Cambridge University Press.
- Ricketts, T.H., G.C. Daily, P.R. Ehrlich & C.D. Michener (2004). Economic value of tropical forest to coffee production. *PNAS*. 101(34). 12579-12582.
- Rouget, M. (2003). Measuring conservation value at fine and broad scales: implications for a diverse and fragmented region, the Agulhas Plain. *Biological Conservation*. 112. 217-232.
- Thuiller, W., D.M. Richardson & G.F. Midgley (2007). Will climate change promote alien plant invasions? *Ecological Studies*. 193(4). 197-211.

Turpie, J. (2004). The role of resource economics in the control of invasive alien plants in South Africa. *South African Journal of Science*. 100. 87-93.

Turpie, J., B. Heydenrych & R. Hassan (2002). Fynbos: a preliminary assessment of its status and economic value. In R. Hassan (ed.) *Accounting for stock and flow values of woody land resources*. Chapter 4.

Turpie, J., B.J. Heydenrych & S.J. Lamberth (2003). Economic value of terrestrial and marine biodiversity in the Cape Floristic Region. *Biological Conservation*, 112(1-2). 233-251.

Van Wilgen, B.W., R.M. Cowling & C.J. Burgers (1996). Valuation of Ecosystem Services. *BioScience*. (46(3)). 184-189.

Van Wilgen, B. W., D.M. Richardson, D.C. Le Maitre, C. Marais & D. Magadlela (2001). The economic consequence of alien plant invasions: examples of impacts and approaches to sustainable management in South Africa. *Environment, Development and Sustainability*. 3. 145–168.