AN ASSESSMENT OF SELECTED NON-WATER BENEFITS OF THE WORKING FOR WATER PROGRAMME IN THE EASTERN AND SOUTHERN CAPE

BY

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EXECUTIVE SUMMARY

1.1 BACKGROUND TO, AND MOTIVATION FOR, THE STUDY

The Working for Water programme (WfW) is a public works programme designed to clear South Africa of water-consuming invasive alien tree and plants, and to replace them with low water-consuming indigenous species. This would prevent a loss of more than 4000 million cubic metres water per annum from the hydrological cycle (DWAF, 1998). The economic viability of the programme has been established in the Western Cape and Kwazulu-Natal (van Wilgen, Little, Chapman, Görgens, Willems and Marais, 1997; Gilham and Haynes, 2001), but questioned in the Eastern and Southern Cape (Hosking, du Preez, Campbell, Wooldridge and du Plessis, 2002). Hosking *et al.* (2002) investigated the economic case for the programme by performing a Cost Benefit Analysis (CBA), based on increased water yield and livestock potential, on six selected sites in the Eastern and Southern Cape, viz. Albany, Kat River, Pot River, Tsitsikamma, Kouga and Port Elizabeth Driftsands.

1.2 RESEARCH OBJECTIVE

This study commences with a critique of the work of Hosking *et al.* (2002). The Hosking *et al.* (2002) study was a very important one. Its use of actual cost data, scientific approach to the calculation of water benefits and innovative approaches taken to pricing the estimated water gains, are commendable. However, it also has a number of shortcomings, one of which was that only a part of the benefit stream was compared with the cost stream. Non-water benefits emanating from the programme were excluded. In the construction of a complete CBA, all the benefits and costs of the WfW need to be included, resulting in the need for quantification of the non-water benefits arising from WfW activities. As a start to filling the gap left by Hosking *et al.* (2002), three non-water benefits are identified, estimated and incorporated into a revised CBA. These benefits are: the gain in potentially productive land (grazing potential, livestock production and other agricultural practices), the reduction in direct fire-fighting costs due to the removal of alien trees, and the satisfaction of people's taste for indigenous vegetation, often referred to as the biodiversity and ecosystem resilience benefit. The valuation of these benefits is discussed further below.

1.3 METHODOLOGICAL APPROACH TO THE STUDY

The net agricultural benefit of the WfW programme at the six project sites was estimated by subtracting the agricultural potential with infestation, from the agricultural potential without infestation. All current farming practices, as well as other suitable land uses and their contribution to the area's overall productive capacity, were traced. The current ownership of cleared land played a role in the determination of future possible land uses (publicly owned land was usually earmarked for conservation, while privately owned land could be used for agricultural purposes). The agricultural practices included were categorised as livestock, horticulture and agronomy. Alternative land practices such as wildflower and honey bush harvesting, together with commercial afforestation, were also considered.

In the estimation of the net agricultural livestock benefit, the Department of Agriculture's Enterprise Budget (Dissemination of information, 2002) was used. Six factors were used to develop a model for the calculation of this benefit. These were: hectares available for land use, livestock categories, carrying capacity, level of alien infestation, hectares cleared, and margin above cost. In the calculation of a horticultural benefit, information from the Enterprise Budget (Dissemination of information, 2002), in conjunction with that from agricultural extension officers, the Department of Agriculture and the Döhne Agricultural Institute, was used to identify crops suited to the cleared areas. The number of hectares available for horticulture were adjusted for the share of that crop in total horticultural activity, and the share of horticulture in total farming activity. The assumption was made that crops prevalent in the region where the site was situated, would be appropriate for cleared areas. The horticultural benefit was deemed to be the per-hectare difference in the cost of clearing indigenous vegetation versus clearing alien vegetation in the preparation of crop cultivation.

Increased agricultural activity at cleared areas implies increased water use, which would impact on the water benefit calculated by Hosking *et al.* (2002). This introduces a complication to the analysis: although income can be generated through increased agricultural practices, these activities require water, and this had to be taken into account when the agricultural benefit was estimated. For this reason, the additional water use of each potentially productive land activity was subtracted, and a revised water benefit profile generated.

For the estimation of the fire benefit, the question was explored whether unplanned fires in alien vegetation translated into higher fire management costs during and after such fires. The direct fire-fighting costs at the six sites were assessed using a scenario with and without alien vegetation. The costs of fighting fires in pristine indigenous vegetation, such as grasslands and fynbos, were compared with fire-fighting costs in areas where alien infestation was present. The difference in these costs was deemed to constitute a benefit of the WfW programme. Fire-fighting costs were generated by reference to expert opinions. These expert opinions connected the cost of fires with the alien infestation level. This study did not estimate values for fire management taking place in the absence of fires, such as the creation and maintenance of firebreaks, but focused attention on direct fire-fighting costs only.

In this study, the biodiversity benefit of the WfW programme was deemed to be the increase in area covered by indigenous vegetation. The Contingent Valuation Method was used to determine people's willingness to contribute money towards the restoration of indigenous vegetation through continued WfW activities. These valuations were carried out as pilot studies. The questionnaires used were simplified, and the samples selected were very small.

Following the valuation of the benefits, distinct cost benefit profiles were constructed for each site. The costs used were those estimated by Hosking *et al.* (2002) adjusted to 2001 price levels. From these profiles net benefits were calculated, and discounted to present values, in order to establish a standard of comparison. Following the same procedure as Hosking *et al.* (2002), a social discount rate of 10.1% was used to derive present values. This rate reflected the opportunity cost of government and foreign funding for the WfW programme in South Africa. It was calculated as a weighted average annual rate from 1996 – 2000. The net present value (NPV), internal rate of return (IRR), and the benefit cost ratio (BCR) were then recalculated.

1.4 SUMMARY OF RESULTS OF THE STUDY

The results of the incorporation of non-water benefits are shown in the table below.

Summary of results

			Sites					
CBA	**CBA used**	**CBA criteria**	**PE Driftsands**	**Albany**	**Kat River**	**Pot River**	**Kouga**	**Tsitsikamma**
1	**Hosking *et al.* (2002)**	**NPV (R)**	-14 674 240	-15 232 753	-1 031 609	-1 446 624	-33 854 196	-31 757 404
		IRR (%)**	0	1.13	3.60	-3.14	7.25	5
		BCR	0	0.21	0.43	0.03	0.75	0.54
2	**Revised decision criteria including agric. and fire benefits**	**NPV (R)**	-15 407 671	-9 058 614	-1 109 142	-1 034 188	-35 950 176	-32 765 901
		IRR ** (%)	Undefined*	4	4	1	7	5
		BCR	0.01	0.56	0.42	0.21	0.74	0.55
3	**Revised decision criteria including agric., fire and biodiversity benefits**	**NPV (R)**	67 721 069	-3 046 798	16 767 386	16 137 316	-18 244 864	-26 875 031
		IRR (%)**	202	8	Undefined*	Undefined*	9	6
		BCR	5.37	0.85	9.82	13.3	0.74	0.63

* An undefined value indicates that no sign change occurs during the whole cost benefit stream. In these cases only benefits, and no costs, were identified (only positive values).
** The estimated social discount rate of 10.1% was used.

Where only the agricultural and fire benefit are incorporated (CBA 2), the NPVs are all negative, the IRR values are less than the social discount rate, and the BCRs are all less than one. When all the projects are combined into a regional cost benefit profile, the NPV is –R95 325 696, and the BCR is 0.62. It is deduced that the findings of Hosking *et al.* (2002) remain valid even if the agricultural and fire benefits are incorporated. As argued by Hosking *et al.* (2002), only at lower discount rates and with a lower cost structure would this result change – the Kouga and Tsitsikamma sites become worthwhile propositions for the WfW programme.

When the preference for indigenous vegetation as a non-water benefit was added to the cost benefit profile (CBA 3), the picture changed significantly. With the inclusion of this benefit, the PE Driftsands, Pot River and Kat River sites become efficient. The magnitude of the NPV values for these sites is high. Moreover, if the project is then redefined in terms of the sum of all the subprojects, the NPV comes to R52 459 077, and the BCR comes to 1.14. However, to this finding an important qualification must be added. The contingent valuations carried out were of a pilot study nature only.

1.5 CONCLUSIONS DRAWN FROM STUDY

Firstly, it is recommended that decisions about where the WfW programme will function should not be made on the basis of the water benefit alone. Secondly, it is suggested that proper in-depth contingent valuations be undertaken at the six WfW sites, in which a more rigorous questionnaire is adopted, and far more attention is given to the sampling process. Pilot studies suggest that the findings of this analysis may radically change the decision criteria.

Thirdly, the social aspects of the WfW programme should be evaluated, and incorporated into the Cost Benefit Analysis. In particular, the implications of poverty alleviation transfers made through the WfW programme need to be taken better account of. The WfW programme is undoubtedly a conduit for transfer payments that need to be made anyway, and are going to be made. The issue needs re-examining in order to decide whether allocations of funds from transfer budgets should be costed in the same way as allocations from service-generating budgets.

Finally, it is recommended that more research work be carried out on aspects of the fire benefit of the WfW programme not covered in this study; in particular that of reduced soil movement costs owing to reduced fire intensities.

Keywords: Cost Benefit Analysis; water yield; productive land use; horticulture; agronomy; fire-fighting; mop-up costs; biodiversity; preference for indigenous vegetation; contingent valuation.

OPSOMMING

1.1 AGTERGROND EN MOTIVERING VIR DIE STUDIE

Die Werk vir Water Program (WfW) is ‘n openbare werke program wat in die lewe geroep is om indringerplante en bome in Suid-Afrika uit te roei, en dit te vervang met inheemse boom- en plant spesies, wat baie minder water vir oorlewing nodig het. Hierdie uitroeiing sal verhoed dat meer as 4000 miljoen kubieke meter water per jaar uit die hidrologiese siklus verlore gaan (DWAF, 1998). Die ekonomiese lewensvatbaarheid van die program is reeds in die Wes-Kaap en KwaZulu-Natal aangespreek (van Wilgen, Little, Chapman, Görgens, Willems en Marais, 1997; Gilham en Haynes, 2001), terwyl dit in die Oos- en Suid-Kaap betwyfel word. Hosking, du Preez, Campbell, Wooldridge en du Plessis (2002) het die ekonomiese waarde van die program, gebasseer op verhoogde wateropbrengs en die potensiaal vir lewende hawe boerdery, op ses verkose WfW areas in die Oos- en Suid-Kaap vasgestel deur van ‘n koste voordele analise (KVA) gebruik te maak. Die ses areas sluit die volgende in: PE Driftsands, Albany, Kat rivier, Pot rivier, Kouga en Tsitsikamma.

1.2 NAVORSINGSDOELWIT

Hierdie studie neem ‘n aanvang met die identifisering van tekortkominge van die werk van Hosking *et al.* (2002). Die Hosking *et al.* (2002) studie was belangrik in vele opsigte. Feitelike data is gebruik vir die beraming van kostes, terwyl ‘n wetenskaplike werkswyse gevolg is in die berekening van water voordele. ‘n Innoverende benadering is gebruik in die vasstelling van die prys van beraamde wateropbrengste. Die Hosking *et al.* (2002) studie het egter nietemin verskeie tekortkominge. Eerstens is net ‘n deel van die voordele stroom met die totale koste stroom vergelyk. Verder is die nie-water voordele wat uit die program spruit nie in ag geneem nie. ‘n Volledige koste voordele analise behoort die nie-water voordele verbonde aan die program by die totale voordele stroom in te sluit. Daar bestaan dus ‘n behoefte om die nie-water voordele wat uit die program spruit, te kwantifiseer. Hierdie studie poog om die leemte wat gelaat is deur die uitsluiting van die nie-water voordele te vul, deur die berekening en insluiting van drie nie-water voordele in ‘n volledige, hersiende KVA.

Die drie nie-water voordele behels die volgende: die vermeerdering van potensiële produktiewe landbougrond vir lewende hawe, akker- en gewasverbouing; die impak van onbeplande vure op vuurbestrydingskoste in areas met indringerplante, en die bewaring van biodiversiteit en ekostelsels, soos gemeet aan mense se voorkeur vir inheemse plantegroei. Die kwantifisering van hierdie voordele word hieronder bespreek.

1.3 METODOLOGIESE BENADERING TOT DIE STUDIE

Die netto waarde van potensieël produktiewe landbougrond op die ses WfW areas is bereken deur die beraamde geldelike waarde van landboupotensiaal sonder die program, van die landboupotensiaal met die program, af te trek. Alle landbouaktiwiteite en geskikte landbou-aktiwiteite in elke omgewing, sowel as die bydrae van elk tot die area se total produktiwiteit, is nagespoor. Huidige grondeienaarskap op areas wat deur WfW vir indringerplantuitroeiing geteiken is, het 'n rol in die voorspelling van moontlik toekomstige landbougebruike gespeel (private land kan vir boerdery aktiwiteite gebruik word, waar staatsgrond nie noodwendig daarvoor ingespan kan word nie, maar meestal vir bewaring gebruik word). Die landbouaktiwiteite is as lewende hawe, akker- en gewas verbouing geklassifiseer. In alle gevalle is die Departement van Landbou se Vertakkingsbegrotings (Dissemination on information, 2002) geraadpleeg. Alternatiewe landbouaktiwiteite, soos die oes van veldblomme (proteas en fynbos) en heuningbostee, is ook in ag geneem.

Die Departement van Landbou se Vertakkingsbegroting (2002) is vir die berekening van die lewende hawe voordeel geraadpleeg. Ses faktore is gebruik om 'n model vir die bepaling van hierdie voordeel te ontwikkel. Dit behels: die aantal hektaar beskikbaar vir landbou, lewende hawe kategorieë, die drakrag van grond, die vlak van indringerbesmetting, aantal hektaar skoongemaak, en marge bo-kostes. Landbouvoorligters in elke gebied en die Döhne Landbou Instituut is ingespan om die geskikte landbougewasse in skoongemaakte gebiede te indentifiseer. Die aantal hektaar beskikbaar vir elke gewas is vir die deel wat dit tot die totale gewasproduksie bydra aangepas, asook vir die bydrae wat dit tot totale landbouproduksie gelewer het. Die aanname is gemaak dat huidige gewasverbouing in die omgewing geskik sou wees vir skoongemaakte areas. Die akker- en gewasverbouingsvoordeel is die verskil in per hektaar koste om areas met indringerplante vir landboudoeleindes skoon te maak, en areas sonder indringerplante daarvoor skoon te maak (ter voorbereiding van gewasverbouing).

Verhoogte landboubedrywighede op skoongemaakte gebiede veroorsaak egter 'n hoër vraag na water, wat die water voordeel soos deur Hosking *et al.* (2002) bereken, kan benadeel. Hoër water opbrengste wat deur die WfW program voortgebring is, kan deur verhoogte landbouaktiwiteite weer uitgewis word. Landboubedrywighede benodig dus water, en hierdie watergebruik van elke bedrywigheid is in 'n hersiende waterprofiel opgeneem om die verhoogte watergebruik te weerspieël.

Vir die bepaling van die vuur voordeel is die vraag of onbeplande vure in indringerplantegroei tot verhoogte brandbestrydingskostes lei, by die ses WfW terreine ondersoek. Direkte vuurbestrydingskostes in ongerepte fynbos en graslande (die dominante plantegroei in die besmette areas), en dan in dieselfde tipes plantegroei wat met indringerplantegroei besmet is, is ondersoek. ‘n Vergelyking tussen hierdie vuurbestrydingskostes is getref. Hierdie verskil in kostes vorm die vuur voordeel van die WfW program. Die kostes van beide soort vure is met behulp van vuurdeskundiges bepaal. Hulle opinies verbind die koste van vuurbestryding met die vlak van indringerplantegroei. Die koste van voorkoming van vure, soos byvoorbeeld die skep en instandhouding van vuurbane, is nie in berekening gebring nie, aangesien daar slegs op direkte vuurbestrydingskostes gefokus is.

In hierdie studie is die biodiversiteitsvoordeel in terme van die WfW program as die verhoging in grondoppervlak deur inheemse plantegroei beslaan, gesien. Mense se voorkeur vir ongerepte, inheemse plantegroei, en hul bereidwilligheid om daarvoor te betaal, is gebruik om die waarde van hierdie voordeel te bepaal. Die kontingente waardebepalings metode is hiervoor gebruik. Die waardebepalings wat by elke terrein onderneem is, moet egter slegs as voorlopig beskou word, aangesien die vraelys eenvoudig was, terwyl die steekproef in al die gevalle baie klein was.

Nadat waardes vir al die nie-water voordele bepaal is, is ‘n koste voordele profiel vir elke terrein opgestel. Die kostes soos deur Hosking *et al.* (2002) beraam, is aangepas tot 2001 prysvlakke. Daarvandaan is die netto voordele bereken en die resultate is tot huidige waardes verdiskonteer. ‘n Sosiale verdiskonteringskoers van 10.1% is gebruik. Dit weerspieël die geleentheidskoste van regerings- en oorsese befondsing wat tans vir die WfW program gebruik word. Hierdie koers is as ‘n jaarlikse geweegte gemiddelde koers vanaf 1996 tot 2000 bereken. Die netto huidige waarde (NPV), interne opbrengskoers (IRR) en voordeel-koste verhouding (BCR) is as kriteria vir investering ingespan.

1.4 OPSOMMING VAN DIE RESULTATE VAN DIE STUDIE

Die resultate van die koste voordele analise vir elke terrein word in die onderstaande tabel aangetoon.

Opsomming van die koste voordele analise

			WfW terreine					
KVA	**KVA gebruik**	**KVA kriteria**	**PE Driftsands**	**Albany**	**Kat rivier**	**Pot rivier**	**Kouga**	**Tsitsikamma**
1	**Hosking *et al.* (2002)**	**NPV (R)**	-14 674 240	-15 232 753	-1 031 609	-1 446 624	-33 854 196	-31 757 404
		IRR (%)**	0	1.13	3.60	-3.14	7.25	5
		BCR	0	0.21	0.43	0.03	0.75	0.54
2	**Gewysigde besluitnemi-ngskriteria met die landbou en vuur voordele ingesluit**	**NPV (R)**	-15 407 671	-9 058 614	-1 109 142	-1 034 188	-35 950 176	-32 765 901
		IRR ** (%)	Ongedef.*	4	4	1	7	5
		BCR	0.01	0.56	0.42	0.21	0.74	0.55
3	**Gewysigde besluitnemi-ngskriteria met die landbou, vuur en biodiversiteit voordele ingesluit**	**NPV (R)**	67 721 069	-3 046 798	16 767 386	16 137 316	-18 244 864	-26 875 031
		IRR (%)**	202	8	Ongedef.*	Ongedef.*	9	6
		BCR	5.37	0.85	9.82	13.3	0.74	0.63

* ‘n Ongedefinieërde waarde dui daarop dat geen tekenverandering gedurende die voordele stroom plaasvind nie. In hierdie geval is daar net voordele, en geen kostes nie.
** Die beraamde sosiale verdiskonteringskoers van 10.1%, soos bepaal deur Hosking *et al*. (2002), is gebruik.

Wanneer die landbou en vuur voordele by die KVA van Hosking *et al.* (2002) ingesluit word (KVA 2), is al die NPV waardes negatief, terwyl die IRR waardes almal minder as die sosiale verdiskonteringskoers is. In al die gevalle is die BCR kleiner as 1. ‘n Kombinasie van al die projekte in ‘n streekskosteprofiel lewer ‘n NPV van –R95 325 696, terwyl die BCR op ‘n waarde van 0.62 te staan kom. Die bevindinge van Hosking *et al.* (2002) bly dus geldig, selfs al word die landbou en vuur voordeel by die van verhoogte wateropbrengste gevoeg. Soos deur Hosking *et al.* (2002) aangevoer, kan die resultate slegs gunstig beïnvloed word indien die verdiskonteringskoers verlaag word, of die kostestruktuur van WfW aktiwiteite verlaag word. In beide gevalle sal die Kouga en Tsitsikamma terreine bevoordeel word.

Die byvoeging van die inheemse plantegroei as nie-water voordeel tot die KVA (KVA 3) het die resultate aansienlik beïnvloed. Met die insluiting van hierdie voordeel, word die PE Driftsands, Pot- en Kat rivier projekte ekonomies lewensvatbaar. Die NPV waardes vir hierdie terreine is hoog. Die resultaat van die herdefiniëring van die projekte in terme van die som van die ses terreine, lewer ‘n NPV waarde van R52 459 077 op, terwyl die BCR op 1.14 te staan kom. Dit is belangrik om daarop te let dat die kontingente waardebepalings wat op die ses terreine onderneem is, slegs voorlopige studies is.

1.5 GEVOLGTREKKINGS

Eerstens word daar voorgestel dat besluite oor waar WfW spanne aktief moet funksioneer, nie net op die watervoordeel moet berus nie. Tweedens word dit aanbeveel dat 'n meer in-diepte kontingente waardebepaling op die ses terreine onderneem word, waar meer aandag op die steekproefproses bestee word. Die vraelys behoort ook meer gestipuleerd te wees. Die voorlopige studies dui daarop dat hierdie voordeel die besluitnemingskriteria aansienlik kan beïnvloed.

In die derde plek moet die sosiale aspekte van die WfW program omskryf, nagevors en by die KVA ingesluit word. Daar word geargumenteer dat 'n deel van die kostes in terme van arbeidsloon eintlik as 'n voordeel gesien behoort te word, aangesien 'n deel van die geld in elk geval as regeringsoordagte aan mense betaal sou word. Die vraag of die allokasie van fondse vanaf oordragbegrotings met dieselfde kam geskeer moet word as allokasie van diensgenererende begrotings, moet heroorweeg word.

Laastens word daar aanbeveel dat meer navorsing op aspekte van die vuur voordeel wat nie in hierdie studie behandel is nie, gedoen word. Spesifiek die ekologiese kostes verbonde aan onbeplande vure in indringerplantegroei (erosie en grondverlies) moet aangespreek word.

Sleutelwoorde: Koste voordele analise; wateropbrengs; produktiewe grondgebruik; gewasverbouing; akkerbou; vuurbestryding; opruimkoste; biodiversiteit; voorkeur vir inheemse plantegroei; kontingente waardebepaling.

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BCR	Benefit cost ratio
C	Degrees Celcius
CBA	Cost Benefit Analysis
CVM	Contingent Valuation Method
DBH	Diameter at breast height
FPA	Fire Protection Associations
ha	hectares
HPM	Hedonic Pricing Method
IRR	Internal rate of return
Km/h	kilometers per hour
MAR	Mean Annual Runoff
MCDA	Multi-Criteria Decision Analysis
m^3/ha	cubic metres per hectare
NPV	Net Present Value
PE Driftsands	Port Elizabeth Driftsands
SOCC	Social opportunity cost of capital
Spp.	Species
STPR	Society’s time preference rate
TCM	Travel Cost Method
WTA	Willingness to accept
WTP	Willingness to pay
WfW	The Working for Water programme

CHAPTER 1
INTRODUCTION

1.2 BACKGROUND

The Working for Water programme (WfW) is a public works programme designed to clear South Africa of water-consuming invasive alien tree and plant species, and to replace them with low water-consuming indigenous species. Alien trees use up to 7% of the country's water run-off (www.sun.ac.za/gei/aliens.html). Eventually this programme hopes to prevent a loss of more than 4000 million cubic metres water per annum from the hydrological cycle (DWAF, 1998). The economic viability of the programme in the Western Cape has been addressed by van Wilgen, Little, Chapman, Görgens, Willems and Marais (1997). Gilham and Haynes (2001) showed, in a cost benefit analysis (CBA) that the WfW programme is economically viable in Kwazulu-Natal.

Hosking, du Preez, Campbell, Wooldridge and du Plessis (2002) investigated the economic case for the programme on selected sites in the Eastern and Southern Cape, by performing a CBA. The Hosking *et al.* (2002) study is an important one, because actual cost data was used and considerable effort was put into valuing the increased water yield from WfW activities. However, there are economic aspects of the Hosking *et al.* (2002) assessment that merit more attention than was given them; one of these is the issue of non-water benefits. Since the initiation of the programme in September 1995, numerous non-water benefits have been identified, but not yet valued, not even in the Hosking *et al.* (2002) analysis.

These benefits include reduced fire protection costs and reduced damage to infrastructure as a result of wildfires, conservation of biodiversity and ecosystem resilience, gain in potentially productive land (grazing potential, livestock production and other agricultural practices), value added industries, increase in water quality, improved river system services, social development and poverty alleviation, job creation, economic empowerment and training, flood control, and the containment of erosion and a decrease in the siltation of dams (Marais, Eckert and Green, 2000).

In the construction of a complete CBA, all the benefits and costs of the WfW need to be incorporated, not merely increased water yield. This study aims to extend the analysis of Hosking *et al.* (2002) by incorporating selective non-water benefits in the calculations. The results from the CBA of the WfW programme on six representative sites in the Eastern and Southern Cape conducted by Hosking *et al.* (2002), funded through the Water Research Commission (WRC), are presented in this chapter, and critiqued in Chapter 2. Chapters 3, 4 and 5 respectively, describe the valuations of the agricultural, fire, and biodiversity benefits. Chapter 6 presents a revised CBA to that of Hosking *et al.* (2002), incorporating the non-water benefit valuations, and Chapter 7 presents the conclusion and recommendations.

The sites researched by Hosking *et al.* (2002) were those of Albany, Kat River/ Balfour, Pot[1] River/Ugie, Tsitsikamma, Kouga and Port Elizabeth Driftsands.

1.2 OBJECTIVES OF THE STUDY

This study was funded by the WfW programme. Its objectives were to:

- Provide a critique of the Hosking *et al.* (2002) study.
- Value the benefit derived from potentially productive land freed up through WfW activities.
- Determine the impact of wildfires in alien vegetation on fire management costs and the risk of damage to infrastructure.
- Provide a value for local residents and tourists' preference for indigenous vegetation at the six sites. This value was intended to serve as a proxy for increased biodiversity and ecosystem resilience at the six sites.
- Perform cost benefit analyses (CBAs) on the six representative sites where the non-water benefits are included.
- Present conclusions and recommendations based on the results of the CBAs.

The value of potentially productive land, the impact of alien vegetation on fire fighting costs, and the ecosystem resilience benefit, were the non-water benefits included in this study. Other non-water benefits, although identified, were excluded on the basis of financial and time constraints. These benefits remain to be valued.

1.3 BRIEF OUTLINE OF THE WFW PROGRAMME

1.3.1 Background of the WfW programme

Although alien eradication programmes in South Africa took place as far back as the 1970s, the WfW programme was officially introduced as a public works programme in South Africa in September 1995 (Hosking *et al.*, 2002). Funds to clear alien tree and plant species were secured by the then minister of Water Affairs and Forestry, Kader Asmal, on the basis that such a programme would increase water runoff, facilitate biodiversity and ecosystem functioning, and provide social benefits through job creation. The poor were to be targeted, particularly through the recruitment of disabled people, female heads of households, and young people in rural areas (DWAF, 1999a).

[1] The Hosking *et al.* (2002) study used the spelling 'Pott' River.

From October 1995 to the end of 2001, an area in excess of 602 225 hectares was cleared, while follow-up operations on an area of more than 380 115 hectares were completed. Approximately 80 783 new jobs were created during this period (DWAF, 2001).

1.3.2 Objectives of the programme

The primary and secondary objectives of the WfW programme, as reflected in its mission statement, stem from the overriding goal of controlling alien trees and plants in South Africa:

'By the year 2020 the Working for Water Programme will have contributed to a South Africa in which invasive alien plants are sustainably controlled, in order to contribute to economic empowerment, social equity and ecological integrity' (DWAF, 2001).

The Working for Water programme has set out to meet a number of objectives. These are:

- Hydrological: To enhance water security through regaining control over the spread of invading alien plants in South Africa and to promote the quest for equity, efficiency and sustainability in the supply and use of water.
- Ecological: To improve the ecological integrity of natural systems through the removal of alien plants, and to protect and restore biodiversity, thereby countering abnormal fires, soil erosion, flooding, scouring of rivers, siltation of rivers, dams and estuaries.
- Social: To optimise the social benefits that are possible as a community-based public works programme by investing in the most marginalized sectors in South African society and enhancing their quality of life.
- Natural Resources: To restore the productive potential of land, in partnership with the Land Care and Combating of Desertification initiatives, and to promote the sustainable use of natural resources.
- Economic: To develop the economic benefits (from land, water, wood and people) from clearing these plants, by facilitating economic empowerment and the development of secondary industries, and to play its part in protecting the economic integrity of the productive potential of the country (DWAF, 2001).

The intention of the WfW programme’s 20 year plan is to clear approximately 750 000 hectares of alien infested land annually, at a cost of R600 million (at 1998 price levels). The expected benefits derived from this strategy are:

- An increase of more than 4000 million cubic metres of water from the hydrological cycle per annum.
- Clearing of more than 1 million hectares of land for agricultural use.

- Improved fire management and control.
- Creation of 50 000 direct jobs per annum.
- Usage of wood for building materials, furniture, charcoal, and toys from alien trees at a magnitude of more than 1 million tonnes of wood annually (DWAF, 1998).

Over and above the benefits mentioned above, unintended benefits from the WfW programme have been cited. For instance, it is alleged that Grahamstown residents have enjoyed reduced respiratory-related diseases through the WfW programme because of the reduction in pollen emanating from *Acacia spp.* (Buckle, pers. comm., 2002). Furthermore, some crops in the Kouga area have suffered less frost damage as a direct result of the removal of adjacent Blackwattle trees (Moore, pers. comm., 2002).

1.3.3 Control operations followed by the WfW programme

The control technique used for eradication is determined by the type of alien species present in an area. Control operations can be manual and mechanical, chemical, or biological in nature.

Manual, mechanical and chemical control

Chain saws, brush cutters and slashers are used in manual and mechanical clearing of Pines and *Acacia spp.* Mature trees (more than 10cm diameter at breast height (DBH)) are felled using a chainsaw, while brushcutters are used for dense stands of *Hakea*, as well as young Pine trees and *Acacia spp.* The slashing of invasive plants takes place where the individual trees are less than 15cm DBH (Marais, 1998).

Cost and practicality issues restrict the extensive use of chemical control to destroy alien species. However, herbicides are used with stump treatment on *Acacia spp.* Mattocks and spraying equipment, such as boom and knapsack sprayers, are used for follow-up operations. Follow-up treatment is initiated after the first wildfire in an area or after a controlled burn (Marais, 1998).

Biological control

One of the reasons for alien trees becoming invasive is the absence of their natural enemies in South Africa. One way of eradication is by the release of these biological control agents. The Plant Protection Research Institute (PPRI) has investigated and initiated biological control programmes in respect of many invader plant spp., notably *Hakea* and certain *Acacia spp.*

Biological control has been successful in a number of cases, such as the reduction of seeds of *Acacia longifolia* through the application of the bud-galling wasp *Trichilogaster Acacia longifoliae* (Marais, 1998) and the reduction of seed production of *Acacia saligna* through the gall rust *Uromycladiun tepperiarum* (Van Wilgen, Bond & Richardson, 1992). *Hakea spp*. have also been attacked by the release of the *Hakea* fruit weevil, *Erytenna consputa* and the *Hakea* seed moth, *Carposina autologa. Cydmaea binotata*, a leaf-boring weevil specific to *Hakea sericea,* reduces growth and competitiveness of seedlings, while *Collectotrichum state of Glomerella cingulata,* an endemic fungus, has also been used (Hosking *et al.*, 2002).

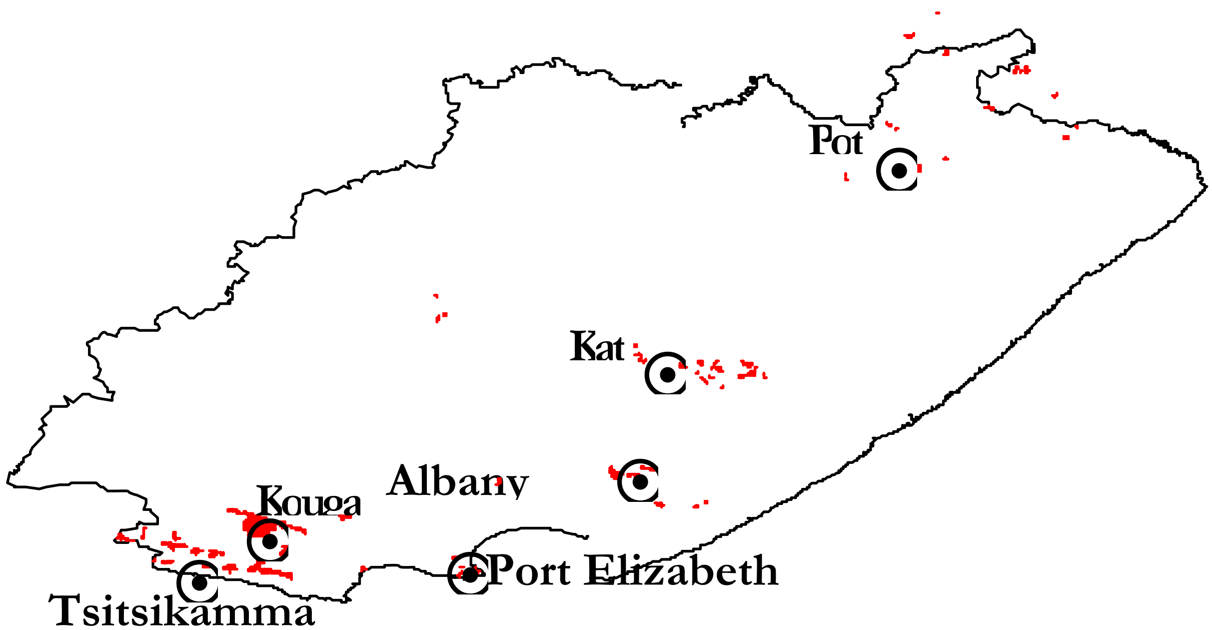
Alien species grown commercially (e.g. *Pinus pinaster* and *Pinus radiata)* have not been subject to biological control because they are definitely grown for profit. However, the use of biological control is being explored by the WfW programme management as a solution to the eradication of alien invaders, which produce a high seed load, especially the *Acacia spp.* Recently, the seed eating snout beetle (*Melanterius meculatus*) has been released on *Acacia mearnsii* trees in the Western and Eastern Cape. Biological control could reduce the costs of follow-up and maintenance by up to 50% in the long-term – depending on the biological agent that is used (Buckle, pers. comm., 2002).

A number of cost benefit analyses have been completed on biological control. Van Wilgen, de Wit, Anderson, Le Maitre, Kotze, Ndala, Brown and Rapholo (2002) conducted a CBA of biological control of six weed species on selected areas in South Africa. Their analysis showed biological control agents to be very efficient. They concluded that, from the initial release of the biological control agents up to the year 2000, the benefit cost ratios were between 8:1 for *lantana* and 709:1 for jointed cactus. Ratios generated based on the inclusion of estimates of future benefits were between 34:1 for *lantana* and 4 333:1 for golden wattle.

McConnachie, Hill, Byrne and De Wit (in press) conducted a CBA whereby nine studies on biocontrol programmes in South Africa were reviewed. They calculated benefit cost ratios of between 1,9:1 and 53:1. Research conducted by Nordblum, Smyth, Swirepik, Sheppard and Briese (2001) on the biological control of Patterson's curse in Australia also yielded positive benefit cost ratios of 14:1 in the year 2015, increasing to 47:1 in the year 2050[2].

[2] The extensive use of biological control agents, however, could threaten the job creation objective formulated by WfW. As more biological control agents are released and become efficient, manual clearing jobs could decrease.

Figure 1.1 The representative WfW programme sites in the Eastern and Southern Cape used in this study.



Note: Red dots indicate areas where WfW clearing activities were undertaken by the end of 2001
Source: DWAF

1.4 SELECTED STUDY SITE INFORMATION

Of the 21 WfW sites operational in the Eastern and Southern Cape in 1999, six were selected for analysis by Hosking *et al.* (2002). This study attempts to fill the gap in the Hosking *et al.* (2002) analysis. For this reason the same sites were used, namely Albany, Balfour/Kat River, Kouga, Pot River/Ugie, PE Driftsands and Tsitsikamma (see Figures 1.1 to 1.7). The Department of Economics and Economic History at the University of Port Elizabeth, together with Japie Buckle (technical advisor for the Working for Water programme in the Eastern Cape) and the Water Research Commission carried out the site selection. It was done on the basis of obtaining a sample of sites which characterised the variety of areas in the Eastern and Southern Cape[3] where WfW teams were operational. Special consideration was given to factors such as the topography, and the indigenous and alien vegetation present at sites. Each site is described below.

[3] The Tsitsikamma site is situated in the Southern Cape and does not fall within the auspices of the Eastern Cape WfW branch. However, it was included because of its potential importance as water source for the Eastern Cape. The potential exists for water runoff from the Tsitsikamma mountain to be piped to the Kouga/Krom river water supply system (Hosking, *et al.*, 2002).

1.4.1 Albany

The Albany area (33°18'S; 26°31'E) is situated in the upper catchment of the Kariega and Kowie rivers (Figure 1.2). The project site covers an area of 11 400ha. The indigenous groundcover comprises grassy fynbos, grassland and Eastern Cape Thicket (Low and Rebelo, 1996), but species such as *Acacia spp., Pinus pinaster, Hakea spp.* and *Eucalyptus spp*. have invaded the area. The relative infestation level as a percentage is estimated at between 5.1% and 10%. Eastern Cape Thicket, one of the dominant veld types in the Albany region, rarely burns, but the existence of aliens introduces a fire hazard, as these species burn easily due to their huge biomass volume. Moreover, aliens are well adapted to fire, as the heat from fire stimulates the release of huge quantities of seeds from serotitious cones, and promotes germination and growth of seedlings by creating favourable microsites for it (Buckle, pers. comm., 2002).

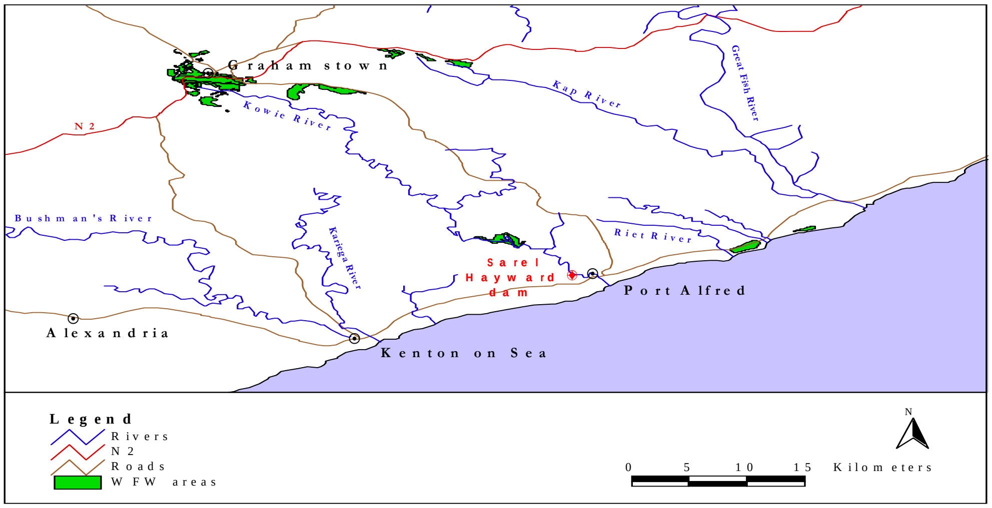
Topography, climate and rainfall

The topography is composed of Cape Fold Mountains, with exposed rocky outcrops and rolling hills closer to the coast. Soils in this area are derived from Quartsic sandstone and shale, but these are poor in nutrients (Hosking, *et al.*, 2002). The months with the highest rainfall are February/ March and October/November, while June/July is normally the driest period. The mean annual precipitation is 650mm (Low and Rebelo, 1996). The average fire cycle in grassy fynbos at the Albany site is four years. The last fire occurred in 1999 (du Preez, pers. comm., 2002).

Ownership

Both public and private land ownership occur. The privately owned land is predominantly used for game (especially kudu) and livestock farming (Hahndiek, pers. comm., 2002), while the publicly owned land, under the auspices of the Makana municipality, is not used for anything specific (Knipe, pers. comm., 2002).

Figure 1.2 The Albany Working for Water site.



Source: DWAF

Clearing methods used

Initial clearing in Albany takes place using chainsaws and brushcutters. The areas are burnt within two months of clearing, with follow-up operations undertaken for two years following initial clearing. Herbicides are used during follow-up control. Maintenance of management units is continued for five years after follow-up operations (Hosking *et al.*, 2002).

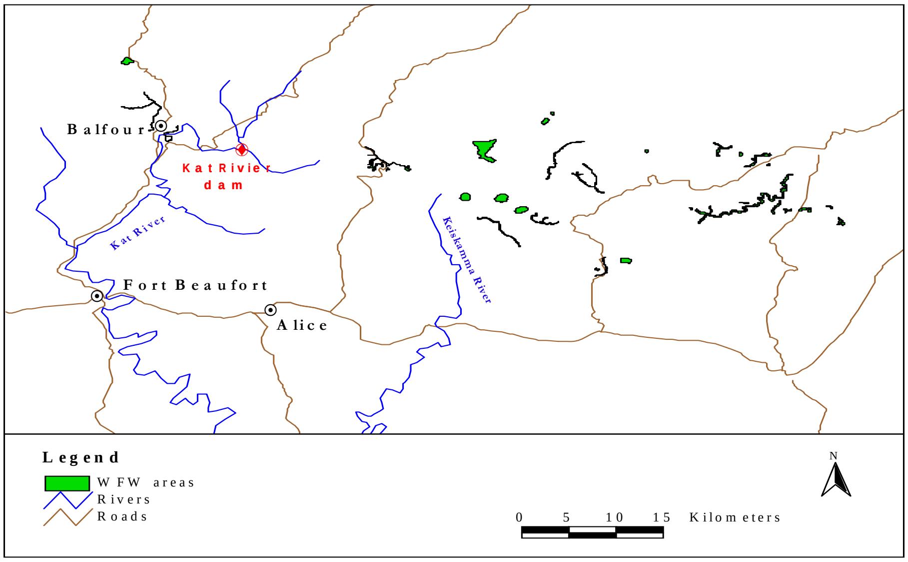
1.4.2 Kat River/Balfour

Balfour is a mountain catchment area (32°31'S; 26°40'E) and forms part of the Amatola escarpment (see Figure 1.3). The project site spans 1 196ha. The relative alien infestation varies between 1.1% to 5% per hectare, mainly with *Wattle* and *Pine spp*. The indigenous groundcover comprises forests and grasslands (Low and Rebelo, 1996). Alien infestation poses a threat to potentially productive agricultural land, creates a loss in water yield, threatens biodiversity and increases fire risks (Buckle, pers. comm., 2002).

Topography, climate, rainfall and fire cycle

The topography of this area is characterised by mountains, with the soils derived from weathered sandstone, dolorite, and shale. On average 37% (350.6mm) of the mean precipitation per annum (950mm) falls during winter (Low and Rebelo, 1996). The average fire cycle is four years, with the last fire having occurred in 1999 (Hosking, *et al.*, 2002).

Figure 1.3 The Kat River WfW site



Source: DWAF

Ownership

The Kat River project area consists mainly of state-owned forestry plantations. The most important agricultural activity on privately owned farmland is the production of cattle products (Buckle, pers. comm., 2002).

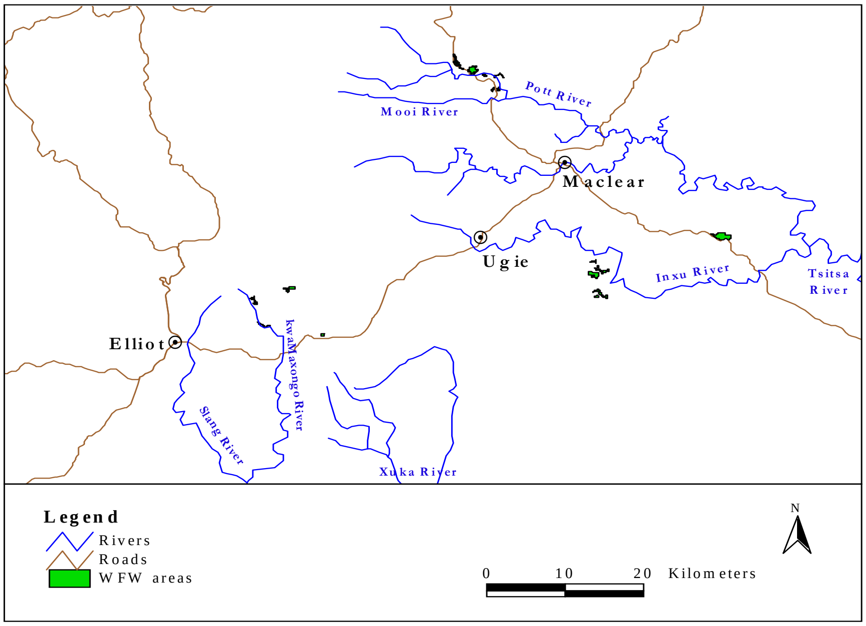
Clearing methods used

Controlling operations used in this area include initial clearing with mechanical means (brushcutters, chainsaws, bowsaws and slashers). Stump treatment of *Acacia mearnsii* occurs in the first year, and follow-up treatment is done for two years, using herbicides. Management unit maintenance is exercised for four years following clearing (Hosking, *et al.*, 2002).

1.4.3 Pot river/Ugie

The Pot River site (31°11'S; 28°14'E), spanning an area of 490 ha, is located in the grass areas of the foothills of the Eastern Cape Drakensberg (see Figure 1.4). The indigenous vegetation is grassveld (Low and Rebelo, 1996), while the relative alien infestation is estimated at 0.1 – 1% per hectare. Aliens species present are *Acacia spp.*, Crack Willow and *Populus spp*.

Figure 1.4 The Pot River WfW site



Source: DWAF

Topography, climate, rainfall and fire cycle

The topography of the Pot River site is characterised by mountains, with the soils derived from weathered sandstone, dolorite, and shale. Between 5 and 10% of the annual rainfall occurs during the months of April and September. The mean annual precipitation is 939mm (Low and Rebelo, 1996). Because grassland is the predominant vegetation, the average fire cycle is four years, and the last fire occurred in 1999 (Hosking *et al.*, 2002).

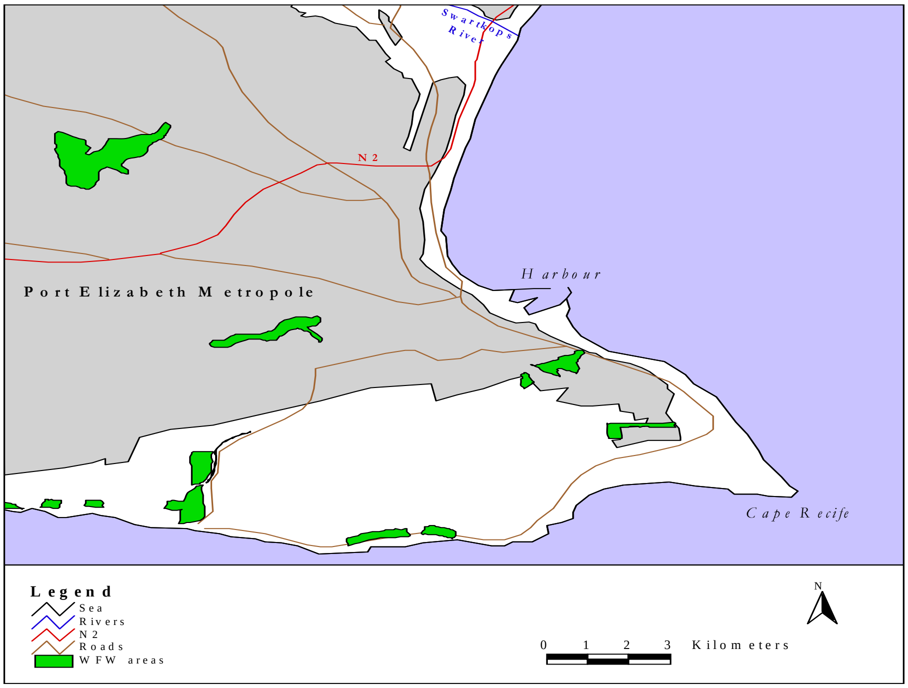
Ownership

The Pot river site falls on privately owned land, with the main land uses being cattle, goat and sheep farming, and commercial forestry.

1.4.4 Port Elizabeth Driftsands

This area comprises coastal dunes, positioned in and around the city of Port Elizabeth (33°55'S; 25°35'E). It stretches over an area of 8 700 ha (see Figure 1.5). Two river valleys are found within this area, namely the Baakens and the Papenkuils. The indigenous vegetation found is coastal fynbos. Infestation with alien species from the *Acacia* family, such *as Acacia cyclops, Acacia saligna, Acacia longifolius* and *Eucalyptus spp*. occurs, with the relative infestation level estimated at between 5.1 to 10% (Hosking *et al.*, 2002). The PE Driftsands site is not situated in a catchment area, but problems associated with aliens include biodiversity loss and increased fire risks (Buckle, pers. comm., 2002).

Figure 1.5 The Port Elizabeth Driftsands WfW site



Source: DWAF

Topography, climate, rainfall and fire cycle

In the dune system, sandy soil is predominant. Alluvial clay is found in the river valleys. Between 60 to 65% of the annual rainfall occurs between April and September, and the annual mean precipitation is 500mm. The fire cycle in fynbos is 12 to 15 years (Marais, pers. comm., 2000). In the PE Driftsands area, the average fire cycle is 12 years, with the last fire having been recorded in 1997 (Hosking *et al.*, 2002).

Ownership

The PE Driftsands area is owned and managed by the Nelson Mandela Metropole.

Clearing methods used

Most clearing efforts are done mechanically, with herbicide also used in both initial clearing and follow-up operations. Cleared areas are monitored over the first 10-year period after follow-up activities (Hosking, *et al.*, 2002).

1.4.5 Kouga

The Kouga site covers an area of 158 678 ha and falls within a catchment area (33°43'S; 24°35'E). It consists of a series of parallel mountain ranges, with the Langkloof valley in between (see Figure 1.6). The site spans the northern slopes of the Tsitsikamma mountains and the Southern slopes of the Kouga mountains. Relative infestation varies between 5.1 - 10 %, with *Acacia mearnsii, Acacia dealbata, Acacia melanoxylon, Poplar spp., Hakea* and *Pinus spp*. being the main culprits. The indigenous groundcover is fynbos. The runoff from the mountain catchment area is captured in the Kouga and Kromme rivers (Hosking *et al.*, 2002).

Alien tree and plant species pose a threat to the productive capacity of land, while also constituting a danger to biodiversity at the Kouga site. The Kromme River and surrounding areas are recognised as wetland areas, which are hosts to rare habitats, and assist in water purification (wetlands act as a water filter). Wetland degradation leads to sedimentation into storage dams, and increase the risk of floods (Egan, pers. comm., 2001). Erosion is another problem related to wetland degradation. The loss of water yield and fire risks are other major threats.

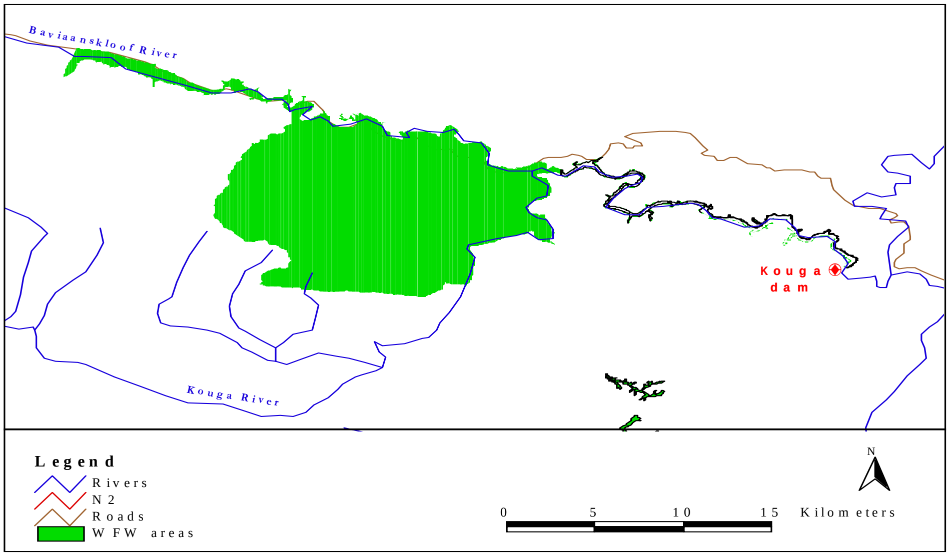
Topography, climate, rainfall and fire cycle

The mountain ranges are part of the Cape Fold Mountain structure, and the parent rock is Table Mountain Sandstone. The soil is poor and shallow, with Quartsic sandstone as its origin. The western regions do not receive as much rain as those in the east. Although rain falls all year round, December to February tend to be dry months. The annual mean precipitation is 547mm (Low and Rebelo, 1996). The average fire cycle is 12 years, with the last fire having been recorded in 1999 (Hosking *et al.*, 2002).

Ownership

The majority of land within the Kouga project site is privately owned, with the main agricultural activities being deciduous fruit and livestock farming (cattle and sheep). The areas that are state owned are characterised by the presence of untouched plant and animal communities. Conservation is the major type of activity in these areas (van der Merwe and Moore, pers. comm., 2002).

Figure 1.6 The Kouga WfW site



Source: DWAF

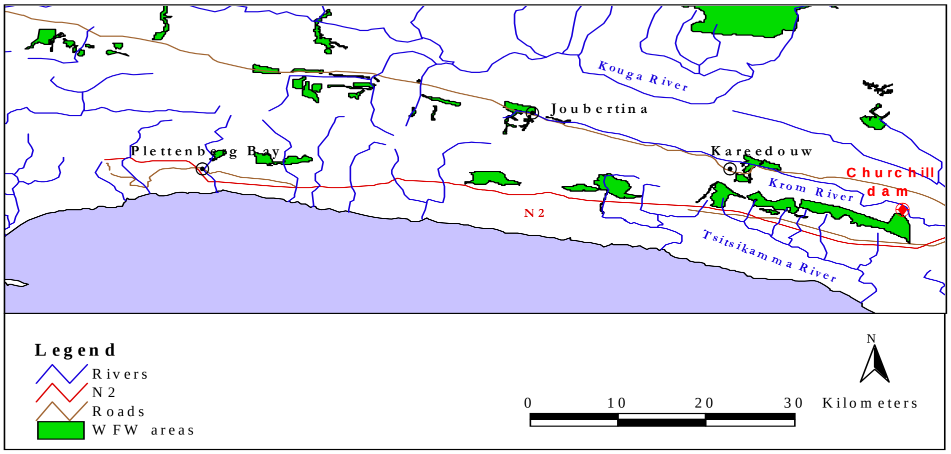
Clearing methods used

WfW programme clearing efforts concentrate on mechanical methods via the use of brushcutters, etc., and follow-up is done for two years after initial clearing, using herbicides. Maintenance of cleared areas occurs for five years after the completion of follow-up control (Hosking, *et al.*, 2002).

1.4.6 Tsitsikamma

The Tsitsikamma site covers an area of 128 783 ha and falls within a catchment area of the Keurbooms River (34°01'S; 23°54'E). Fynbos is the indigenous vegetation (see Figure 1.7). Alien infestation covers between 10.1 to 20% of the site. *Acacia mearnsii, Acacia melanoxylon, Hakea sericea, Eucalyptus spp.* and *Pinus spp*. are the main invaders (Hosking *et al.*, 2002). Alien infestation poses a threat to the water yield, a fire hazard to commercial plantations, creates erosion problems, and could lead to a loss in biodiversity in the indigenous forests in this area (Buckle, pers. comm., 2002).

Figure 1.7 The Tsitsikamma WfW site



Source: DWAF

Topography, climate, rainfall and fire cycle

The area consists of mountains and a narrow coastal plain. The Uitenhage outcrop lies on either side of Plettenberg Bay, comprising rolling hills. The hills increase in size towards the Cape Fold Mountains, which run parallel to the coastline. The elevations range from sea level to 1675m. The major soil types include those derived from sandstone and shale. It is acidic, poor in nutrients, and shallow. The soil in the lower reaches and the plateau is less acidic, deeper, and higher in nutrients. On average 41.25% of the mean rainfall per annum occurs between April and September. The mean annual precipitation is 960mm. The average fire cycle is 12 years, owing to the predominance of fynbos. The last fire occurred in 1998 (Hosking *et al.*, 2002).

Ownership

The Tsitsikamma project area is currently managed by the Tsitsikamma National Park, where nature conservation is the main activity for the protection of plant and animal communities (Booth and Jungbauer, pers. comm., 2002). Clearing on privately owned land in the area adjacent to the site is not envisaged for some time. The main agricultural activity on privately owned land is dairy farming. This type of farming is intensive, and based on pastures planted on small patches of irrigated land, as fynbos is poor food for livestock (Weitz, pers. comm., 2002). Commercial afforestation by SAFCOL (South African Forestry Company Limited) occurs on areas which it owns.

Clearing methods used

WfW clearing on this site is carried out using a combination of mechanical equipment, such as brushcutters, slashers and chainsaws. Felled trees are transferred above the flood line, cut up and put in windrows to contain erosion. Trees are also sometimes ring-barked. Two years after initial clearing, follow-up clearing is done, and thereafter maintenance is carried out for at least another five years (Hosking, *et al.*, 2002).

1.5 RESULTS OF THE CBA PERFORMED BY HOSKING *et al.* (2002)

The four basic elements of cost benefit analysis with regard to the WfW programme are discussed below (Hosking *et al.*, 2002).

1.5.1 Time considerations

All estimated cost and benefit flows derived by Hosking *et al.* (2002) were captured in annual terms, and expressed at 2000 price levels. A distributional weighting of one was assumed for all cross-sectional costs and benefits over the full project period, i.e. no distinction between benefits and costs was made based on who experienced the impact. The time horizon of the project was set at 100 years (Hosking *et al.*, 2002).

1.5.2 The cost of clearing alien plants

The costs of alien plant clearing were estimated on the basis of actual costs incurred since the inception of the various projects and projections made by the various project managers. These costs are shown in Table 1.1.

The estimates of the cost of clearing alien infestations included initial clearing operations, as well as intensive follow-up control and maintenance for about 5 to 10 years thereafter. Initial clearing entails the removal of alien vegetation, whereas follow-up operations entail the removal of the re-growth of alien vegetation in a previously cleared area. Follow-up operations in areas that have already been cleared normally take priority in field operations, because, if re-growth is allowed to occur, the initial investment is wasted. Two initial follow-ups are normally carried out after initial clearing, each in consecutive years. The eradication methods include manual, mechanical, chemical, and biocontrol techniques. Control programmes differ depending on the species present, the density of the stands, and the accessibility of the management units.

Table 1.1 Cost of clearing, follow-up operations and maintenance for the six WfW project sites*+

Treatment	Tsitsikamma (R/ha)	Kouga (R/ha)	Port Elizabeth Driftsands (R/ha)	Albany (R/ha)	Kat River (R/ha)
Initial (clearing)	1 236	2 300	2 650	2 440	1 440
1st follow-up	400	400	700	750	840
2nd follow-up	248	200	400	360	450
Maintenance (1st year)	140	50	200	170	255
Maintenance (2nd year)	65	20	70	140	110
Maintenance (3rd year)	25	20	20	70	60
Maintenance (4th year)	15	20	20	60	0
Maintenance (5th year)	0	20	20	50	20
Maintenance (6th year)	15	0	20	20	0
Maintenance (7th year)	0	0	0	20	20
Maintenance (8th year)	15	0	0	20	0

Notes: * The costs presented in Table 1.1 were provided by individual project managers and represent the average costs for all density classes.
+ Management costs are included.

Source: Hosking *et al.* (2002).

1.5.3 The benefits of clearing alien plants

1.5.3.1 Primary benefits

It has been argued that the primary benefit of the WfW programme is increased water yield (Hosking *et al.*, 2002).

The CBA of Hosking *et al.* (2002) estimated the increased water yield (cubic metres/ha/year) for the six sites in the Eastern and Southern Cape, by applying the model forwarded by Versveld, Le Maitre and Chapman (1998), with a “rate of spread” element included as suggested in Le Maitre Van Wilgen, Chapman and McKelly (1996). These estimates of increased water yield in cubic metres/ha per fire cycle are shown in Table 1.2. This benefit stream, in terms of incremental water yield, increases proportionally as more areas undergo initial clearing. The total benefit is only realised after all initial clearing in the total area earmarked for clearing has been completed.

Table 1.2 Net incremental water yield (m^3/ha) per fire cycle for the six selected sites

Fire cycle (years)*	Tsitsikamma	Kouga	Port Elizabeth Driftsands	Albany	Kat River	Pot River
	Water yield (m^3/ha)	Water yield (m^3/ha)	Water yield (m^3/ha)	Water yield (m^3/ha)	Water yield (m^3/ha)	Water yield (m^3/ha)
1	32,22	7,24	63,21	1421,73	668,89	1051,02
2	96,67	21,74	189,65	1434,78	710,70	1081,63
3	161,12	52,93	356,32	1443,47	752,50	1112,24
4	267,89	100,83	528,73	1452,17	710,70	1132,65
5	401,45	146,20	655,17	-	-	-
6	510,16	188,11	752,87	-	-	-
7	602,95	229,08	833,33	-	-	-
8	684,48	270,04	913,79	-	-	-
9	758,25	311,63	982,75	-	-	-
10	825,80	355,12	1034,48	-	-	-
11	888,31	406,49	1086,20	-	-	-
12	947,33	448,39	1137,93	-	-	-

* The Tsitsikamma, Kouga and Port Elizabeth Driftsands sites have a 12 year fire cycle whereas the Albany, Kat River and Pot River sites have a four year fire cycle.
Source: Hosking *et al.* (2002).

Hosking *et al.* (2002) estimated the value of water generated at the six representative WfW sites by using both the willingness-to-pay[4] and marginal cost methods[5], whichever was applicable at the selected WfW sites (see Table 1.3).

[4] The willingness-to-pay method comprises the estimation of water values for agricultural use by looking at the difference between the values of land under irrigation and dry land farming (corrected for the cost of improvements to get land in a suitable state for irrigation) (Hosking *et al.*, 2002).

Table 1.3 Values of water for the six WfW sites in the Eastern and Southern Cape

Site	Value of water (per cubic metre) in 2000 prices	Type of value
Tsitsikamma	12.5	Willingness-to-pay
Kouga	74	Marginal cost
Port Elizabeth Driftsands	0	Potential user response
Albany	5*	Environmental opportunity cost
Kat River	15.7	Willingness-to-pay
Pot River	0**	Non-scarce resource

* In the case of the Albany project, no water value could be determined for urban or agricultural use. Indirectly, however, WfW activities do provide fresh water to the Kowie estuary. The estuary service benefit of freshwater inflow into the Keurbooms estuary was used as a measure for this benefit. This was done using the contingent valuation procedure at the Keurbooms estuary.
** No water value could be established at the Pot River site, as water supply is abundant at this location and no direct link could be made between this water and the health of the Umzimvubu estuary. The Pot River flows into the Umzimvubu River.
Source: Hosking, *et al.* (2002).

The water yield benefit (R/ha) per fire cycle for the six sites is shown in Table 1.4 below.

Table 1.4 The water yield benefit (R/ha) per fire cycle for the six selected sites

Fire cycle (years)	Tsitsikamma	Kouga	Port Elizabeth Driftsands	Albany	Kat River	Pot River
1	4,02	5,35	0	71,08	105,01	0
2	12,08	16,08	0	71,73	111,57	0
3	26,14	39,16	0	72,17	118,14	0
4	33,48	74,61	0	72,60	111,57	0
5	50,18	108,18	0	-	-	-
6	63,77	139,20	0	-	-	-
7	75,36	169,51	0	-	-	-
8	85,56	199,82	0	-	-	-
9	94,78	230,60	0	-	-	-
10	103,22	262,78	0	-	-	-
11	111,03	296,36	0	-	-	-
12	118,41	331,80	0	-	-	-

Source: Hosking *et al.* (2002).

[5] The marginal cost of equivalent water supply method, where the additional cost of bringing water to urban consumers is measured, is the most common approach used (see Hosking and du Preez, 2002, Marais, 1998 and van Wilgen *et al.*, 1997). The cost of providing additional water to urban areas is assessed as a reference value price, where the costs include those of capital, operational equipment and maintenance. This reference value price is created per unit of water generated and is used to value water produced with the WfW programme.

1.5.3.2 Secondary benefits

The only secondary benefit measured by Hosking *et al.* (2002) was the incremental livestock capacity benefit. This benefit was calculated for the Albany, Pot and Kat River sites, and is listed in Table 1.5 below[6].

Table 1.5 Net agricultural livestock benefit for selected WfW sites

Site	**Net agricultural benefit in Rands**
Albany	44705.93
Pot River	181.15
Kat River	2265.42

Source: Hosking *et al.* (2002).

1.5.4 The social discount rate

The social discount rate is an important factor in CBA, as the choice of a discount rate impacts substantially on the viability of the project. A zero social discount rate implies that timing of benefits and costs are not important – future effects are as valuable as current ones. A high social discount rate sharply reduces the weight given to future costs and benefits. Projects where most of the benefits accrue far into the future are adversely affected by high discount rates.

Hosking *et al.* (2002) estimated the social discount rate for the WfW programme at 10.1% per year. This figure constituted a weighed social discount rate, using the three main sources of funding available for the WfW programme from 1996 to 2000, namely foreign aid (smallest portion), government borrowing, and taxes (see Hosking, *et al.*, 2002).

1.5.5 CBA results

Table 1.6 shows the summary of results of the Hosking *et al.* (2002) study. The estimates of costs, benefits and the discount rate were integrated into three decision-making criteria, namely the NPV, IRR, and BCR (see Chapter 6 for detailed discussion and formulae of these decision-making criteria).

Table 1.6 Summary of the Hosking *et al.* (2002) results

	CBA criteria		
Project	**NPV (R)**	**IRR (%)**	**BCR**
Tsitsikamma (agricultural water value) (estuarine water value)	-31 757 404 -55 492 203	5,00 1,20	0,54 0,20
Kouga	-33 854 196	7,25	0,75
Port Elizabeth Driftsands	-14 674 240	0	0
Albany	-15 232 753	1,13	0,21
Kat River	-1 031 609	3,60	0,43
Pot River	-1 446 624	-3,14	0,03

Source: Hosking *et al.*, (2002)

[6] The incremental livestock capacity benefit and agricultural benefit for all six sites are dealt with more comprehensively in Chapter 3 than in Hosking *et al.* (2002).

At a real social discount rate of 10,1%, the BCRs were less than one, the NPVs were less than zero, and the IRRs were less than the social discount rate for all six WfW project sites. When the water benefit in the Tsitsikamma case was valued at the estuarine value, the NPV was less than zero, the BCR less than one, and the IRR less than the social discount rate. The sum NPV of all six projects was also negative, namely, –R97 996 826 (Hosking *et al.*, 2002).

The use of CBA is subject to uncertainties (where the probabilities are unknown) and risks (where the nature of the probability distribution of future events is known). The environmental consequences of projects are seldom known, even though these effects are often irreversible. The use of sensitivity analysis can, to some extent, be used to address concerns about uncertainty in CBA. This type of analysis shows the variation in the measure of project worth, for example of NPV, IRR, and BCR, as changes are made to the values of particular variables.

1.5.6 Sensitivity analysis

A sensitivity analysis was performed by Hosking *et al.* (2002) in which costs were reduced (by increased productivity levels and improvements in management efficiency) and the social discount rate lowered (because some referees of their work were arguing it was too high).

The social discount rate

The viability of the representative WfW sites was calculated with a discount rate of 8.1% and 5.1%. The results are shown in Table 1.7 below.

Table 1.7 Sensitivity analysis results with varying discount rates

Project	**Criterion**	**Discount rate**	
		8,1%	**5,1%**
Kouga	NPV (R) BCR	-15 029 416 0,91	78 304 839 1,37
Tsitsikamma (agricultural water value)	NPV (R) BCR	-27 712 341 0,66	-1 100 502 0,99
Port Elizabeth Driftsands	NPV (R) BCR	-16 942 817 0	-21 491 714 0
Albany	NPV (R) BCR	-16 698 118 0,26	-17 887 841 0,38
Kat River	NPV (R) BCR	-1 003 887 0,51	-638 843 0,75
Pot River	NPV (R) BCR	-1 542 548 0,03	-1 706 982 0,04
Tsitsikamma (estuarine water value)	NPV (R) BCR	-61 405 091 0,24	-66 842 173 0,36

Source: Hosking *et al.*, (2002).

Even with discount rates of 5.1 and 8.1%, the NPV and BCR criteria for the Pot River, Tsitsikamma, Albany, PE Driftsands and Kat River sites were unfavourable, suggesting that at these sites the WfW programme was almost certainly inefficient. The Kouga project yielded a positive NPV value and a BCR that is greater than one when a discount rate of 5.1% was used. For this reason it was deduced that the case for this project was based on the social discount rate being equal to, or below 5,1% (Hosking *et al.*, 2002).

Productivity of clearing teams and management efficiency

Hosking *et al.* (2002) also sensitised the results to reducing clearing costs by 10%, 20% and 30% respectively. This was done on the grounds that cost reductions could be achieved through increases in productivity levels of clearing teams, and improvements in management efficiency, as has already been achieved in some other sites (Marais, 1998). The results of this sensitivity analysis are shown in Table 1.8 below.

Table 1.8 Sensitivity analysis of the effect of improvements in productivity/management efficiency

Site	**10% clearing cost reduction decision-making criteria (10,1%)**		
	NPV (R)	**IRR (%)**	**BCR**
Kouga	-20 508 422	8,20	0,83
Tsitsikamma	-24 826 157	5,70	0,60
Port Elizabeth Driftsands	-13 206 816	0	0
Albany	-13 294 830	1,44	0,24
Kat River	- 851 793	4,10	0,47
Pot River	-1 298 392	-2,99	0,02
Site	**20% clearing cost reduction decision-making criteria (10,1%)**		
	NPV (R)	**IRR (%)**	**BCR**
Kouga	-7 162 647	9,32	0,93
Tsitsikamma	-17 894 911	6,50	0,68
Port Elizabeth Driftsands	-11 739 392	0	0
Albany	-11 356 906	1,80	0,27
Kat River	- 671 978	4,70	0,53
Pot River	-1 150 527	-2,83	0,03
Site	**30% clearing cost reduction decision-making criteria (10,1%)**		
	NPV (R)	**IRR (%)**	**BCR**
Kouga	6 183 126	10,90	1,07
Tsitsikamma	-10 963 664	7,60	0,77
Port Elizabeth Driftsands	-10 271 968	0	0
Albany	-9 418 982	2,24	0,31
Kat River	-492 163	5,60	0,61
Pot River	-1 002 662	-2,63	0,03

Source: Hosking *et al.*, (2002).

Only the Kouga project was positively affected by clearing costs being reduced. The NPV was greater than zero, the IRR exceeded the social discount rate (10,1%), and the BCR was greater than one, if a 30% cost reduction is achieved.

If a social discount rate of 8,1% (instead of 10,%) was used, together with a cost reduction, the Kouga project becomes a viable option. Once again, their case for the Kouga project was a qualified one – it was based on the social discount rate not rising above 8,1%. As argued above, these cost reductions are feasible. In the case at the Kouga site, the number of person days required to clear one hectare fell from 40 days in 1999 to 22 days in 2002[7] (Buckle, pers. comm., 2002), suggesting that clearing cost reductions of up to 30% can indeed be attained.

The Tsitsikamma project proved efficient if a social discount rate of 5.1% was used, and cost reductions of 10% or more were achieved.

1.5.7 Conclusion and recommendations of Hosking *et al.* (2002)

Hosking *et al.* (2002) concluded that all six projects investigated in the Eastern and Southern Cape were inefficient in terms of the water benefit valued at the social discount rate of 10.1%: the NPVs were less than zero, the BCRs were less than one and the IRRs were less than the discount rate.

Their conclusion, however, was subject to three qualifications:

- Except for increased livestock capacity, non-water benefits were excluded.
- At a discount rate of 5%, the Kouga project was deemed feasible.
- With 30% cost savings and a discount rate of 5%, both the projects on the Kouga and Tsitsikamma sites were efficient.

Hosking *et al.* (2002) recommended that activities at four of the six sites – Albany, Kat River, Pot River, and PE Driftsands, be stopped unless high non-water benefits were expected in these sites. They argued that decision makers of the WfW programme should divert their attention to areas where a high demand for water for consumptive use was present. They also noted that widespread use of biological control agents could decrease costs and increase the viability of the programme, because of their cost-effectiveness.

[7] This was mainly due to learning-by-doing.

CHAPTER 2
A CRITIQUE OF THE HOSKING *et al.* (2002) CBA

2.1 INTRODUCTION

The Hosking *et al.* (2002) study has some notable strengths. Its use of actual cost data, scientific approach to the calculation of water benefits, and innovative approaches taken to pricing the estimated water gains are laudable. However, it also has some serious shortcomings. These shortcomings are related to subjective elements and omissions. This critique focuses attention on four of these shortcomings:

a) failure to take into account sustainability in determining the discount rate,
b) failure to take into account the poverty alleviation aspect of the programme in the costing of the WfW programme,
c) the inadequate valuation of the environmental reserve, and
d) making recommendations on the WfW programme on the basis of a CBA that only includes one non-water benefit.

The first three of these are shortcomings are briefly discussed in this chapter. The last one is the subject of the remaining chapters of the study. Chapter 3 reviews the benefit of the increased productive capacity of land freed up through the WfW programme for agricultural and other purposes. Chapter 4 discusses reduced fire-fighting costs as a result of WfW clearing activities. Chapter 5 estimates the benefit of increased ecosystem resilience and biodiversity through the use of contingent valuation procedures. The CBA developed by Hosking *et al.* (2002) is revised in Chapter 6 to include the three non-water benefit values estimated in Chapters 3, 4, and 5.

2.2 SUSTAINABILITY AND THE DISCOUNT RATE

Natural resources are “natural capital” when they yield a flow of future services that are traded in the market place. Their value as natural capital depends on various things, one of which is the discount rate. The role of the discount rate is twofold: it reflects the social opportunity cost of capital (SOCC) for the uncosted component of capital, and it reflects society’s time preference rate (STPR) in the consumption of the natural resource services (Conningarth economists, 2002). The theoretical basis for the determination of a social discount rate is a much-debated issue, especially amongst environmentalists (Quiggin, 1997). It fills a decisive role in the CBA process, but researchers disagree on how it should be set. An efficient discount rate reflects the SOCC and the STPR of the current generation, but many would argue that the preferences of future generations should also be incorporated in determining the social discount rate (Foster, 1997).

The incorporation of future generation interests is rationalised under the sustainability criterion (Quiggin, 1997).

Part of the sustainability debate is over the extent to which natural capital can be substituted for human capital (Foster, 1997). Can physical capital be a true substitute for nature (Foster, 1997)? The weak sustainability criterion treats natural capital as substitutable by manmade capital up to a certain “critical” level (Jacobs, 1995). In contrast, the strong sustainability criterion is based on the premise that human-manufactured capital can never take the place of natural capital in the social welfare function.

Foster (1997) holds the view that strong sustainability is the more moral and ethically correct perspective on nature. This perspective recognises existence value (Willis, 1995).

From both weak and strong sustainability perspectives, high discount rates are seen as a two-edged sword. High discount rates can sometimes discourage development that has negative consequences for nature, but equally, they discourage projects and policies that yield environmental benefits far into the future.

In the United States of America, government institutions typically use a discount rate in line with long-term Treasury bond rates. Although it is a nominal rate, it is nonetheless applied as a real rate. The World Bank utilises the opportunity cost of capital in the determination of discount rates. They employ rates of between 8-15 % in developing countries, with 14% being the most frequently used level (Quiggin, 1997).

Unsurprisingly, the appropriate discount rate of the WfW programme and many other social projects are subject to many opposing views. At first glance the 10.1% social discount rate used in the Hosking *et al.* (2002) study appears quite reasonable, given international practice (see above), as does the fact that a social discount rate of 8% per annum is regularly used for the WfW programme and other projects from the Department of Water Affairs and Forestry (Marais, 1998). Moreover Hosking *et al.* (2002) also undertook a sensitivity analysis with lower discount rates of 5.1 and 8.1%. A discount rate of 8% has also been proposed in other studies in South Africa (Hosking *et al.*, 2002). The South African National Treasury uses a standard discount rate of 10% for public expenditure[8] (Schwartzman, pers. comm., 2003).

[8] The resemblance between the Hosking *et al.* (2002) and National Treasury Department’s discount rate is hardly surprising, given that government expenditure played a central part in the determination of the Hosking *et al.* (2002) discount rate.

The WfW programme competes with other government projects for funding, sourced largely through taxes, which relates to a higher opportunity cost and hence a higher social discount rate. Hosking *et al.* (2002) traced this opportunity cost in their calculations by focusing mainly on taxes, government borrowing and foreign aid. Against this background, Hosking *et al.'s* argument is plausible, that a discount rate of 10.1%, derived through first principles, is efficient.

On deeper reflection however, there are some significant weaknesses in the method used to determine this rate of 10.1%. A project such as the WfW programme will become largely irrelevant after about 30 years if a social discount rate of 10.1% is used, because more of the environmental benefits accrue far in the future and are therefore trivialised (Quiggin, 1997). The WfW programme is a long-term project where eradication of aliens is foreseen within 20 years. However, this target is highly optimistic. The programme seems likely to run for longer (Marais, pers. comm., 2002). For this reason the full benefits of the WfW programme will in all likehood only be realised by future generations. As the costs are most likely to be incurred by the present generation, the programme gives rise to the problem of intergenerational equity. The use of a discount rate of 10.1% effectively renders a weighting of almost zero to the benefits experienced by the future generations.

For an intergenerational perspective, a more equitable weighting would be unity – but this would amount to an argument for a 0%, or very low discount rate. This perspective is particularly reflective of the strong sustainability criterion. It is for this reason that the relatively high discount rate used in the Hosking *et al.* (2002) study is found to be wanting. The rate they selected pre-supposes that a weak sustainability criterion is appropriate. It does not allow for equity between generations (generation discrimination).

Human beings rely on nature for survival. For example, some ecosystems provide us with clean water. For this reason nature should be preserved for the survival of current and future generations. The Hosking *et al.* study (2002) reflects that the Working for Water programme currently does not fulfil this objective at the six representative sites in the Eastern Cape. However, if sustainability played a bigger role in the determination of the discount rate in this study, this rate would be lower. Some compromise between the arguments in favour of a 0% discount rate (concentrating on ethical reasons and intergenerational equity) on the one hand, and a higher discount rate such as the one proposed in the Hosking *et al.* study (2002), (based on efficiency considerations) on the extreme other, needs to be reached. This is not to say that moral considerations should take preference over efficiency, but a balance should be achieved (Jacobs, 1995).

2.3 EQUATING TRANSFERS WITH COSTS AND EXCLUDING WELFARE CONSIDERATIONS

Approximately 70% of WfW's funds are made available through poverty relief funds (DWAF, 2001). For this reason part of the costs (wages) as incorporated by Hosking *et al.* (2002) is a benefit for the people involved in this public works programme. Was it right to treat these wage payments as costs? It could be argued that this money would have been spent on poor people anyway and so these wage payments were really transfers, not costs[9].

By people being actively engaged in the programme, they acquire skills, while at the same time the government gets rid of alien species. The WfW programme specifically targets the poorest of the poor people for its workers: female-headed households in rural areas, disabled people, and unemployed youths[10] (DWAF, 2001). HIV/AIDS training is a particular focus, as "the Working for Water programme works with those living in poverty, and focuses on rural areas, (where) it is likely to have higher than average levels of infection in its ranks".

The Hosking *et al.* (2002) investigation was concerned with efficiency of the WfW programme, and steered away from constructing explicit value judgments on welfare and equity. These issues are difficult to incorporate, to be sure, but difficulty is not a sufficient reason for omission (Rosen, 1995). By avoiding the issues of welfare weighting and equity Hosking *et al.* (2002) implicitly weighted one Rand's worth of the project as being equal for everybody. This weighting makes no distinction between more and less deserving individuals, such as poor and disabled people targeted by the WfW programme. Distributional issues should, however, be kept in mind when policy decisions are made. An alternative to CBA is Multi-Criteria Decision Analysis (MCDA), where the viability of a project depends on multiple factors (Conningarth economists, 2002).

2.4 THE INADEQUATE VALUATION OF THE ENVIRONMENTAL RESERVE

All habitats need a certain amount of water to fulfil ecological functions (Huntley, 1991). This environmental reserve, otherwise known as the minimum flow requirement of rivers or the in-stream flow needs, assumes that beyond a certain point of water extraction from rivers, habitats and biodiversity will be lost owing to interference in ecological processes (Huntley, 1991:270). Many models have attempted to explain the magnitude of the environmental reserve, but in most

[9] Some members of the Economic Development and Resource Economics panel from the WfW argue that, due to the WfW's public works aimed at creating jobs and social upliftment, the labour component must be valued at its shadow price, which in this case would be zero or very close to zero. The wages paid to workers should be seen as a benefit, rather than a cost, implying that it should enter the CBA on the benefit side.
[10] In 2000/1 54% of workers were women, while 24% were young people, and the disabled made up 1% of its labour source (DWAF, 2001).

cases these models still need much more work. The variety of river systems complicates matters further (Huntley, 1991:270).

The Department of Water Affairs and Forestry has acknowledged the requirement of water for environmental needs in rivers throughout South Africa. The recommended allocation was set at 11% of Mean Annual Runoff (MAR). However, this was put forward as a first estimation, and warnings were issued that research on the subject was incomplete: different river systems have different in-stream needs, and, because most rivers would be kept at a functional rather than pristine level, in-stream requirements may differ (Huntley, 1991). In most cases, 11% is seen as the absolute minimum (Marais, pers. comm., 2003).

Not enough is yet known by experts about the value of the environmental reserve to make this kind of judgment with confidence (Huntley, 1991 and Marais, pers. comm., 2002).

Hosking *et al.* (2002) made only limited use of the value of the environmental reserve in their estimation of water values at the six WfW sites. This use took the form of a contingent valuation at the Keurbooms estuary (which was only used in the Albany case). Issues regarding the quality of water were also ignored. There is a distinct possibility that the quality of water has improved at selected sites, because of the WfW programme (Buckle, pers. comm., 2002).

2.5 CONCLUSION

The Hosking *et al.* (2002) investigation has some notable strengths. The derivation of water values for six representative WfW sites was done in a scientific manner, and actual cost data was used. Although the data is not disputed, some shortcomings are evident in the way this data is used in the CBA. These shortcomings include: using a selected sustainability criterion to derive the discount rate; ignoring transfer components and welfare issues with respect to costing of the WfW programme (especially the poverty alleviation aspects), and inadequate valuation of the environmental reserve.

These factors are, admittedly, very difficult to incorporate in CBA, but are important points to take into account from a policy perspective. Last, but by no means least, Hosking *et al.* (2002) excluded some notable non-water benefits in their CBA. Chapters 3, 4 and 5 will discuss the values of three selected non-water benefits. Of these only one was incorporated in the Hosking *et al.* (2002) analysis – that of increased livestock farming. It will be shown that, when these are taken into account, the results of the CBA change significantly (Chapter 6).

CHAPTER 3
THE NET BENEFIT OF POTENTIALLY PRODUCTIVE LAND

3.1 INTRODUCTION

The net agricultural benefit of the WfW programme is the most obvious non-water benefit generated through WfW activities (Marais, pers. comm., 2000). This benefit comprises the gain in potentially productive land. Land freed up through the WfW can be used for various land practices, depending on the ownership of land and what it is suited to (Palmer, pers. comm., 2001). Typical options are livestock production, horticulture and harvesting flowers, honey bush tea, medicinal plants, food, sour figs, buchu, and thatch in fynbos regions (pers. comm., Marais, 2001). Cleared land can also be utilised for commercial afforestation with alien tree species (Marais, Eckert and Green, 2000).

Hosking *et al.* (2002) estimated livestock benefits for the Albany, Kat and Pot River sites, but no other agricultural practices were included in their analysis. This study expands on the benefit calculated by Hosking *et al.* (2002), to include all possible agricultural activities suited to the areas being cleared.

In the derivation of a net benefit of potentially productive land, two steps were taken to simplify the procedure. The first step involved the valuation of respective land uses. The second step entailed a reformulation of the total benefit profile for every site, adjusted for increased water use of the potential agricultural activities. Increased agricultural practices would alter the water use of cleared areas, resulting in a trade-off between increased agricultural production (together with increased income) and increased water runoff. Recognition of this trade-off was the reason for the construction of the revised water benefit profile.

The productive capacities of cleared land are dependent on the terrain. As most of the WfW activities take place in mountainous areas, this productive capacity is substantially lower than that on normal, flat terrain. This chapter values the income benefit that can be gained on this land. The data used for this purpose were obtained from the Department of Agriculture’s records of selected farming practices in its annual Enterprise Budget. These records do not allow accurate estimates to be made, only approximate ones.

3.2 THE METHODOLOGY EMPLOYED BY OTHERS TO CALCULATE VALUES FOR LIVESTOCK BENEFITS

In 1996 a study was done on the impact of knapweed (invasive species) on the economy of Montana, USA (Hirsch and Leitch, 1996). The monetary effect of knapweed on grazing land and wilderness areas was estimated. For grazing land, acres of infested private and public land were estimated. An acre with a patch of knapweed was considered the same as an acre totally infested with the weed, causing that acre to be lost for grazing purposes. Clearing was not assumed to increase the carrying capacity as such, but only the area available for livestock farming. The direct economic impacts on grazing land were divided into reduced income of stock growers and landowners, and reduced production outlays by ranchers. The percentage of land that provides wildland benefits was estimated from survey data. Knapweed impacted negatively on wildlife habitat and watershed capacity. The direct economic impacts were identified as reduced wildlife-associated leisure, increased soil erosion, and reduced water quality. The Montana study made use of an input-output model analysis, where the total direct and secondary economic impacts of knapweed on Montana's economy were estimated (Hirsch and Leitch, 1996:2, 3).

Hirch and Leitch's results indicated that, on an annual basis, more than $14 million was lost directly owing to knapweed infestation. The secondary impacts on Montana's economy pushed this figure up to $42 million per annum, with the loss of approximately 518 jobs (Hirsch and Leitch, 1996:19).

A cost benefit analysis of a soil conservation project done in Eppalock, Australia, in 1979, provides an interesting point of tangency to this study. In the Eppalock analysis, the agricultural benefits owing to improved pastures were calculated (Abelson, 1979). As in this study, the benefits were restricted to those accruing from increased livestock capacity. In the Abelson study (1979:87, 88), the livestock benefit was determined by the following formula:

$$B = \sum_{L=1}^{3} [(Q1-Q2)(P-C) - A(N1-N2)]$$

Where

B	=	net annual agricultural benefit in years that project is running
Q1	=	annual output with project
Q2	=	annual output in base case (without project)
P	=	price per unit of output each year
C	=	variable costs of producing one unit of output
A	=	cost of acquiring additional stock
N1	=	annual number of stock purchased with project

N2	= annual number of stock purchased in base case
L	= livestock categories (wethers, mixed sheep flock and cattle)

The output from livestock (Q1 – Q2) was calculated as a product of the area carrying livestock, the amount of livestock per hectare and the output per head of livestock. Potential stocking rates (carrying capacity) depended on soil types and rainfall conditions (Abelson, 1979:88).

Operating profits for livestock (P – C) were determined in various ways. For sheep, this was done by using historical wool prices (1974 A$) and forecast figures. Shearing, deaths, veterinary costs and dipping made up part of the operating costs, and the composition of the flock was taken into account (for example, 44% wethers, 31% ewes). For cattle, a breeding-cow enterprise was chosen as representative of cattle activities in the catchment area, with costs determined in similar ways. Capital costs of purchasing additional livestock were also included under costs.

In this study, the Enterprise Budget (2002) was used. It contains information on costs and prices, as well as the composition of flocks and herds. This constitutes a similar methodology to that followed in the Eppalock study, but adjustments had to be made, because some information, such as the cost of acquiring additional stock, is included in the Enterprise Budget. The annual number of stock purchased in the base and project case, were not applicable to this study.

3.3 METHODS

The benefit of clearing alien tree and plant species by WfW is that more land becomes available for productive purposes. In order to calculate this benefit, all current farming practices, as well as other suitable land uses, were identified, and their contribution to the area's overall productive capacity was traced. The current ownership of cleared land played a role in the determination of future possible land uses. The assumption was made that land freed up by WfW activities would be used for the best suitable – in most cases the current – farming practices.

The agricultural practices included were categorised under livestock, horticulture, and agronomy (including citrus). Alternative land practices such as wildflower and honey bush harvesting, together with commercial afforestation, were also considered. The contribution of each activity was expressed in terms of a percentage of total productive activity in the area. The potential productive capacity for each site was calculated, using the methods set out below. The net benefit of these activities was then summed.

3.3.1 Valuing the potentially productive capacity of land cleared by the WfW

3.3.1.1 Determination of the net livestock benefit

Six factors were used to develop a model in the determination of the net agricultural livestock benefit. These included:

(i) Hectares available for land use
(ii) Livestock categories
(iii) Carrying capacity
(iv) Level of alien infestation
(v) Hectares cleared
(vi) Margin above cost

(i) Hectares available for land use

The ownership of land is an important determinant of the present and future land use of cleared areas. In most cases, cleared publicly owned land is earmarked for conservation, and there is no foreseeable alternative agricultural use for these areas, except for the Kat River area, where land ownership is still being negotiated between the government and the town of Balfour (Buckle, pers. comm., 2002). The possibility of productive use of state-owned land in the future exists, where such land is accessible and suitable. This could alter the productive capacity of land benefit when land reform policies are ratified and executed in future. This study focused attention on current land ownership in the calculation of the productive capacity of land benefit.

On privately owned land the productive capacity was calculated using the predominant land uses identified by farmers, the Department of Agriculture, and agricultural extension officers in the areas (taking factors such as climate and topography into account). Productive capacity was estimated as a percentage of total productive land use, and the number of hectares for every land use was determined from these percentages. If 60% of clearing was done on privately owned land, it was assumed that 60% of the total number of hectares cleared would be used for farming.

(ii) Livestock categories

Cattle, sheep, and goat farming are the main livestock activities prevalent at the six sites, although game farming is becoming increasingly important at many of them (Buckle, pers. comm., 2002). Goat farming – particularly Angora goat farming – has traditionally made up a substantial part of livestock activity in the Eastern Cape, but has been declining because of the increase in small stock theft (Zeeman and Buckle, pers. comm., 2001).

The 1995 Veterinarian livestock census (Döhne Agricultural Institute, 1996:10) was used to determine the composition of cattle, goat, and sheep farming as percentages of total livestock activity. Agricultural extension officers' estimates were used when Census figures were lacking. The livestock census provided data by magisterial district. The Eastern Cape Province map of regions, sub-regions, agricultural and veterinary offices (Hall, Döhne Agricultural Institute) was used to determine the representative magisterial district of the WfW sites. The Low and Rebelo (1996) map of veld types of South Africa also provided information on natural grazing areas.

(iii) Carrying capacity

Determining the gain in potentially productive land for livestock production for the project sites entailed the establishment of the average carrying capacity in the area. The term “carrying capacity” was developed in agricultural circles to give an indication of the number of animals that could be sustained in an area. The carrying capacity is expressed in terms of hectares per Large Stock Unit (ha/ LSU) and hectares per Small Stock Unit (ha/SSU).

An LSU is defined as a three-year-old cow (dry), weighing 400kg (Departement van Landbou, 1982:2). This unit would typically be a cow belonging to a small frame meat cattle herd, such as Aberdeen or Herefords, or a medium-frame milk cow such as an Ayershire[11]. The carrying capacity gives an indication of the number of animals per hectare that can be sustained, given the amount of foliage (worked out per ton per annum) available (Weitz, pers. comm., 2002).

SSUs can be converted into LSUs by using Meissner conversion tables, where all ratios are expressed in terms of LSUs[12]. Meissner conversion tables enable people to calculate the carrying capacity of almost any animal (game and farm animals) on a piece of land. As a rough estimate, in sweetveld, one LSU is equal to six SSUs (Maphuma & Scheltema, pers. comm, 2000). In the case of SSUs, the ha/LSU unit ratio is divided by six, in order to calculate the carrying capacity per SSU (Maphuma & Scheltema, pers. comm., 2001). If 5.5 ha were needed to sustain one LSU, only 0.92 ha would be needed to sustain one SSU.

No exact carrying capacity figures are available, as capacities vary substantially within the same area, due to factors such as changing slopes, soil types and soil depths (Maphuma, pers. comm., 2000). Moreover, some animals eat bush even though they are grazers by preference - suggesting an overlap in grazing areas and carrying capacity (Zeeman, pers. comm., 2001). For this reason the Döhne Agricultural Institute in Stutterheim and the agricultural extension officer in the area were consulted with respect to each site, in order to determine the carrying capacity in

[11] The assumption was made that only dry milk cows are put on grazing land. Pastures are usually planted for dairy farms, due to the intense nature of such farming practice (Departement van Landbou, 1982:2-4). Planted pastures will yield a higher carrying capacity than dry land (areas not under irrigation, with natural grass).
[12] Sometimes also known as Animal Units (AU).

terms of SSU and LSU. The averages of the carrying capacity provided by them were used. The carrying capacity was for natural veld in good condition with no heavy encroachment of bush.

The use of carrying capacity as a yardstick for grazing potential was criticised by some natural resource managers because it did not provide for natural cycles - such as droughts and wet years. It also does not provide for mixed grazing patterns, such as the combined impact of grazers and browsers (Marais, pers. comm., 2003). For this reason a sensitivity analysis, based on varying the carrying capacity, was undertaken, and is discussed in section 3.5. Carrying capacity figures were used because of the relative ease with which they could be incorporated into a quantitative study.

Ideally, the carrying capacity of indigenous and infested areas should be calculated and compared with each other in order to determine the net agricultural livestock benefit of clearing, but no data was available on the carrying capacity of areas with and without infestation. For this reason, calculations were done on the assumption that the carrying capacity remained constant regardless of the level of infestation, but the area available for livestock farming increased as more alien infestation was cleared.

The over-sowing of cleared areas with grass seeds after clearing can increase grass production and retard the process of re-establishment of bush and alien species, thus retaining grazing capacity for longer (Maphuma, pers. comm., 2000). However, there is a complication with this practice – it comes at a cost, and in no cases could this cost be determined. For this reason the cost of sowing seeds to increase grazing capacity of agricultural land after initial clearing could not be taken into account, and only natural regeneration was provided for.

The rental income per hectare of grazing land was used as a cross-reference for the livestock benefit. Farms in the vicinity of the WfW sites included in this study are rented out at between R25 and R30 per LSU (beef cattle) per month. This rate increases as the intensity of farming activity increases. The going rate for dairy farms, which are intensive in nature, was about R50 per LSU per month in the year 2001 (Jones-Phillips and Weitz, pers. comm., 2002). These rates vary according to the prices received for the agricultural products being farmed[13].

[13] Other ways to derive the rental income per farm per hectare exist. As a rule of thumb, farms in general (e.g. growing crops) can be rented out at a quarter of the income generated by it per year (van der Merwe, pers. comm., 2002), while livestock farms are rented out at approximately 13% of the value of the livestock per year (Weitz, pers. comm., 2002). However, the rental income per hectare was only used as a cross-reference in the estimation of the livestock benefit.

(iv) Level of alien infestation

The level of alien infestation in the sites under consideration was obtained from the WfW offices in the relevant areas. Average infestation levels were used (WfW figures provided a percentage range of infestation levels).

Areas with high infestation levels that are cleared, need rehabilitation through the cultivation of the indigenous vegetation, to provide grazing and to out-compete the regeneration of alien species. The indigenous vegetation takes between one and five years to make a complete return after the clearing of alien vegetation. For this reason cultivated grazing costs needed to be added to total costs in areas where average infestation levels above 10% were prevalent (only the Tsitsikamma site). In some cases teff was planted to help regeneration, especially on land prone to erosion after clearing efforts (Zeeman & Scheltema, pers. comm., 2001)[14].

(v) Hectares cleared

Initial and follow-up clearing operations were undertaken on the WfW sites. Initial clearing was done in the upper parts of mountain catchment areas, as infestation was usually the highest in these areas, and the increased water yield benefit was realised through this action (Hosking *et al.*, 2002).

The average level of alien infestation at each site was multiplied by the number of hectares cleared, in order to condense the area cleared to an equivalent of 100% alien infestation.

(vi) Margin above cost

The difference between the agricultural profit before clearing (smaller area) and after clearing (larger area) is the net agricultural livestock benefit of the WfW clearing programme.

The Enterprise Budget's (2002) margin above cost figures per LSU or SSU were used, where cost included only variable costs. These variable costs, also known as directly allocable costs, comprise medicine, lick and feed, transportation, shearing (in the case of sheep) and marketing costs (see Enterprise Budget, 2002, Department of Agriculture for further details). These costs pertain to 2001 prices.

The margin above cost was determined using the formula:

Margin above cost / LSU or SSU = Total Gross income - directly allocable costs

[14] Average infestation levels were above 10% on the Tsitsikamma site only. Farming practices in this area, primarily dairy farming, are very intensive. Many pastures of Lucerne and teff have been established, not only to replace alien vegetation but also fynbos (Weitz, pers. comm., 2002).

No fixed costs (indirectly allocable costs or overheads) or capital costs, such as fencing, were included in the Department of Agriculture's estimation of the margin above cost (Enterprise Budget, 2002:3,4)[15].

The assumption was made that areas cleared by the WfW and used for livestock purposes would be run by existing farmers (as opposed to new farmers), resulting in no additional fixed costs[16].

3.3.1.2 Determination of a net horticultural[17] benefit

Information from the Enterprise Budget (2002), in conjunction with agricultural extension officers, the Department of Agriculture and the Döhne Agricultural Institute, was used to identify crops suited for the cleared areas. The number of hectares available for horticulture was adjusted for the share of that crop in total horticultural activity and the share of horticulture in total farming activity. The assumption was made that crops prevalent at the site areas would be appropriate for cleared areas.

The difference in cost faced by farmers to clear indigenous vegetation and alien infested areas in the preparation of crop cultivation was estimated. The difference in these costs was multiplied by the number of hectares cleared, and this was deemed to constitute the net horticultural benefit. The agricultural extension officers in the region, as well as individual contractors involved in land clearing operations, provided figures for these costs. It was assumed that farmers would only clear land with low infestation levels (up to 10%), where the cost would amount to labour wages

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[15] Overheads include items such as fuel consumption of tractors and other vehicles, depreciation on vehicles, telephone, electricity, maintenance of implements, insurance and accounting costs (van Rensburg, pers. comm., 2002; Sub-Directorate of Agricultural Economics and Financing, 1998). The most important fixed costs are fences, water (pipes and tanks) and dip facilities (Els, pers. comm., 2002).

Personal visits to farms need to be made in order to assess these types of expenses, because they vary significantly between areas (owing to the topography of the veld). The calculation of overhead costs requires a full analysis of a farm business. Such full farm business analyses were previously done in the South African wheat and maize industries, when the government was still responsible for the setting of prices of these goods. Surveys on other branches of farming, such as citrus, livestock and sugar were done in the 1970s (Antrobus, pers. comm., 2002). No more recent information is available (Antrobus, pers. comm., 2002; Sub-Directorate of Agricultural Economics and Financing, 1998; Els, pers. comm., 2002). The Department of Agriculture in the Eastern Cape does not have figures available on fixed and indirectly allocable costs. It restricts its contribution to consultation by in-house experts in order to assess the viability of farms (Nyokana, pers. comm., 2002).

[16] This assumption was substantiated by the fact that overheads did not vary directly with production, and were usually shared between a number of enterprises. The size of the operation determined the average overhead cost, and not the size of the enterprise (Nyokana, pers. comm., 2002). A map of over/ understocking (stock numbers relating to carrying capacity) of the Eastern Cape, constructed by the Döhne Agricultural Institute (Raath, 1999), revealed that the sites situated in the eastern parts of the Eastern Cape fell within a balanced to overstocked area - strengthening the assumption that additional stock purchases, hence an increase in capital costs - would not be a crucial consideration. For instance, the adjacent area to the east of the Albany site was judged to be severely overstocked, suggesting that increased land for grazing could be used for a better distribution of livestock.

[17] The terms "agronomy" or "crop cultivation" can be used instead of horticulture, as is the case in the Enterprise budget. The term horticulture was used in order to standardise the terms used at all the sites.

(chopping down trees and digging out stumps) and the use of tractors for the removal of stumps (Weitz and van der Merwe, pers. comm., 2003). It would be unprofitable for farmers to clear dense stands of aliens for farming activities, as substantial costs (approximately R6000 per hectare) would be incurred using bulldozers or crawling tractors (van der Merwe, pers. comm., 2003). It was assumed that farmers would previously have cleared infested areas at their own initiative if they were perceived as being fertile. For this reason the only difference between a with- and without-alien infestation scenario would be the cost faced by farmers of clearing indigenous vegetation, and vegetation with scattered infestation levels of up to 10%[18].

The cost of soil preparation, once clearing has been done for crop planting, was not included in the estimation of a horticultural benefit, as these costs (such as phosphate enrichment) would be incurred with or without the presence of alien trees (van der Merwe, pers. comm., 2002). The horticultural benefit captures only the difference in clearing pristine indigenous vegetation as opposed to the clearing of land with infestation levels of 10% or lower.

3.3.1.3 Determination of an afforestation benefit

In the estimation of the value of potentially productive land, all potential land uses need to be taken into account. Commercial afforestation with alien trees makes up a substantial part of the economic land use[19] in areas close to three of the six study sites, namely those of Tsitsikamma, Pot River and Kat River (Morgan, pers. comm., 2002; Buckle, pers. comm., 2002). This type of land use was not included in the determination of a net agricultural benefit, as WfW policy attempts to steer away from clearing land for commercial afforestation purposes (Buckle, pers. comm., 2002), because it would be counterproductive to clear a crop of land in order to establish the same crop again.

Most clearing at the WfW project sites takes place in mountain catchment areas with steep slopes that are difficult to access (Buckle, pers. comm., 2002). This access problem most often rules commercial afforestation out as a viable option. In addition, some mountain catchment areas do not satisfy legal water-table requirements. Government laws state that plantations may only be established in areas where the water table is more than 1 metre deep (Buckle, pers. comm., 2002). In the Tsitsikamma, the financial viability of increased commercial afforestation is also threatened by the regular occurrence of fires (Marais, pers. comm., 2003).

[18] The decision to clear alien infested land depends on each farmer's individual situation. In some areas in the Kouga (along rivers in the Langkloof and Patensie) farmers would spend substantial amounts of money on bulldozers for the clearing of fertile land. In general, however, land on which fynbos grows is not very fertile (Buckle and van der Merwe, pers. comm., 2003).

[19] In the Eastern Cape, plantations of predominantly *Pinus spp.* are found.

3.3.2 Revised total benefit profile

Cleared land can be used for productive purposes such as agriculture, including livestock and horticultural practices. Agricultural practices would alter the water use in cleared areas, impacting on the water benefit calculated by Hosking *et al.* (2002). Although income can be generated through these agricultural practices - constituting the benefit of potentially productive land – these activities require water. For this reason it was necessary to determine the water use of each potentially productive land activity in order to assess the trade-off between increased water use and increased land activity. The increase in water required by these activities was included in a revised water benefit profile, with the aim of constructing the optimal benefit profile for each site.

The water requirements for various crops grown under similar environmental circumstances differ widely owing to genetic factors, population density and planting configuration (Green, 1985:1). For these reasons various environmental, water, management, weather, soil, and economic aspects need to be included in the estimation of water requirements and irrigation needs. Two methods have been devised to estimate the water requirements of crops in South Africa. The Department of Agriculture and Water Supply's Estimated Irrigation Requirements of Crops in South Africa (Green, 1985) provides water requirements for various crops, based on pan evaporation. This method implies that over a given time period, evapotranspiration (the daily rate of water loss) occurs in direct proportion to evaporation from a pan (Green, 1985:6).

The second method applies the computer programme Sapwat in order to obtain water requirements of crops, with evapotranspiration dependent on evaporation from a grasscover, instead of a pan (Kruger, pers. comm., 2002). Essentially, three steps are followed in the estimation of the water requirement of a crop. During the first step, the amount of water needed by the crop is calculated, then the rainfall efficiency is established, and lastly the difference between these steps – constituting the irrigation requirement – is determined (Kruger, pers. comm., 2002). Both these methods have been subject to criticism, but are widely used in irrigation decisions, as no alternative is available. Results from both methods were used in the determination of water requirements of potential crops at the WfW sites. A normal growing season, as opposed to a very favourable or unfavourable one, was assumed, with 100% evapotranspiration.

3.4 CALCULATIONS

The livestock benefits for the Albany site was calculated using the steps set out in section 3.4.1.1 and 3.4.1.2. Similar calculations were also carried out for all the other sites.

3.4.1 Albany

The agricultural potential of regions differs because of differing climatic and soil conditions. The Albany region is suitable for ostrich, game farming, beef cattle and small stock enterprises (goats and sheep for wool and mohair purposes). Chicory, cabbage and pineapple growing are potential enterprises for areas closer to the coast (Department of Agriculture, leaflet; Morgan, pers. comm., 2002).

3.4.1.1 Livestock benefit – LSUs

Most livestock practices (40%) in the Albany area are centred on game farming (kudu). The remainder of livestock farming is taken up by cattle (approximately 6%), goat (17%) and sheep (37%) farming (Veterinary livestock census, 1995, Hahndiek, pers. comm., 2002). The Enterprise Budget[20] (2002:3, 4) contains projected cost and income flows for beef cattle in the Queenstown area. Similar flows apply to the Albany region (Zeeman, pers. comm., 2002).

Most cattle farmed in the area are targeted for the beef market. Although some pastures are planted for dairy, this type of farming is relatively minor here. Two budgets for a beef cattle herd were available – that for weaned calves and excess heifers sold at 7 or 30 months respectively, and that of cattle sold at 7 or 12 months, or mated at 15 months. The net cattle benefit was calculated for both these budgets, with the average representing the overall net agricultural livestock benefit for cattle.

In order to establish the goat benefit, two budgets were used - a Boergoat ewe flock from the Grahamstown area, weaned at 5 months and sold at 6 or 10 months, and an Angora breeding ewe flock, also from Grahamstown, sold at 6 or 18 months (Enterprise Budget, 2002:2,5).

Sheep are farmed for both wool and meat (Scheltema, pers. comm., 2001). Döhne Merino sheep are typically used to produce wool, and Dorpers typically used to produce meat (Department of Agriculture, 1982:3). Two sheep Enterprise Budgets were included - that for a Dorper ewe flock from the Grahamstown region, assuming that ewes lamb 3 times in 2 years and that lambs were sold at 5 months, and that for a Döhne Merino ewe flock, also from the Grahamstown area, assumed to be weaned at 5 months and sold at 6 months (Enterprise Budget, 2002:9).

The average net cattle, goat, and sheep benefits, as percentages of the livestock activity in the Albany region, were determined by multiplying the average margin above cost of each livestock

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[20] The Enterprise Budget is often condemned for underestimating the true economic potential of land according to scientists, and underestimating it according to landowners. It is, however, published every year and contains information which would otherwise be hard to come by, as the calculation of such budgets is a tedious process. For this reason it is used regularly and deemed as fairly reliable by the experts (Els and Nyokana, pers. comm., 2002).

activity by the number of hectares available for that activity. The number of hectares available for every activity was determined from the landownership and current land practices in the area.

Table 3.1 below lists the steps followed in order to derive the net agricultural livestock benefit for the Albany site.

Table 3.1 Calculation of the beef cattle (LSU) benefit in step form on the Albany site

Step	Description	Beef cattle (Queenstown, sell at 7, 30 months)	Beef cattle (Queenstown, sell at 7, 12 months)
1	Hectares (total) under WfW clearance	11 400	11 400
2	Hectares with equivalent 100% infestation	860.7	860.7
3	Hectares used for livestock farming	258.21	258.21
4	% of beef in all livestock activity (including game)	6	6
5	Hectares available for beef activity	15.49	15.49
6	Hectares / LSU	5.5	5.5
7	Number of LSU on land (ha) available for beef activities	2.82	2.82
8	Margin above cost/LSU (in Rand)	592.23	789.23
9	Beef cattle benefit (in Rand)	1 668.21	2 223.13
10	**Average beef cattle benefit (R)**	**1 945.67***	
11	**Average beef cattle benefit per hectare (R)**	**125.59**	

* This is a weighed benefit; the other components of the livestock benefit are discussed in section 3.4.1.2 below.

Step 1 : Determination of the number of hectares earmarked for clearing by the WfW.

Step 2 : The number of hectares actually cleared (100% infestation equivalents) was determined. It was assumed that the carrying capacity of the land would stay constant, regardless of the infestation level - only the area available for farming/ grazing would decrease as a result of infestation. At the Albany site, the average infestation level amounted to 7.5%, and 11 400 ha infested were earmarked for clearing. Hence the total area to be cleared of alien tree infestation was 860.7 ha.

Step 3: The land that could be used for livestock farming was identified. Only 30% of land cleared was on private land. For this reason only 30% of the total land cleared could be used for private farming activities.

Step 4: The beef cattle component of the livestock total was then identified. Beef cattle farming made up 6% of all livestock activity, as set out in the 1995 Veterinarian livestock census.

Step 5: The number of hectares available for livestock farming was then adjusted for that proportion used for beef cattle (i.e. 6%).

Step 6: The average carrying capacity was determined from information supplied by the Döhne Agricultural Institute and agricultural extension officers.

Step 7: The additional number of LSUs held on the cleared land was calculated by dividing the hectares available for beef cattle farming by the carrying capacity. The cleared land would increase the amount of LSUs by a factor of 2.82.

Step 8 : The profit per LSU was then determined. It was estimated from the Enterprise Budget (2002). Margin above cost was expressed in terms of LSU/SSU (which is the standard). The margin above cost for an enterprise stays constant, but the number of LSUs accommodated in the Albany area would increase because of WfW activities.

Step 9 : The total benefit of increased cattle stocking was calculated as the margin above cost per LSU multiplied by the number of LSUs kept on the cleared area.

Step 10 : The average of two beef cattle enterprises was used for the purpose of this valuation. The same was done for the net goat and sheep livestock benefit, as farming with mixed herds occurred (Angora goats, Boergoats, Merino's and Dorpers).

Step 11: The average beef cattle benefit was divided by the number of hectares available for this activity.

3.4.1.2 Livestock benefit – SSUs

The steps followed to determine the benefit of sheep and goats were essentially the same as those followed for cattle (see Table 3.2), the only exception being that the LSU values were replaced by SSU values. In the case of SSUs, the ha/LSU unit ratio was divided by 6, in order to acquire the carrying capacity per SSU, as it is estimated that the area of land required to carry 1 LSU is sufficient to carry 6 SSUs (Maphuma & Scheltema, pers. comm., 2001).

Table 3. 2 Calculation of the goat benefit (SSU) in step form on the Albany site

Step	Description	Boergoat ewe flock	Angora breeding ewe flock
1	Ha (total) under WfW clearance	11 400	11 400
2	Hectares with infestation if 100% infested	860.7	860.7
3	Ha used for farming	258.21	258.21
4	% of goats in all livestock activity (including game)	17	17
5	Ha available for goat activity	43.9	43.9
6	Ha / SSU	0.92	0.92
7	Number of SSU on ha cleared by WfW activities	47.89	47.89
8	Margin above cost/LSU (in Rands)	182.54	240.68
9	Goat benefit (in Rands)	8 741.15	11 525.25
10	**Average goat benefit (R)**	**10 133.21**	
11	**Average goat benefit per hectare (R)**	**230.85**	

Following the same procedure as for Table 3.1, the sheep benefit was calculated in Table 3.2 at R 23 210.45. This benefit amounted to R 242.95 per hectare per year.

The kudu benefit was determined, assuming it constituted 40% of all livestock activity[21]. This benefit amounted to R10 963.13 per year, or R106.15 per hectare per year.

The agricultural livestock benefit was determined as the sum of the cattle (6%), sheep (37%), goat (17%) and kudu (40%) benefit. The total benefit amounted to R46 252.45 per year, or R179.13 per hectare per year.

3.4.1.3 Horticultural/-agronomic benefit

Some agronomic activities, such as cabbage, pasture, pineapple and chicory farming (Morgan, pers. comm., 2002) occur in the Albany area. These activities are established on farms closer to the coast, near Alexandria, Kenton on Sea and Port Alfred (Nyokana, pers. comm., 2002), and not in the area being cleared by the WfW programme. For this reason no horticultural benefit is relevant to this site.

3.4.1.4 Revised total benefit profile

The water use per LSU and SSU respectively is 50 litres and 10 litres per day (Zeeman, pers. comm., 2002). This use sums to an increase of 1017.8 cubic metres per year for livestock farming.

[21] Game farming in the Albany region has steadily been increasing (Hahndiek, pers. comm., 2002). Ostrich farming used to be another productive enterprise, but has shown a steady decline in the last couple of years, and has not be included (Hahndiek, pers. comm., 2002).

According to Hosking *et al.* (2002), the value of water in Albany is approximately 4.9 cents/cubic metre (at 2001 price levels). This value was set by proxy - using the value of freshwater inflows into the Keurbooms estuary. At this price, and with an increased livestock water consumption of 1017.8 cubic metres, the net benefit of potentially productive land at the Albany site would decrease to R46 202.96. After making this deduction, the agricultural benefit of the WfW programme in the Albany site works out to be R178.94 per hectare per year [22] (see Table 3.3).

Table 3.3 Summary of the net agricultural benefit on the Albany site

Agricultural activity	**Number of hectares available**	**Total net benefit (R)**	**Water use cost (R)**	**Net benefit adjusted for water use (R)**	**Net benefit per hectare (R/hectare)**
Livestock	258.21	46 252	50	46 202	178.94

The total number of hectares earmarked for clearing at the Albany site will only be cleared over a period of 20 years. For this reason only a part of the agricultural benefit would be realised in year 1 of clearing, increasing every year as more clearing is done. This increase was based on WfW managers' assumptions on the proportion of hectares cleared per annum (Hosking *et al.*, 2002). For this reason the full benefit of R46 202.96 would only be realised in year 20. This benefit would be the current one, based on a constant infestation level of 7.5%. However, alien infestation levels increase over time, and without the WfW programme this level of infestation would also intensify. For this reason the agricultural benefit in future would be higher than the current benefit as a result of WfW clearing. Alien trees are removed and cannot spread. The current benefit had to be adjusted for the rate of spread of alien trees.

Hosking *et al.* (2002) made use of fire cycles in the determination of the rate of spread of alien trees. The same method could not be applied in this study. Fires diminish the amount of grazing land available. The assumption was made that the per-hectare benefit would increase in future, in line with the rate of spread of alien trees. This rate of spread was set at 1% per annum up to an infestation level of 40%, starting at year 1. It follows that this infestation level would be attained in year 32, starting from an average infestation level of 7.5% in year 1 (Hosking *et al.*, 2002). The agricultural benefit would increase from year 1 onwards in line with the proportion of hectares cleared, as set by WfW managers, and the assumed rate of spread. The increase in the agricultural benefit over time is shown in Table 3.4.

[22] In order to reach a per-hectare figure the net benefit of the condensed cleared land is divided by the amount of hectares cleared if it was assumed that a 100% infestation level prevailed.

Table 3.4 Increase in the net agricultural benefit over time on the Albany site

Year	Rate of spread (%)	Proportion cleared*	Factor increase in agricultural benefit**	Net agricultural benefit (R)
1	0.01	0.0017	0.0117	540.57
2	0.02	0.1278	0.1478	6828.78
3	0.03	0.2353	0.2653	12257.65
4	0.04	0.257	0.297	13722.28
5	0.05	0.3034	0.3534	16328.13
6	0.06	0.3499	0.4099	18938.59
7	0.07	0.3963	0.4663	21544.44
8	0.08	0.4427	0.5227	24150.29
9	0.09	0.4892	0.5792	26760.75
10	0.1	0.5356	0.6356	29366.60
11	0.11	0.582	0.692	31972.45
12	0.12	0.6285	0.7485	34582.92
13	0.13	0.6749	0.8049	37188.76
14	0.14	0.7213	0.8613	39794.61
15	0.15	0.7678	0.9178	42405.08
16	0.16	0.8142	0.9742	45010.92
17	0.17	0.8606	1.0306	47616.77
18	0.18	0.9071	1.0871	50227.24
19	0.19	0.9535	1.1435	52833.08
20	0.2	1	1.2	55443.55
21	0.21	1	1.21	55905.58
22	0.22	1	1.22	56367.61
23	0.23	1	1.23	56829.64
24	0.24	1	1.24	57291.67
25	0.25	1	1.25	57753.70
26	0.26	1	1.26	58215.73
27	0.27	1	1.27	58677.76
28	0.28	1	1.28	59139.79
29	0.29	1	1.29	59601.82
30	0.3	1	1.3	60063.85
31	0.31	1	1.31	60525.88
32	0.32	1	1.32	60987.91

* Source: Hosking *et a*l., (2002).
** This is the sum of the rate of spread and proportion cleared.

From Table 3.4 it follows that, as a result of the incorporation of a rate-of-spread component, the future agricultural benefit exceeds the current agricultural benefit of R46 202.96 from year 17 onwards. This benefit would increase up to year 32, when the assumed infestation level of 40% is reached. From year 32, this benefit would stay constant at R60 987.91 per annum.

The rental income and annual rate of return on farms

The rental income of farms, as well as its capital value per hectare (and the resultant discount rate), were used as a cross reference to check the net benefit of potentially productive land. Although rental values exist, and the Land Bank of South Africa also calculates the monetary value of farms, these values are extremely case-specific and ultimately depend on the personal decision of the farmer renting out or selling his/her land. The increasing tendency of foreigners to buy land in South Africa for more than its domestic selling value, because of the relatively weak Rand, also limits the accuracy of these calculations (Esterhuize, pers. comm., 2003).

The rental income for the hectares cleared for livestock farming in Albany amounted to R15 492.60 or R60 per hectare per year. A total of 46.9 LSUs can be accommodated on the 258 hectares cleared by WfW, at R30 per LSU per month (Jones-Phillips, 2000).

The average market value of veld-type farms in the Albany region amounts to R1250 per hectare (Nel, pers. comm., 2003). As a percentage of this value, the net benefit of land cleared by WfW (R178/ha) in the Albany area, is 14.3%.

3.4.2 Pot River/Ugie

Pot River falls in the Ugie area. Farming activities in the Ugie area are concentrated around livestock (beef cattle, goats, and sheep) and crops (horticulture). The two major crops are potatoes and maize, while winter cereal is also planted as pastures (Morgan, pers. comm., 2002). All WfW activities are conducted on privately owned land on the Pot River site. The assumption was made that the land freed up through the WfW project would be used in the same way as it was elsewhere in the area.

The carrying capacity, infestation level, and hectares available for productive capacity at the Pot River site area are described in Table 3.5.

Table 3.5 Information regarding productive capacity on the Pot River site

Description	Value
Carrying capacity (Ha/ LSU)	4.25
Average infestation level (%)	0.55
Hectares available for productive capacity	2.7

Sixty per cent of the area farmed is used for livestock farming, and 40% for horticulture and crops (Morgan, pers. comm., 2002). This would imply that 1.62 of the 2.7 hectares being cleared would be used for livestock, and 1.08 hectares for horticultural production.

3.4.2.1 Livestock benefit

Cattle farming makes up 32.9% of all livestock activity, goat farming 0.57%, and sheep farming 66.5% (Veterinary livestock census, 1995). This implies that of the 1.62 hectares set aside for livestock farming, 0.53 hectares would be used for beef cattle farming, 0.01 hectares for goat farming, and 1.08 hectares for sheep farming. The Enterprise Budget (2002:3, 4) contained budgets for beef cattle in the Queenstown area only, but similar figures could be expected to apply in the Ugie region (Zeeman, pers. comm., 2002). The same budgets as those used for beef cattle at the Albany site were incorporated. A budget is provided for weaned calves and excess heifers sold at 7 or 30 months respectively, and a budget is provided for cattle sold at 7 or 12 months. The net cattle benefit was calculated for both these budgets. The average of these two budgets was deemed to be the overall net agricultural livestock benefit for beef cattle.

The Boergoat ewe flock from the Grahamstown area, weaned at 5 months and sold at 6 or 10 months, and an Angora breeding ewe flock, also from Grahamstown, sold at 6 or 18 months, were used to estimate the value of goat farming (Enterprise Budget, 2002:2,5).

For the estimation of a sheep benefit, three reference flocks were used: a Döhne Merino ewe flock from the Queenstown area, weaned at 4 months and sold at 18 months (Enterprise Budget, 2002:8); a Merino ewe flock, also from the Queenstown area, weaned at 5 months and sold at 6 months (Enterprise Budget, 2002: 13); and Dormer ewe flock, from Cathcart, weaned at 4 months and sold at 6 months (Enterprise Budget, 2002: 6).

These reference points were chosen because the sheep in the area are utilised for both meat and wool production. The Döhne Merino and Merino were chosen as examples of wool sheep, while Dormers were chosen because they are multi-purpose sheep (Department of Agriculture, 1982:3-4).

The calculation of the livestock benefit for Pot River was done in an identical manner to that for the Albany site. The livestock data used to calculate the livestock benefit is shown in Table 3.6 below.

Table 3.6 Livestock data used to calculate the livestock benefit for the Pot River site

Description	**Average margin above cost (R)**	**Hectares available for activity**	**Number of LSU/SSU on area**	**Livestock benefit (R)**	**Livestock benefit per hectare (R)***
Beef cattle	690.73	0.53	0.13	86.46	162.52
Goat	211.61	0.01	0.01	2.75	298.74
Sheep	120.64	1.08	1.52	244.19	227.10
TOTAL		**1.62**		**333.40**	**206.19**

* This calculation depicts the benefit per hectare for each livestock activity, assuming that one hectare is available for each practice.

The livestock benefit at the Pot River site amounted to R333.40 per year for the total area cleared and used, or R206.19 per hectare per year.

3.4.2.2 Horticultural/agronomic benefit

Forty percent of potentially productive land in the Pot River area is used for horticulture (Morgan, pers. comm., 2002). For this reason, of the 2.7 ha freed up through WfW activities, only 1.08 ha would be expected to be used for this type of farming. The major crops grown are maize (60%), potatoes (30%), and winter cereal (10%) (Morgan, pers. comm., 2002). The growing of winter cereal was excluded from the calculation of the horticultural benefit, because it is usually planted by livestock farmers for winter grazing for their own livestock, and not for sale in the market. The benefit of this crop is largely a reduction in farmers' grazing costs.

The horticultural benefit of the WfW programme was deemed to be the difference in cost between clearing indigenous vegetation and alien infested land for crop cultivation. The cost of clearing indigenous vegetation in 2001 was approximately R150.00 per hectare (Cobbold and Weitz, pers. comm., 2002). The preferred method for clearing of indigenous bush is through burning, as the burned organic material provides minerals for the soil. The only cost is that of labour used for supervision of the fire (Weitz, pers. comm., 2002). Tractors and ploughs are also sometimes used for clearing bush, but the vegetation type in Ugie is predominantly grassland (Meyer, pers. comm., 2002).

Farmers' cost of clearing alien infested areas entailed the digging out and removal of alien tree stumps. No follow-up costs were provided for, because it was assumed that the establishment of crops would out-compete alien regeneration. The average relative alien infestation level was used to estimate the number of stumps to be removed on a hectare of infested land. In the Pot River area, the average infestation level was estimated at 0.55%, which amounted to approximately 40 adult alien tree stumps to be removed per hectare, provided the density per hectare of predominantly *Acacia spp*. is used (Buckle, pers. comm., 2003). It was assumed that three tree stumps could be dug out manually per day (at a cost of R30 per day, or R10 per tree), while a tractor would be used for 2 hours at a rate of R100 per hour to remove the stumps (van der Merwe, pers. comm., 2003). The total would amount to R600: R200 for the tractor, and R400 for the labour. The horticultural benefit (the difference between the cost of clearing indigenous vegetation and alien infested land) was therefore R450 per hectare, or R486 for the total number of hectares available for horticulture at the Pot River site (see Table 3.5).

The cost of land preparation was not included in the above calculation, because this preparation would be done irrespective of the vegetation cover at the site[23].

[23] Ripping and discing of grassland (at R400 per hectare) (Cobbold, pers. comm., 2002), together with fertilizer and phosphate treatment would be done in both cases after clearing.

Table 3.7 The horticultural benefit on the Pot River site

Description	Value
Ha used for horticulture	1.08
Cost of clearing indigenous land (R/ha)	150
Cost of clearing infested land (R/ha)	600
Difference in cost of clearing (R)	450
Total horticultural benefit (R)	**486.00**

3.4.2.3 Revised total benefit profile

Water is not a scarce resource in the Ugie area. For this reason, it has a scarcity value of zero (Hosking, *et al.*, 2002). It is deduced that the expansion of current land uses - and increased water requirement - via increased horticultural and livestock performances would not impact on the increased water yield benefit.

Table 3.8 Summary of the net agricultural benefit on the Pot River site

Agricultural activity	Number of hectares available	Benefit (R)	Water use cost (R)	Net benefit adjusted for water use (R)	Net benefit per hectare (R/hectare)
Livestock	1.62	333.40	0	333.40	206.19
Horticulture	1.08	486.00	0	486.00	450.00
Afforestation	0	0	0	0	0
TOTAL	**2.70**	**819.40**	**0**	**819.40**	**304.05**

The summed net benefit of potentially productive land yielded through the WfW programme would amount to R819.40 per year, or R304.05 per hectare per year (see Table 3.8).

The total clearing of alien infestation at the Pot River site was expected to take 4 years. The agricultural benefit could be expected to increase, in line with the WfW managers' projections of the proportion of land cleared every year (Hosking *et al.*, 2002). The total benefit would be realised from year 5 onwards. However, as is the case with the Albany site, this constitutes the current benefit, and the future benefit could be expected to be higher than the current one, based on the assumption that WfW activities ensure that aliens do not spread. As a result more land would be available for agricultural use in the future. The rate of spread of alien trees was set at 1% per annum, and the agricultural benefit would increase over time by the factor of the increase in the proportion of land cleared and the rate of spread per annum. As the average infestation level at the Pot River site was set at 0.5%, the assumed infestation level would be achieved in year 39, as shown in Table 3.9.

Table 3.9 Increase in the net agricultural benefit over time on the Pot River site[24]

Year	Rate of spread	Proportion cleared*	Factor increase in agricultural benefit**	Net agricultural benefit (R)
1	0.01	0.3571	0.3671	300.80
2	0.02	0.4469	0.4669	382.58
3	0.03	0.7693	0.7993	654.96
4	0.04	0.8857	0.9257	758.52
5	0.05	1	1.05	860.37
6	0.06	1	1.06	868.56
7	0.07	1	1.07	876.76
8	0.08	1	1.08	884.95
9	0.09	1	1.09	893.15
10	0.1	1	1.1	901.34
11	0.11	1	1.11	909.53
12	0.12	1	1.12	917.73
13	0.13	1	1.13	925.92
14	0.14	1	1.14	934.12
15	0.15	1	1.15	942.31
16	0.16	1	1.16	950.50
17	0.17	1	1.17	958.70
18	0.18	1	1.18	966.89
19	0.19	1	1.19	975.09
20	0.2	1	1.2	983.28
21	0.21	1	1.21	991.47
22	0.22	1	1.22	999.67
23	0.23	1	1.23	1007.86
24	0.24	1	1.24	1016.06
25	0.25	1	1.25	1024.25
26	0.26	1	1.26	032.44
27	0.27	1	1.27	1040.64
28	0.28	1	1.28	1048.83
29	0.29	1	1.29	1057.03
30	0.3	1	1.3	1065.22
31	0.31	1	1.31	1073.41
32	0.32	1	1.32	1081.61
33	0.33	1	1.33	1089.80
34	0.34	1	1.34	1098
35	0.35	1	1.35	1106.19
36	0.36	1	1.36	1114.38
37	0.37	1	1.37	1122.58
38	0.38	1	1.38	1130.77
39	0.39	1	1.39	1138.97

* Source: Hosking *et al.*, (2002).
** This is the sum of the rate of spread and proportion cleared.

As a result of the incorporation of a rate-of-spread component, the future agricultural benefit exceeds the current agricultural benefit of R819.40 per annum. The total benefit would be realised from year 39 onwards, when the assumed alien infestation level of 40% is reached.

[24] Horticultural activities would have a negative impact on the indigenous vegetation (biodiversity) benefit (determined in Chapter 5) and both cannot be accommodated. In terms of opportunity costs, the biodiversity benefit would be the best alternative. For this reason, the agricultural benefit in the CBA calculated in Chapter 6 is the livestock benefit of R333.40 only. See Chapter 6 for the discussion.

The rental income and annual rate of return on farms

The rental income for grazing for the 1.62 ha freed up in Pot River amounted to R125.79, or R77.6 per hectare per year in 2002.

The average market value of farms in the Ugie area amounts to R1600 per hectare (Els, pers. comm., 2003). As a percentage of this value, the net benefit of land cleared by WfW (R819/ha) in the Kat River area is 19%.

3.4.3 Port Elizabeth Driftsands

The PE Driftsands site forms part of the Nelson Mandela Metropole and falls mostly under the control of the metropolitan authority. There is no agricultural activity on the PE Driftsands site, and no increase in potentially productive land was envisaged in this area as a result of WfW clearing efforts. The re-introduction of game for recreational and tourism purposes is currently being negotiated, under the auspices of the Madiba Bay project. The contribution of WfW activities to the appeal of the area is captured as people's preference for indigenous vegetation, and is discussed in Chapter 5.

3.4.7 Kat River/Balfour

Approximately 30% of the Kat River WfW site is privately owned land (six existing farms). The other 70% is on government property (van der Merwe, pers. comm., 2002). Farming in the Kat River area includes citrus, crop growing and livestock farming. Tobacco used to be grown, but the amounts grown have steadily declined. An estimated 75% of farming is centred on crop growing and horticulture, and 25% on livestock. Citrus makes up 70% of all horticulture, 10% of crops consist of cabbage, and the remaining 20% is unutilised, or left idle for rotation purposes (Morgan, pers. comm., 2002). The carrying capacity, infestation level, and hectares available for productive capacity at the Kat River site area are shown in Table 3.10.

Table 3.10 Information regarding the productive capacity on the Kat River site

Description	**Value**
Carrying capacity (Ha/ LSU)	4.60
Average infestation level (%)	3.05
Hectares available for productive capacity	36.48

3.4.4.1 Livestock benefit

Beef cattle, sheep and goat farming are the predominant livestock activities in the area, but small stock farming (goats and sheep) has decreased owing to increased theft. Beef cattle farming makes up 10% of all livestock activity, goat farming 26%, and sheep farming 64% (Veterinary livestock census, 1995). Of the total area cleared, it would be expected that only 30% would be used for agricultural purposes, and of that, only 25% for livestock farming. It follows that the amount of land made available for beef cattle, sheep and goat farming through the WfW project would be expected to be a mere 2.74 hectares.

Once again, the Enterprise Budget (2002:3, 4) containing budgets for beef cattle in the Queenstown area, was used to estimate the benefit values. Two budgets were used: one for weaned calves and excess heifers sold at 7 or 30 months respectively, and one for cattle sold at 7 or 12 months, or mated at 15 months. The net cattle benefit was calculated for both these budgets. The average of these two calculations was taken to be the overall net agricultural livestock benefit for beef cattle.

The Boergoat ewe flock from the Grahamstown area (weaned at 5 months and sold at 6 or 10 months), and an Angora breeding ewe flock (from Grahamstown, sold at 6 or 18 months), were used to estimate the value of goat farming (Enterprise Budget, 2002:2,5).

Dorper, Dormer and Döhne Merino ewe flock budgets were used to estimate the value of sheep farming (Enterprise Budget, 2002:6, 7, 9). In the Dormer case, an Enterprise Budget from Cathcart, where the lambs were weaned at 4 months and sold at 6 months, was used. A Dorper Enterprise Budget from the Grahamstown region, with ewes lambing 3 times within a 2 year period and sold at 5 months, was used. In the Merino case, a Grahamstown enterprise was selected where lambs were weaned at 5 months, and sold at 6 months. These Enterprise Budgets were chosen because sheep were utilised for both meat and wool purposes.

The calculation of a livestock benefit for Kat River was done in the identical manner to that done for the Albany and Ugie sites. The information used in the calculation of the livestock benefit is shown in Table 3.11.

Table 3.11 Information used to calculate the livestock benefit for the Kat River site

Description	**Average margin above cost (R)**	**Hectares available for activity**	**Number of LSU/SSU on area**	**Livestock benefit (R)**	**Livestock benefit per hectare (R)***
Beef cattle	690.73	0.27	0.06	41.08	150.16
Goat	211.61	0.71	0.93	196.34	276.01
Sheep	209.34	1.75	2.28	478.09	273.05
TOTAL		**2.74**		**715.51**	**261.52**

* This calculation depicts the benefit per hectare for each livestock activity, assuming that one hectare is available for each.

The total gain in agricultural output from clearing at the Kat River site was estimated at

R715.51 per year. The contribution of each livestock activity per hectare, according to the number of hectares assigned to each activity, is as follows: R150.16 for beef cattle, R276.01 for goats, and R273.05 for sheep[25] (see Table 3.11).

3.4.4.2 Horticultural/agronomic benefit

Citrus farming is the most important productive activity in the Kat River area (70% of all crops), but it was not included in the estimation of a potential productive capacity. Most WfW clearing in this area is done in catchment areas, in narrow river valleys or steep slopes - fairly inaccessible areas. This land is not suitable for citrus farming (Buckle, pers. comm., 2002). However, there is some scope in the area for cabbage cultivation – on 10% of the land, i.e. 0.82 ha.

The cost of clearing indigenous vegetation amounts to approximately R150 per hectare, using the same methods of clearing as that for Ugie[26] (Weitz, pers. comm., 2002). The cost faced by farmers for clearing land infested with alien vegetation depends on the labour and equipment used. The average current infestation level is 3.05%, which related to a density of approximately 25 adult stems per hectare for Pine and Blackwattle trees (Buckle, pers. comm., 2003). It was estimated that a tractor would be used for stump removal for 2 hours, at a rate of R100 per hour, while the labour to dig out the stumps was estimated at R250 (R10 per tree). The difference in the cost of clearing alien vegetation, as opposed to indigenous vegetation for crop cultivation – and hence the horticultural benefit – was calculated at R300 per hectare. This amounted to R246 for the area assigned to horticulture at the Kat River site (0.82 hectares).

Revised total benefit profile

The total water requirement for increased livestock activity (including cattle, sheep and goats) sums to 12.81 cubic metres per annum. The time of planting is a crucial factor in the determination of the water requirement of cultivated crops. The cultivation of cabbage in the Kat River area cannot take place without irrigation (Kruger, pers. comm., 2002), because dry-land cultivation would lead to more than a 50% loss. For this reason, a cabbage crop's water requirement varies between 3500 and 5000 cubic metres per hectare, depending on whether it was planted in early spring (September) or in summer (December). The assumption was made that a cabbage crop would be planted in late September, with a normal rainfall season and 100% cover. The water requirement in this case would be 5000 cubic metres per hectare per year (Kruger, pers. comm., 2002). For the Kat River area, this would amount to 4104 cubic metres for the 0.82 hectares set aside for cabbage cultivation[27].

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[25] This benefit may well increase as more state-owned land is converted to productive use by private farmers. At the moment the ownership issue is still being negotiated.
[26] As more bush is present in the Kat River area, a cost of R150 for clearing per hectare is regarded as the minimum.
[27] The computer programme Sapwat was used to determine the water requirement, as it provided the most up to date information on cabbage crops. Figures for Winterberg Agricultural School, which is located at Fort Beaufort were used.

The water requirements for increased livestock and horticultural activities on the areas earmarked for clearing amount to 4116.81cubic metres per annum. At a price of 16.6 cents/cubic metre (2001 prices), which excludes extraction and irrigation costs, the increased water requirement for livestock and horticulture would amount to a value of R683.18. A summary of the agricultural benefit at the Kat river site, adjusted for the water requirement, is shown in Table 3.12.

Table 3.12 Summary of the net agricultural benefit on the Kat River site

Agricultural activity	**Number of hectares available**	**Benefit (R)**	**Water use cost (R)**	**Net benefit adjusted for water use (R)**	**Net benefit per hectare (R/hectare)**
Livestock	2.74	715.51	2.13	713.78	261.53
Horticulture	0.82	246.00	681.05	0*	0
Afforestation	0	0	0	0	0
Unused (rotation)	7.39	0	0	0	0
TOTAL	**10.94**	**961.51**	**683.18**	**713.78**	**65.19**

*The water use cost for horticultural activities exceeds the benefit derived from such activities. For this reason no horticultural benefit is realised (the total benefit adjusted for water use is R0).

The water use from increased horticultural activities would offset the benefit derived from such activities. The total benefit adjusted for water use is zero for horticulture, leaving the livestock benefit as the only agricultural benefit. For this reason, the net agricultural output benefit of potentially productive land from WfW activities at the Kat River site is R713.78, which equates to R65.19 per hectare per year.

To calculate the agricultural benefit, the proportion cleared per year by WfW teams, as estimated by WfW managers, had to be incorporated. Clearing of the total area would only be concluded in year 17. However, another factor needed to be included in the calculation of the agricultural benefit - the rate of spread of alien trees. As a result of WfW activities, alien trees would not be able to spread, and the agricultural benefit would be higher in future, as more land would be available for it, instead of for being invaded by aliens. This rate-of-spread component was added to the proportion of land cleared, to reflect the increased future benefit. The average infestation level at the Kat River site was estimated at 3.5%, and at an assumed rate of spread of 1% per annum, up to a maximum infestation level of 40%, it follows that the maximum benefit would be achieved in year 36 (R 970.74). The agricultural benefit would increase from years 1 to 35, in line with the factor of increase in the rate of spread and the proportion cleared. The increase in the agricultural benefit over time is shown in Table 3.13.

Table 3.13 Increase in the net agricultural benefit over time at the Kat River site

Year	Rate of spread	Proportion cleared*	Factor increase in agricultural benefit**	Net agricultural benefit (R)
1	0.01	0.1563	0.1663	118.70
2	0.02	0.2341	0.2541	181.37
3	0.03	0.2817	0.3117	222.49
4	0.04	0.3294	0.3694	263.67
5	0.05	0.377	0.427	304.78
6	0.06	0.4247	0.4847	345.97
7	0.07	0.4724	0.5424	87.15
8	0.08	0.52	0.6	428.27
9	0.09	0.5677	0.6577	469.45
10	0.1	0.6153	0.7153	510.57
11	0.11	0.663	0.773	551.75
12	0.12	0.7107	0.8307	592.94
13	0.13	0.7583	0.8883	634.05
14	0.14	0.806	0.946	675.24
15	0.15	0.8536	1.0036	716.35
16	0.16	0.9013	1.0613	757.53
17	0.17	0.9489	1.1189	798.65
18	0.18	1	1.18	842.26
19	0.19	1	1.19	849.40
20	0.2	1	1.2	856.54
21	0.21	1	1.21	863.67
22	0.22	1	1.22	870.81
23	0.23	1	1.23	877.95
24	0.24	1	1.24	885.09
25	0.25	1	1.25	892.23
26	0.26	1	1.26	899.36
27	0.27	1	1.27	906.50
28	0.28	1	1.28	913.64
29	0.29	1	1.29	920.78
30	0.3	1	1.3	927.91
31	0.31	1	1.31	935.05
32	0.32	1	1.32	942.19
33	0.33	1	1.33	949.33
34	0.34	1	1.34	956.47
35	0.35	1	1.35	963.60
36	0.36	1	1.36	970.74

* Source: Hosking *et al.*, (2002).
** This is the sum of the rate of spread and proportion cleared.

The rental income and annual rate of return on farms

The rental income for the area cleared in Kat River is estimated at R196.57 per year, or R71.74 per hectare per year.

The average market value of veld, irrigation and dam-water type farming in the Kat River region amounts to R5600 per hectare (Esterhuize, pers. comm., 2003). As a percentage of this value, the net benefit of land cleared by WfW (R713/ha) at the Kat River site is 0.5%.

3.4.8 Kouga

WfW activities in the Kouga area span a vast area, including patches adjacent to Humansdorp, Joubertina, Hankey and the Gamtoos valley. Farming outputs include livestock (10%), citrus (Gamtoos), honey bush tea and deciduous fruit (Joubertina), and dry land vegetable growing (Nyokana, pers. comm., 2002; van der Merwe, pers. comm., 2002). Almost all (99%) of the land being cleared is under private ownership (Moore, pers. comm., 2002).

Approximately 65% of the land being cleared has potential productive capacity (approximately 7709 hectares). This percentage was estimated by considering three possible situations of land reclamation from alien trees. The first situation is land next to rivers. When cleared, this ground has high potential for farming (approximately 80% could be used). The second situation relates to land with a slight gradient. This land holds potential for livestock farming of an extensive nature, where farming activity takes place on a large area of land. The natural vegetation (fynbos and renosterbos) can be used for grazing once it returns after clearing, but the carrying capacity is low. For this reason, one LSU needs a substantial number of hectares for grazing purposes. About 50% of this land can be used for livestock farming (about 771 hectares). The growing of honey bush tea is another land use, although less than 0.1% of farming activity in these areas is currently used for it. No wildflower harvesting currently occurs in these areas (Moore and van der Merwe, pers. comm., 2002). The third situation relates to inaccessible areas in the Kouga mountains. These yield little potential for farming (van der Merwe, pers. comm., 2002). Information regarding the productive capacity is provided in Table 3.14.

Table 3.14 Information regarding the productive capacity on the Kouga site

Description	Value
Carrying capacity (Ha/ LSU)	31.25
Average infestation level (%)	7.55%
Hectares available for productive capacity	7709.25

3.4.5.1 Livestock benefit

The predominant vegetation in the Kouga area is a variety of fynbos. Fynbos does not provide good grazing and is low in nutrients (van der Merwe, pers. comm., 2002). For this reason, most livestock activities on the estimated 771 hectares assigned to this activity had to be of an extensive nature. About 50% of livestock farming in the area is devoted to beef cattle. Dairy farming does not occur because of its intensive nature. Intensive livestock farming entails farming on small areas of land, usually under irrigation. The carrying capacity is much higher under intensive farming, because of pasture use. In the case of dairy farming pastures are planted. The other 50% is used for sheep farming (especially for wool production). Goat farming is a less attractive option than sheep and cattle in this area (van der Merwe, pers. comm., 2002).

The same beef cattle and Merino Enterprise Budgets used for the other WfW sites were employed for the Kouga site. No Merino budget was available for the Kouga area, although various budgets were available for Merino's in the Cathcart and Stutterheim areas (eastern part of the Eastern Cape). The Grahamstown budget was chosen as appropriate, because of the broad similarity in vegetation, namely fynbos. Grassy fynbos is found in the Grahamstown area, while mountain and coastal fynbos and renosterbos are found in the Kouga area.

Table 3.15 below reflects some of the key values used to determine the livestock benefit for the Kouga area.

Table 3.15 Livestock data used to calculate the livestock benefit for the Kouga site

Description	Average margin above cost (R)	Hectares available for activity	Number of LSU/SSU on area	Livestock benefit (R)	Livestock benefit per hectare (R)*
Beef cattle	690.73	385.5	12.33	8520.02	22.10
Sheep	226.63	385.5	74	16 767.25	43.50
TOTAL		**771**		**25 287.27**	**32.80**

* This calculation depicts the benefit per hectare for each livestock activity, assuming that one hectare is available for each.

It was deduced that the livestock benefit in the Kouga area was about R25 287.27 per annum, or R32.80 per hectare per year[28]. The average beef cattle benefit per hectare per year amounted to R22.10, while the average sheep benefit per hectare per year amounted to R43.50.

3.4.5.2 Horticultural/agronomic benefit

The Kouga area is well known for its deciduous fruit production. To calculate the horticultural benefit, the difference between farmers' costs of clearing an alien infested area and an indigenous area was calculated. The profit of apple, pear, nectarine, peach, plum, apricot or citrus orchards (deciduous fruit) did not form part of the potential increase in productive capacity, as it was assumed that if farmers wanted to plant orchards, they would not have waited for a government-initiated clearing programme to get rid of alien trees and plants, but would have cleared infested land themselves. Following this logic, it was deduced that the only difference in monetary terms between a with-WfW and without-it scenario would be in the costs of clearing an area with alien infestation and without it.

[28] The rental income for livestock farming in the Kouga area is estimated at R10.16 per hectare, or R3014.46 for the area cleared and suitable for livestock farming.

Honey bush plants (for honey bush tea) grow wild in mountainous areas in the Kouga area, but the cultivation of honey bush tea has not yet taken off in this region. For this reason it was not included in the determination of the value of potentially productive land. Similarly, the area has potential as a supplier of wildflowers (proteas and fynbos), but this industry has not yet been established in this area, and so was also excluded from consideration (van der Merwe and Moore, pers. comm., 2002)[29]. Attempts have been made to establish the economic value of fynbos on the Agulhas plain (Heydenrych, 1996; Turpie & Heydenrych, 2000), and the commercial value of wild flowers and honey bush tea (www.agric.za/elsburg/personeel/-fynbos; http://FineBushPeople.co.za).

To clear indigenous fynbos for crop cultivation, farmers usually burn the area, at an estimated cost of R300/ha (van der Merwe and Moore, pers. comm., 2002). The cost of clearing fynbos infested with alien vegetation is estimated at R850 per hectare. This figure reflects the cost of a tractor for approximately 3 hours (at R100 per hour) and the cost of labour for digging up the trunks of aliens, estimated at 55 adult stems per hectare, on average, for Hakea, Pine, *Acacia spp*. and Blackwattle infestations of up to 5% (Buckle, pers. comm., 2003), at an average cost of R10 per tree (R550 for 55 trees). The average infestation level is estimated at 7.5%, but a level of 5% was used, as no density classification (stems/ ha) exists for an infestation level of 7.5%.

The difference in the cost of clearing alien and indigenous vegetation amounted to R550[30]. Of the estimated area that would be cleared through the WfW programme, an area of 6938.33 hectares could potentially be used for deciduous fruit farm practices. At an excess cost of clearing of R550/hectare, this benefit amounts to R3 816 079.55 for the Kouga site (see Table 3.16).

Table 3.16 The horticultural benefit on the Kouga site

Description	**Value**
Ha used for horticulture	6938.33
Cost of clearing indigenous land (R/ha)	300
Cost of clearing infested land (R/ha)	850
Difference in cost of clearing (R)	550
Horticultural benefit (R)	**3816079.55**

[29] Thatch can also be grown in the coastal zones of the Kouga. At Port St Francis, a piece of land cleared by WfW was replanted with thatch, as climatic conditions were suitable for the cultivation of it and there is significant local demand for it. The Port St. Francis site did not form part of the Kouga area studied, and was therefore not included.

[30] The difference in the cost of clearing alien and indigenous vegetation was deemed to be the horticultural benefit. The preparation costs of land for various crops are not included in this figure, as these costs would be incurred irrespective of the type of clearing done. For instance, if land is cleared in order to plant lucern for grazing purposes, land needs to be more thoroughly prepared (at a cost of approximately R800 per hectare) for nutritional purposes, than in the case of extensive farming (van der Merwe, pers. comm., 2002).

3.4.5.3 Revised total benefit profile

When alien infested areas are cleared for, amongst others, agricultural practices, the water requirements for these activities need to be taken into account, in order to assess the impact thereof on the water made available through WfW actions. The increase in productive capacity of land from clearing of previously idle land constitutes a benefit of the WfW, but at the same time, the water requirements of these activities may be so great that they negate the increased water flow made possible by WfW.

The water requirement per LSU per day is approximately 50 litres, and 10 litres per SSU per day. In the Kouga area, increased livestock activity on cleared land would increase the total water requirement to 495.2 cubic metres per annum (for both cattle and sheep farming). For the Langkloof area, the irrigation requirement for deciduous fruit during midseason would amount to 3290 cubic metres per hectare (Green, 1985:228-229). For this reason, the 6938.3 hectares set aside for deciduous fruit farming would necessitate approximately 22.8 million cubic metres of water per year.

The total increase in the water requirement owing to agricultural activities would come in at approximately 22.8 million cubic metres. At a price of 74 cents/cubic metre (2000 prices) (Hosking, *et al.* 2002), or 78 cents/cubic metre in 2001 prices, the cost of water significantly alters the net benefit of potentially productive land. The cost of the increased water requirement is calculated at approximately R17.86 million.

Farming activities on cleared areas would exert pressure on the water made available through the WfW programme. On the one hand, water flow is increased through the clearing of alien trees and species, but on the other hand, the water requirement of increased farming practices may offset this benefit, as is the case in the Kouga area. A summary of the agricultural benefit at the Kouga site is shown in Table 3.17.

Table 3.17 Summary of the net agricultural benefit on the Kouga site

Agricultural activity	**Number of hectares available**	**Benefit (R)**	**Water use cost (R)**	**Net benefit adjusted for water use (R)**	**Net benefit (R/hectare)**
Livestock	771	25 287.27	387.30	24 899.97	32.80
Horticulture	6938.33	3 816 079.55	17 854 896.43	0*	0
TOTAL	**7709.25**	**3 841 366.82**	**17 855 283.73**	**24 899.97**	**3.23**

*The water use cost for horticultural activities exceeds the benefit derived from such activities. For this reason no horticultural benefit is realised (because the total benefit adjusted for water use is R0).

The horticultural benefit is completely offset by the increased water requirement of such activities, and the livestock benefit is the only agricultural benefit. The latter amounted to R24 899.97 per annum for the whole Kouga site, or R64.60 per hectare per annum.

To calculate the agricultural benefit, the proportion cleared per year by WfW teams, as estimated by WfW managers (Hosking *et al.*, 2002), had to be incorporated. Clearing of the total area would only be concluded in year 20. For this reason, the agricultural benefit would increase from years 1 to 19, and the total benefit would only be realised in year 20. However, another factor needed to be included in the calculation of the agricultural benefit - the rate of spread of alien trees. As a result of WfW activities, alien trees would not be able to spread, and the agricultural benefit would be higher in future, as more land would be available for it, instead of for being invaded by aliens.

This rate-of-spread component was added to the proportion of land cleared to reflect the increased future benefit. A rate of spread of 1% per annum was assumed, up to a maximum infestation level of 40%. When an average alien infestation level of 7.5% was assumed for the Kouga site, it followed that the agricultural benefit would increase from years 1 to 31, in line with the factor of increase in the rate of spread and the proportion cleared. The maximum (future) benefit would be achieved in year 32 (R32 867.96), when the assumed infestation level of 40% is reached. This future benefit is higher than the current benefit of R24 899.97 from the rate-of-spread assumption.

The increase in the agricultural benefit over time is shown in Table 3.18.

Table 3.18 Increase in the net agricultural benefit over time at the Kouga site

Year	Rate of spread	Proportion cleared*	Factor increase in agricultural benefit**	Net agricultural benefit (R)
1	0.01	0.0111	0.0211	525.39
2	0.02	0.0238	0.0438	1090.62
3	0.03	0.0686	0.0986	2455.14
4	0.04	0.0762	0.1162	2893.38
5	0.05	0.1339	0.1839	4579.10
6	0.06	0.1917	0.2517	6267.32
7	0.07	0.2494	0.3194	7953.05
8	0.08	0.3071	0.3871	9638.78
9	0.09	0.3649	0.4549	11327.00
10	0.1	0.4226	0.5226	13012.72
11	0.11	0.4803	0.5903	14698.45
12	0.12	0.5381	0.6581	16386.67
13	0.13	0.5958	0.7258	18072.40
14	0.14	0.6536	0.7936	19760.62
15	0.15	0.7113	0.8613	21446.34
16	0.16	0.769	0.929	23132.07
17	0.17	0.8268	0.9968	24820.29
18	0.18	0.8845	1.0645	26506.02
19	0.19	0.9422	1.1322	28191.75
20	0.2	1	1.2	29879.96
21	0.21	1	1.21	30128.96
22	0.22	1	1.22	30377.96
23	0.23	1	1.23	30626.96
24	0.24	1	1.24	30875.96
25	0.25	1	1.25	31124.96
26	0.26	1	1.26	31373.96
27	0.27	1	1.27	31622.96
28	0.28	1	1.28	31871.96
29	0.29	1	1.29	32120.96
30	0.3	1	1.3	32369.96
31	0.31	1	1.31	32618.96
32	0.32	1	1.32	32867.96

* Source: Hosking *et al.*, (2002).
** This is the sum of the rate of spread and proportion cleared.

The rental income and annual rate of return on farms

The rental income for livestock farming in the Kouga area was estimated at R10.16 per hectare per year, or R3014.46 for the area cleared and suitable for livestock farming.

The average market value of veld-type farms (mostly for livestock) in the Kouga region amounts to R1750 per hectare (Nel, pers. comm., 2003). As a percentage of this value, the net benefit of land cleared by WfW (R64.60/ha) in the Kouga area is 3.7%.

3.4.6 Tsitsikamma

All WfW activities in the Tsitsikamma are carried out on government-owned land (Buckle, pers. comm., 2002), under the management of the Tsitsikamma National Park (Jungbauer, pers. comm., 2002). The expansion of WfW activities to assist clearing privately owned land is not envisaged for the near future (Jungbauer, pers. comm., 2002). For this reason no potential for productive capacity of land could be determined.

Nature conservation, mountain catchment management and biodiversity protection are the major concerns in this area (Jungbauer and Booth, pers. comm., 2002).

Table 3.19 summarizes the net benefit of potentially productive land for the six sites under investigation.

Table 3.19 The net benefit of potentially productive land for WfW sites in the Eastern Cape

Site	**Net agricultural benefit (R)**	**Net agricultural benefit per hectare* (R/ha)**
Albany	46 202	178.94
Kat River	713.78	65.19
Kouga	24 899.97	3.23
Pot River	819	304.05
Port Elizabeth Driftsands	0	0
Tsitsikamma	0	0

*The net agricultural benefit was divided by the total number of hectares cleared (condensed) that could be used for agricultural purposes.

3.5 SENSITIVITY ANALYSIS

A range of variables, such as dry and wet years and changing weather patterns, impact on the carrying capacity of agricultural land (Weitz and van der Merwe, pers. comm., 2002). These uncertainties affect the number of livestock held per hectare, and hence the potential of land. The impact of changes in rainfall can, to some degree, be dealt with through the application of sensitivity analysis, where the carrying capacity is adjusted upwards and downwards to indicate variation in the net benefit of potentially productive land. The impacts of upward and downward adjustments to the net benefit are shown in Table 3.20.

Table 3.20 Results of sensitivity analysis

Site	**20% improvement in carrying capacity of land (R/ha)**	**20% deterioration in carrying capacity of land (R/ha)**
Albany	223.67	149.11
Kat River	325.58	217.05
Kouga	41.00	27.35
Pot River	256.91	171.71
PE Driftsands	0	0
Tsitsikamma	0	0

From the above, it is clear that a 20% variation (upward and downward) in the carrying capacity does not have a significant positive impact on the net potential of productive land.

3.6 CONCLUSION

The benefit arising from the potential productive use of land in areas that are cleared of invasive alien species is perhaps the most obvious of all the non-water benefits. In the estimation of this benefit, all possible land uses for the WfW sites were included, and the assumption was made that current land practices would guide what would be established in the cleared areas. The main farming activities were livestock and horticulture.

The net agricultural output benefits of increased potentially productive land at the six sites are small in value. When the water requirement of the farming practices is taken into account and valued, using the water prices at the six sites generated by Hosking, *et al.*, (2002), it becomes clear that the water requirement of these activities undermines the net agricultural benefit that can be derived from the WfW programme. This influence is particularly strong at two of the four sites where agricultural potential is present - the Kouga and Kat River sites. At these sites, the agricultural benefit consists only of the livestock benefit.

A sensitivity analysis on different land uses fell outside the scope of this study. Such an analysis could, however, prove useful for determining which agricultural activity should be established on land where clearing has been completed. This remains as a future research question.

The Hosking *et al.* (2002) study calculated only the livestock benefit as an agricultural benefit of the WfW programme. This study incorporates all other possible agricultural land uses (in most cases a horticultural benefit). From the results, it is clear that not a great deal changes about the agricultural benefit by adopting a more inclusive model than that employed by Hosking *et al.* (2002).

CHAPTER 4
THE FIRE BENEFIT OF THE WFW PROGRAMME

4.1 INTRODUCTION

Phenomena such as fire regimes, fire cycles, intensity of fires and severity of fires have been the subject of much research (Van Wilgen, 1996). On the basis of this, it is hypothesised that invasion by alien vegetation increases fire-associated costs. As most alien invasive species have a higher biomass than the indigenous vegetation they invade (for instance grasslands), they generate more material to burn, and the fires in this type of vegetation are much hotter and more severe than they would otherwise be (Campbell, pers. comm., 2000). As a result of this heat, there are adverse ecological consequences and increased damage costs. These damage costs are direct - to property and natural vegetation - and indirect, in the form of soil loss (Marais, pers. comm., 2002).

The problem of increased fire damage due to alien vegetation is a particularly difficult one, in that its causation runs both ways. Not only is fire damage greater in alien vegetation, but fire also acts as a cataliser for the release and germination of large quantities of invasive seed, inducing further increases in alien tree and plant cover (Buckle, pers. comm, 2002) and thereby further escalating the cost of future fire damage (Holmes, 2001). The question that this chapter addresses is whether unplanned fires in alien vegetation translate into higher fire management costs during and after such fires. It is hypothesised that they will do so. This hypothesis is tested in the six selected areas: Pot River, Kat River, PE Driftsands, Albany, Tsitsikamma and Kouga. The fire-fighting costs in the 6 areas are assessed using a with- and without- alien vegetation scenario: the management costs of fighting fires in pristine indigenous vegetation, such as grasslands and fynbos, are contrasted to fire-fighting costs in areas where alien infestation is present. The difference between these costs is deemed to constitute a benefit of the WfW in the form of management cost savings.

Costs of fighting fires in the predominant vegetation types at the six sites are generated by reference to expert opinions. These expert opinions are recorded in a data base, which connects the direct costs of fighting fires with the level of alien infestation[31].

4.2 MODEL

It was hypothesised that fire damage cost was a function of the level of alien invasion and the scale of a fire. Fire damage cost is made up of two components: damage to private property, and damage to public goods. Private property damage includes that to livestock, grazing and crop

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[31] This study does not estimate values for fire management, such as the creation and maintenance of firebreaks.

fields, buildings, and commercial plantations, while damage to public goods refers to soil and species losses. The actual damage incurred in a fire can be established only after the event of a fire. It is the result of various prevalent circumstances, which differ from fire to fire, and make predictions very difficult.

This study does not attempt to measure damage to infrastructure after fires, but focuses attention on the cost of resources committed to fire management during fires. Resources committed to fire management include the labour of hired fire management teams and equipment. Fire managers' philosophy, viz. to fight every fire with all their resources (Gentle, pers. comm., 2002), is used as starting point in the determination of resource costs for fires.

Other role players, such as private property owners and farmers, also contribute resources, depending on the threat of the fire to property and infrastructure. The cost of these other role players was not incorporated into the model. The exclusion of the resources of these role players may well result in favour of the argument that estimates for the fire cost saving are on the low side of the actual figure. In the near future, it may be easier to include the cost of these resources because the Veld and Forest Fire Act (1999) makes provision for the formation of Fire Protection Associations (FPAs). An FPA draws all landowners in an area together on a voluntary basis, to protect them from being held liable for fire damage. Members of FPAs assist each other in the creation and maintenance of firebreaks, in order to protect them from claims. All members provide resources in case of fires (Gentle, pers. comm., 2002). FPAs are still in their infancy, and will only become fully operational in a few years (Gentle, pers. comm., 2002). When they do, more information should become available on the inputs that private landowners commit to fire-fighting.

Attempts have been made to determine the cost of fires to various role players. The Environmental Evaluation Unit of the University of Cape Town (2003) assessed the costs and damages associated with the January 2000 fires in Cape Town. Direct and indirect costs to households, local authorities, and other key role players such as the South African National Parks were estimated to be in excess of R33 million (at 2000 price levels).

The long-run damage costs as a result of wildfires in alien infested vegetation were not estimated in this chapter. These costs relate to soil, species, and biodiversity losses.

4.3 THE ECOLOGICAL IMPORTANCE OF FIRE

Veld fires, *per se*, are not bad, ecologically speaking. They have a place within ecosystems, provided that they are as close to the natural (historical) fire regime as possible (Gentle, pers. comm., 2002). Fires play a beneficial role in maintaining biodiversity, structure, and function of African ecostystems (Van Wilgen, 1996:32). A range of indigenous vegetation depends on fires for seed dispersal, germination, and flowering (Bond and Van Wilgen, 1996; Cowling 1992: 23-25). Ash deposits after fires increase the nutrient level of infertile soils for a period after the fire, which stimulates vegetation growth, and attracts grazers. In savannas, fire plays a major role in balancing competition for space between grass and trees. In fynbos, fire stimulates seed germination, and plays a crucial role in maintaining biodiversity (Van Wilgen, 1985).

Fires are a means by which alien vegetation biomass can be temporarily reduced, as part of an integrated invading alien plant control programme (van Wilgen, 1984). In areas infested with *Acacia spp*., including *Acacia mearnsii*, *Acacia saligna* and *Acacia cyclops,* as well as *Pinus* and *Hakea spp*., fire is being used during follow-up clearing operations. Fires stimulate the growth of alien seedlings in target areas (as already mentioned). When these grow into young plants they reveal themselves, and can be pulled out by hand or sprayed with herbicide, such as Glyphosate or Triclotyr for *Hakea spp*. (Marshall and Buckle, pers. comm., 2002).

4.4. DETERMINANTS OF FIRE

Numerous variables affect the occurrence of fires in indigenous vegetation. A better understanding of these variables is crucial in the determination of the costs of fires, as these variables influence the characteristics and consequences of fires. For a fire to start and burn, the correct type of fuel and sufficient quantities thereof must be present[32]. In addition, weather conditions have to be suitable to sustain the fire, and a source of ignition needs to be present (Bond & van Wilgen 1996: 17). The wind speed, humidity, air temperature and rainfall are all elements of the process. The “fire regime” refers to the characteristics of a fire within a specific vegetation type. The fire regime consists of a combination of four elements: the fire frequency[33], the fire season, the type of fire, and its intensity. Terrain (i.e. slope) also plays a role. For instance - southern facing areas in South Africa are usually moist, while northern slopes are drier. The steeper the slope is, the faster it burns. Plants are adapted to a certain fire regime, and changes in it can cause some species to be favoured above others (Bond & van Wilgen, 1996:16-17). The

[32] This is dependent on the soil type and climate (van Wilgen: 1984).

[33] The term “fire frequency” refers to the time between prescribed fires, whereas the term “fire cycle” refers to the time between wildfires. In this study it is assumed that prescribed fires take place within the average fire cycle, and that the total area under consideration is burned within the fire cycle, but that only parts of it are burnt at regular intervals (Marais, pers. comm., 2000). However, in various nature conservation areas such as the Kamanassie Mountains, the policy has shifted from having prescribed fires towards allowing wildfires to burn without intervention, with monitoring only (especially if they occur high up on mountains, thus forming low risk), in order to let nature take its own way. New strict fire laws and reduced manpower on reserves in mountain catchment areas also contributed to this decision (Marshall and Wessels, pers. comm., 2002).

presence of alien vegetation alters the fire regime of indigenous vegetation, causing hotter, more severe, and slower-burning fires (Euston-Brown, 2000).

4.4.1 Primary determinants of fire

4.4.1.1 Climate

Climate plays a decisive role in the event of a fire (Van Wilgen Little, Chapman, Görgens, Willems and Marais, 1997: 27) through impacting on the moisture content of vegetation, e.g. dry, fine fuel burns most easily. The prevalent climate determines the air temperature, humidity, radiation and rainfall (Bond & van Wilgen, 1996:17, 30). The rainfall in an area determines the amount of fuel available for a fire, which, in turn, affects the frequency and intensity of the fire.

Wind is one of the most important factors for consideration in the incidence of fire, as it influences fire spread and intensity. The risk of fires is greatly increased by hot, dry and windy conditions, which occur in the fynbos biome during the months February to May, when northerly bergwinds blow in the Southern and Eastern Cape (Cowling, 1992:348-9).

4.4.1.2 Soil and fuel

Fires need fuel (plant material) to sustain them. The prevalent soil type influences the fire regime. Little fuel is available in infertile soil, because of its low productivity, but because the fuel rarely gets eaten by herbivores, it accumulates faster than in fertile soils. Fires in the fynbos biome tend to be intense owing to the long interval between fires and the relatively unpalatable nature of fynbos to herbivores. These two factors lead to a high build-up of biomass. As a result, more fuel is available for fires (Bond and van Wilgen, 1996).

4.4.1.3 Herbivory

Herbivores and fire are rivals in the consumption of vegetation. Vegetation, such as grassland, that is consumed by herbivores, results in less fuel being available for fires. However, when exceptionally high rainfall occurs, or herbivore consumption is very low, intense fires can occur (van Wilgen, 1985). Herbivory mainly occurs in savannas and grasslands (Marais and van der Merwe, pers. comm., 2003).

4.4.1.4 Management

In South Africa, burning is permitted in terms of the Agricultural Resources Act, but restricted in terms of other Acts. Commercial plantations are protected through the Forest Act, which determines firebreak standards, and outlaws fires in certain places at certain periods (van Wilgen, 1985).

Fire management can be divided into three categories: fire protection (fire breaks and fire lookouts), prescribed burning, and the control of wildfires. Prescribed burning relates to fires deliberately started under specified conditions (e.g. suitable weather and topography) in order to attain objectives such as reduction in fire damage risk and biodiversity conservation (Bond and Van Wilgen, 1996:189). Prescribed burning - in contrast to wildfires - is carried out at regular intervals, and as a result of fire managers' decisions (van Wilgen, 1985:2). These decisions depend on factors such as vegetation age, the status of alien species and the biomass in the area[34]. Wildfires are unplanned fires caused by people (negligence or arson) or natural factors such as lightning (Gentle, pers. comm., 2002).

One of the most important concerns with respect to fires is safety. Prescribed burns can spiral out of control and become wildfires - threatening areas not earmarked for burning, such as urban land, agricultural ground and plantations. At the same time, the use of fire may be prohibited or constrained by legal factors, especially in urban areas. The National Veld and Forest Fire Act (1999) stipulates that the person in charge of a prescribed burn will be held liable for any damages resulting from it (Marshall and Buckle, pers. comm., 2002). If the farmer on farm A starts a controlled fire, but it runs out of control, causing damages on farm B, and spreads from there to farm C, farmer C would, in terms of this Act, sue farmer B, who in turn would sue farmer A, who would, in the end, be held responsible for all costs (Buckle, pers. comm., 2002). For this reason government authorities, such as WfW and the Department of Water Affairs and Forestry, will typically contract others to perform prescribed burns for them. This Act is largely responsible for reduced prescribed burning activities, and in some areas, the complete closing down of controlled burning operations (Marshall, pres. comm., 2002).

Various fire management tools, developed as models, exist to assist managers in making informed decisions on the optimum time for prescribed burns. One of these models is the BEHAVE model[35], which consists of a set of interactive computer programmes enabling conservationists to predict the behaviour of a fire. Variables in the model include vegetation (from the input side, providing the fuel for the fire), the rate of spread and intensity of fires under varying conditions, and the fuel moisture content. The fire behaviour under specified conditions is an important variable for consideration by fire managers, as it helps them to assess whether a prescribed fire will have the desired results (van Wilgen and Wills, 1988). These models attempt

[34] There is a different school of thought at this stage. This approach is an adaptive interference system where a pragmatic opportunistic method of fire management is being followed to ensure a mosaic of veld ages but with the provision that when veld burns, it has reached maturity and takes place as far as possible during the natural burning season (late summer to early autumn in winter rainfall areas and winter to early spring in summer rainfall areas) (Marais and Gentle, pers. comm., 2002).

[35] Also known as the Rothermel model.

to construct fire danger indices by using variables such as vegetation characteristics and weather patterns.

4.4.1.5 Ignition

A fire is caused by ignition. This ignition can be natural, or of man-made origin. Human ignition accounts for the overwhelming majority of fires. On some occasions this is due to negligence, but more frequently it is the result of a decision to carry out a prescribed burn (Bond and van Wilgen, 1996:18).

The determinants of fire interact with the fuel characteristics (which include the load, chemistry, particle size and arrangement) to form a specific fire regime (Bond and van Wilgen, 1996) (see Table 4.1).

Table 4.1 The determinants of fire

Primary determinants	Fuel characteristics	Fire regimes
	Ignition	
Climate Soils Vegetation Herbivory Management	Load Chemistry Particle size Arrangement	Season Frequency Intensity

Source: van Wilgen, Bond and Richardson (1992).

4.5 VEGETATION TYPES AT THE SIX WFW SITES AND THE IMPACT OF ALIEN VEGETATION ON THEIR FIRE PROPERTIES

The dominant vegetation types present at the selected WfW study sites are grasslands, Eastern Cape Thicket and varieties of fynbos (Low and Rebelo, 1996). Fire cycles and regimes differ among different types of bush (Buckle, pers. comm., 2002). Table 4.2 provides a summary of the fire cycles at the six WfW sites in the Eastern and Southern Cape selected for this study.

Table 4.2 Fire cycles prevalent in the six study sites

Project site	Indigenous ground cover	Average fire cycle (years)	Last fire	Type of area
Tsitsikamma	Mountain fynbos (wet) and natural forests	12	1998	Mountain catchment
Kouga	Mountain and grassy fynbos	12	1999	Mountain catchment
PE Driftsands	Coastal fynbos and Dune Thicket	12	1997	Developed area (urban)
Albany	Grassy fynbos and Eastern Cape Thicket	4	1999	Mountain catchment
Kat River	Grasslands and natural forests	4	1999	Mountain catchment
Pott River	Grasslands	4	1999	Mountain catchment

Source: Hosking *et al.* (2002); Low and Rebelo (1996).

The fire characteristics of fynbos, Eastern Cape Thicket, natural forests, and grasslands, as well as the impact of alien trees and plants on them, are discussed below.

4.5.1 Fynbos

"Fynbos" is an indigenous word which South Africans created for describing the vegetation characteristic of large areas of the southern Western Cape Province and south western Eastern Cape Province up to Port Elizabeth. This includes the types described by Acocks (1953) as macchia, false macchia, and coastal macchia. Fynbos can physiognomically be identified by three elements: restioid, ericoid, and proteoid. A grass component, the graminoids, is also present. The restioid element is the essential component, made up of the Restionaceae and similar aphyllous grass-like plants up to one metre tall, while short shrubs with small, narrow and often rolled leaves characterise plants for the ericoid component. Taller shrubs with moderate-sized sclerophyllous leaves comprise the proteoid element, but this may be absent in certain habitats (van Wilgen, 1982). Additionally, other elements such as sedges (leavy sedges in particular), non-ericaceous ericoids (with more than 5% cover), ericoid Asteraceae, stoeboids (shrubs with crowded leaves in fascicles), leaf spinescence, Penaeaceae and Bruniaceae occur in varying degrees (Cowling, 1992:35).

Fire characteristics

Fynbos type of vegetation grows in nutrient-poor soils. It consists of coarse, reed-like plants, with fine-leaved shrubs (van Wilgen, 1982: 35). The climate in which it grows is predominantly Mediterranean, characterised by dry summers and wet winters. Biomass build-up is sufficient to sustain fires every four years, but the average fire cycle is between twelve and fifteen years, when fuel loads reach a much higher biomass. Extremely high fuel loads have been recorded in areas where no fires have passed in 40 years (van Wilgen, 1985:35).

Fires may occur at any time, provided the necessary conditions are met, but the peak fire season is during the dry summer months. The type of fire that predominantly occurs is canopy fire, with an intensity of between 500 and 30 000 kW per metre (Bond and van Wilgen, 1996). Approximately 70% of the vegetation above the ground gets burned during a fire.

Fynbos has developed unique characteristics in order to survive fires, and is dependent on fire and smoke for regeneration through sprouting, seeding, or seed dispersal via ants (Swanepoel, pers. comm., 2002). It is because fynbos is so well adapted to fires that it is the most important management practice for conserving biodiversity and rejuvenating the vegetation. However, if fires are used extensively at too short fire cycles, or during the wrong season (winter and spring), some species can be lost, impacting adversely on biodiversity (Bond and Van Wilgen, 1996; Cowling, 1992: 148, 160; Euston-Brown, 2000).

Fire is also crucial for the establishment of a border between fynbos shrublands and indigenous forests. Owing to the high moisture content in the live foliage of indigenous forests and its arrangement on the ground, it hardly ever burns, except under extreme fire conditions. In this way indigenous forests form "islands" that limit the spread of fires. Fire frequency is the most important determinant in the creation of forests. If fynbos does not burn for prolonged periods, for example, 50 years, forests are able to establish themselves within the fynbos shrublands. For this reason an absence of fire can also impact negatively on biodiversity in the shrublands, as most fynbos species occur within these lands (Richardson & van Wilgen, 1986).

Fire increases the number of species present in fynbos (van Wilgen, Bond and Richardson, 1992:65). A study done in the Swartboskloof catchment, Jonkershoek Valley, near Stellenbosch, indicated that 32% of the species recorded on the study plots were only visible after fire (Richardson & van Wilgen, 1986). However, if the fire frequency is increased to every five years, biodiversity could also be reduced, as shrubs producing seeds may not have had time to reproduce, and biomass decreases.

Mountain catchment areas fulfil a crucial role in the fynbos biome. Although they comprise only 8% of land surface, they provide 49% of total water run-off (van Wilgen, 1985:9). It follows that management of these catchment areas is an important undertaking, and fires have a valuable ecological role (van Wilgen, 1985:13).

Fire management

Managers undertake prescribed burns by dividing the fynbos veld into "mosaics" of different ages. This management practice decreases the risk of a wildfire destroying large areas, as fires are easier to control in veld of a young age (Gentle, pers. comm., 2002). The number of hectares burned differs from area to area, and manager to manager. In some nature conservation areas in the Western Cape, blocks of about 500 ha are burned at a time, while in other areas the size of the blocks burned varies between 50 to 100 ha (Johns and Gentle, pers. comm., 2002).

Fynbos is highly adapted to warm, fast fires (Gentle, pers. comm., 2002). Prescribed burns take place at different times for coastal and inland zones. Inland, they occur during late summer to early autumn (March to April), while in coastal areas they take place during mid- or late summer or autumn (November to April). The increased moisture content in the vegetation closer to the coast decreases the danger of runaway fires during mid- summer, but these fires are still classified as moderately intense fires (van Wilgen, 1984).

Recently fire managers in fynbos conservation areas have moved away from using prescribed burns (van Wilgen & Richardson, 1985) in favour of monitoring and controlling for damage. Adaptive interference is the current school of thought for natural areas surrounded by development, with natural burning zones for remote wilderness areas. In the case of wildfires, the risk of damage to lives, property, crops, or infrastructure is assessed, and if there is no real threat, these fires are monitored, and left to burn in order to allow nature to take its course (Marshall and Rheeder, pers. comm., 2002). In wilderness areas, natural wildfires (e.g. ignition through lightning) are left to burn while only being monitored (Rheeder, pers. comm., 2002). No burns are undertaken in riverbeds, because of the threat of ecological damage such as erosion. When rainfall increases the stream flow, riverbeds can be washed away if not held together by vegetation (Rheeder, pers. comm., 2002).

Although the use of prescribed burns for management purposes in fynbos conservation areas has been limited, another type of prescribed burn has taken its place - burns to control alien trees and plants. When alien trees and plants have been chopped down by work teams, the area is usually burned to get rid of the huge biomass. The heat from the fire also stimulates the germination of alien seedlings. These seedlings are then pulled out by hand, or sprayed with herbicide in subsequent years (van Zyl & Buckle, pers. comm., 2002).

Impact of alien invaders

Alien infestation of indigenous veld types alters the nature and mechanisms at work in these biomes. In van Wilgen's (1985:3) fire model, adapted for infested fynbos areas, the presence of aliens increased the fuel load and changed the intrinsic nature of fuel beds. As a result, it predicted management problems in the control of fires in extreme weather conditions (1985:3). Van Wilgen and Richardson (1985) and Versfeld and van Wilgen (1986) have shown that fuel loads within mountain fynbos invaded with *Hakea spp.* can increase by 60%, while invasion of mountain fynbos with *Pinus spp.* can increase fuel loads by up to 300%. It is deduced that infestation with *Hakea spp.* can result in an increase in biomass of up to five times that of the dominant fynbos vegetation, while in the case of infestation with *Acacia spp*., the biomass is increased to as much as six times that when pristine fynbos prevails (van Wilgen, 1985:170).

As fire behaviour is dependent on the fuel available, higher fuel loads and different types of fuel change the fire behaviour in fynbos infested with aliens (Martens, pers. comm., 2002).

A case study done by Euston-Brown (2000), after wildfires at Fish Hoek (1999) and the Cape Peninsula (2000), indicated that fire severity was the most damaging in alien vegetation and vegetation cleared of aliens. Fires were, on average, 65% more harsh than under the pristine fynbos counterpart.

Fires in invaded areas can burn live canopies in thickets of invasive shrubs and coniferous trees under extreme weather conditions, making fire management difficult, if not impossible. As a result, extensive damage can occur to the ecosystem. The fire regime under these circumstances is subject to change. The difference in fuel distribution will make fires more infrequent, while the increased fuel loads can make fires more intense (van Wilgen, Bond and Richardson, 1992: 50). Like fynbos, alien trees are well adapted to survive fires. They mature fast, and rapidly establish seed layers in the soil. In South Africa a build-up of these seeds is also facilitated by the absence of natural enemies (Richardson, Lubke and Guillarmod, 1984).

Alien plants also inhibit the accessibility of areas, making it difficult for firefighters to get to burning areas (van Wilgen, 1985, Rheeder, pers. comm., 2002). The net result of alien invasion is that substantial changes occur in the natural community structure of fynbos[36]. Invasion takes place at the expense of understorey herbs and shrubs, impacting negatively on biodiversity, which is in direct opposition to the conservation aim in fynbos areas (van Wilgen, 1985, Euston-Brown, 2000).

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[36] At the Jonkershoek study site, it was found that the density of Protea shrubs in fynbos was 1384 stems/ha. This increased with the presence of alien species. The density increased to 8900 stems/ha for *Hakea spp*., and 9800 stems/ha for *Acacia saligna*.

The incidence of flare-ups, and sparks flying to ignite unburned areas, increases by approximately 75% in fires burning in alien infested fynbos (Martens and Geldenhuys, pers. comm., 2002). This increased flare-up and spark propensity increases the risk of starting more runaway fires.

4.5.2 Eastern Cape Thicket[37] and natural forests

Fire characteristics

Eastern Cape Thicket rarely burns under natural conditions and has historically been classified as not fire prone (van Wilgen, 1997:42). Natural forests[38] also do not burn in their pristine form (Buckle, pers. comm., 2002).

Fire management

Little fire-management-related data is available on this biome because of its history as not fire prone (Low and Rebelo, 1996).

Impact of alien invaders

The presence of alien vegetation is the main reason for the occurrence of fires in these types of vegetation. The fire benefit, in cases where alien vegetation has invaded natural forests and Thicket, would amount to the total fire-fighting cost incurred during and after such fires, because no fires and thus no costs would be sustained in their pristine counterparts. Eastern Cape Thicket and natural forests are found on patches of land in the Albany and Kat River area respectively. These are not the predominant indigenous vegetation types present, and were therefore excluded from the analysis.

4.5.3 Grasslands

Fire characteristics

The frequency of fire in grasslands depends on the rainfall and the grazing regime followed, which, in turn, determine the fuel load. Fires occur when the grass is dry and latent, with fire intensity varying between less than 100 to over 5000 kW per meter (Bond and van Wilgen, 1996:18, 26). Grass swards offer the fine firewood, while trees and dung provide additional loads necessary to sustain predominantly surface fires (van Wilgen, 1997, Bond and van Wilgen 1996, 29), which usually move fast (Butt, pers. comm., 2002). The intensity of grassfires is more stable than it is in woody species such as fynbos.

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[37] Also known as Valley Bushveld or Valley Thicket.
[38] Low and Rebelo (1996) uses the phrase “Afromontane forests”.

Evidence suggests that the fire season has more of an impact than fire frequency (Bond and van Wilgen, 1996). Grasslands that burn annually during winter or late spring produce the highest population growth, while annual summer burns have the opposite result. Spring burns result in lower recruitment of grasses (Bond and van Wilgen, 1996: 72, 96).

Fire management

Fires are used to moderate fuel loads in grasslands, and to improve the quantity and quality of pastures for grazing (Bond and van Wilgen, 1996: 197). Fires remove the unpleasant substances in grasslands. However, too frequent burning out of season causes the growth of palatable grasses in the short run, but diminishes their coverage in the long run (Bond and van Wilgen, 1996). Unfortunately, in the former Transkei and areas surrounding Balfour, in close proximity to the Kat River WfW site, a practice of overgrazing and frequent burning (once a year) in and out of season is followed (Buckle, pers. comm., 2002). As a result the coverage of palatable grass has diminished.

Fires are also important in grassland in order to prevent the invasion of Afromontane forests and grassy fynbos (Low and Rebelo, 1996).

Impact of alien invaders

Alien invader species increase the biomass of grasslands, leading to more intense fires, and intense fires are detrimental to some indigenous species (Buckle, pers. comm., 2002). Another problem in areas covered by alien invading vegetation is that the risk of erosion after fires is increased. Invaders such as Pinus spp. and dead Acacia mearnsii pose the highest fire risk. On the positive side, live stands of Acacia mearnsii can slow down the rate at which grassland fires spread (Butt, pers. comm., 2002).

4.6 A SURVEY OF FIRE MANAGEMENT COSTS

4.6.1 Fynbos

4.6.1.1 Determining the nature of the survey

The difference in direct costs of fighting wildfires in indigenous vegetation and alien infested areas constitutes the net fire benefit of the WfW programme. In order to estimate this net benefit, management cost profiles with and without alien infestation scenarios were created. A survey was conducted among conservation managers who are experts in fighting fires and in most cases also responsible for doing so. Ten experts were surveyed. All had at least 6 years' experience of fire-fighting. Some had more than 20 years of experience in fighting fires (see Appendix A).

These cost profiles were generated with reference to the level of alien infestation, nature of fire, climatic conditions, and hectares implicated.

The cost of fire management does not vary significantly between pristine fynbos and areas with infestation levels of between 1 and 49% (Marshall and Wessels, pers. comm., 2002). Wildfires in pristine fynbos conditions were only contrasted with wildfires in fynbos that was 50-100% infested with aliens[39]. The average infestation levels at the relevant WfW sites are much lower than this. They vary between 1% and 20%. However, within these areas there are patches that have dense infestation levels. The fire benefit was calculated for these areas.

Prescribed burns were excluded from the survey because of the policy of no prescribed burning of alien vegetation above the fynbos canopy, *i.e.* standing aliens (Gentle and Martens, pers. comm., 2002). This policy would result in there being no difference in the cost of prescribed burns with and without alien infestation. The difference in costs only becomes apparent in the fighting of wildfires.

Climatic conditions were classified into three scenarios referred to as risk scenarios. A low-risk scenario entailed temperatures lower than 20C, medium humidity, and a wind speed less than 15 km/h. A medium-risk scenario referred to temperatures between 20 and 28C, medium humidity, and a wind speed of between 15 and 28 km/h. A high-risk scenario was applicable to climatic conditions with temperatures above 28 C, medium humidity, and a wind speed above 28 km/h.

The fire experts all agreed that whenever a fire occurred, they would fight it with all the resources at their disposal, irrespective of the size of the fire[40]. For this reason the low and medium-risk scenarios[41] were omitted from the survey, leaving fire experts with the event of a wildfire under high-risk conditions only.

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[39] Fire reports of wildfires are kept in a central database at the Jonkershoek forest station. On closer inspection, and after various interviews, it became clear that these fire reports would not be helpful for the kind of information needed, as infestation levels were not recorded (infestation levels in a burned area often differ, complicating the reporting of such information). The cost of fires differed with no clear pattern as to which resources contributed most to it. The cost per hectare did not prove to be useful either, as it was skewed towards bigger fires: the bigger the fire (more hectares) the smaller the cost per hectare. Some small fires cost more than big fires to extinguish, while some fires are very expensive because of the damage they cause. However, fire reports did provide insight into how fires were managed, as some reports provided a day-by-day overview of actions carried out, weather and terrain conditions. It also became clear that when helicopters were used as part of a firefighting strategy, the cost increased exponentially.

[40] Most experts chose a fire of 50 ha or bigger. As the size of the fire is an independent variable (as long as the fire for both wildfires in fynbos and invaded fynbos was the same) it did not matter.

[41] In the survey, a clear distinction was made between the risk of damage and the risk of environmental factors. A high-risk scenario referred to factors such as the temperature, wind speed and humidity that would translate into bigger, more intense fires that would spread more rapidly.

In order to assess costs, the resources used in fire-fighting were listed in two categories: the number of person hours spent, and equipment used during and after the fire[42]. The more resources committed to fire-fighting, the more quickly the wildfire could be controlled – no matter where the fire was[43].

The fire managers were presented with an unnamed, unmarked map (except for contours, rivers and nearby infrastructure) of a mountain catchment area, and asked what kind of resources, and in what quantities, they would use to extinguish a wildfire if the area was pristine fynbos, with adjacent agricultural lands (see Appendix B and C). It was assumed that the fire would start at less than 50 hectares, but would spread to approximately 500 hectares. Fires in mountain catchment areas vary between 400 and 800 hectares, but experts agreed that an area of 500 hectares was an acceptable average for them (Gentle, pers. comm., 2002). The experts were then presented with the same scenario, except that the pristine fynbos was replaced with fynbos with a 50-100% alien infestation level (no alien species were specified). They were then asked the same questions to determine if the number of people and resources to combat the fire would change.

There are a vast number of variables to be taken into account in a wildfire simulation exercise. Factors such as the type of alien species present, the accessibility via roads, changes in wind speed, manpower available, terrain of veld, availability of water, risks involved (e.g. plantation/ infrastructure close to fire), duration of the fire, and different veld ages, to name but a few, complicates matters. For these reasons, various assumptions were made to simplify matters. These assumptions included: a prevailing southeasterly wind exceeding 28km/h, temperatures exceeding 28C, medium humidity, fynbos 15 years of age (relatively old) and the availability to managers of unlimited resources[44].

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[42] By regulation, fires have to be "tended to" until it rains (van Zyl, pers. comm., 2002). However, this policy can, in some cases, be impractical as the next rain could be weeks away. Normally fires are tended to until they are deemed safe. After the fire, people are left to monitor the site - the mop-up teams. Usually the team still on duty will do the mop-up, and the number of people doing the mop-up will gradually be reduced (Gentle, pers. comm., 2002).

[43] Research done by Ballart and Riba (2000) in Catalonia, Spain, on the relationship between government measures, volunteer participation, climate variables, and forest fires, showed that fires were extinguished faster as more resources, both human and material, were used. The involvement of the army significantly decreased the number of hectares burned. Multiple regression analysis was undertaken to determine the relationship between government policy instruments and the number of hectares burned in forest fires, while isolating the effects of the weather, climate, topography, orography (slope) and other context variables, such as the area where the fire was detected and number of simultaneous burns in a day.

[44] All the managers were particularly aware of the amount of resources available, as they were used to combating wildfires with very few resources (typically a team of about 20 people stationed on a nature reserve). Sometimes teams from neighbouring reserves would be pulled in, if available. The use of helicopters depends on their availability and the presence of other fires in the regions (Marshall and van Zyl, pers. comm., 2002).

A list of standard equipment used in fire-fighting[45] was compiled, with open categories provided for other special equipment. Only the cost of additional equipment hired and used in the fighting of pristine fynbos and alien-infested fynbos was deemed a cost of fighting fires in alien-infested land.

4.6.1.2 Results

All the experts surveyed agreed that there would be very little difference in the actual cost of fighting wildfires in pristine fynbos and fynbos 50-100% infested with alien vegetation, even though the fire behaviour and damage would be different (Martens, pers. comm., 2002). Aspects such as human safety, environmental conditions, and the risk of damage to property (e.g. plantations, agricultural land and houses), are the important factors to consider in fire management and these are not always influenced in obvious ways by the alien infestation level (Gentle, pers. comm., 2002).

Once a fire occurs, managers always use all resources available to extinguish it, whether it is in fynbos, grassland or their alien-invaded counterparts (Marshall and Wessels, pers. comm., 2002). The biomass of old fynbos is sometimes as high as dense alien infestation (Marshall, pers. comm., 2002), and access to the fire is often as difficult in fynbos as in alien-invaded areas. Slashers and cutters need to be used to access such fires. In most such cases, fires would only be monitored. No attempt would be made to extinguish them, because of the danger involved.

Fynbos fires burn well as a result of the availability of fuel in the form of ground material, while fires in aliens tend to burn up into the crowns. The cost of fighting a fire in dense fynbos and dense *Hakea spp*. would be the same, as both would be almost impenetrable (Marshall and Wessels, pers. comm., 2002).

The differences in direct cost of fire management with and without alien infestation are in the form of post-fire care costs (mop-up costs) and the probability of flare-ups. The duration of mop-up at wildfires in fynbos with a 50-100% alien infestation level needs to be longer than under the pristine condition, as the roots of aliens can smoulder below the ground surface for days, and flare up again with the onset of a bit of wind (Swanepoel, pers. comm., 2002). The chances of fires jumping out in alien infested areas increase by about 75%, as the logs of alien species take a long time to burn out, with the possibility of flare-ups and flames leaping out of a burned area to start a fire somewhere else (Rheeder and Martens, pers. comm., 2002).

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[45] This includes beaters, drip torches, bakkie units, slashers, torches, radios, and in some cases fireproof clothing (Marais, Marshall, pers. comm., 2002). Usually the equipment used in fires would be left behind for the mop-up teams (Rheeder, pers. comm., 2002), incurring no extra costs. Standard equipment is different for different areas: in George for example, beaters are almost never utilised, as fire fighters use branches for the same purpose (Marshall, pers. comm., 2002).

The fire experts estimated that in fynbos with a 50-100% alien infestation level, human mop-up after a wildfire takes more than twice as long and double the number of people, than under pristine fynbos. The equipment used during the fire is usually left behind for the mop-up teams[46]. More water is also needed during and after the fires in fynbos with a 50 to 100% alien infestation level (Rheeder, pers. comm., 2002).

The bulk of mop-up costs was attributed to labour costs[47]. Labour costs consist of a Rand–per-hour component for normal work hours, and an overtime component for the hours between 5pm and 8pm. Special overtime is awarded to people working from 8pm through the night (Marais, pers. comm., 2002). Food parcels are distributed to fire fighters every 8 hours[48] (Gentle, pers. comm., 2002). Table 4.3 shows the costs of fighting wildfires in fynbos with and without an alien infestation level of 50 – 100%. Labour costs are listed for workers, supervisors, managers, and fire bosses, during a wildfire starting at 50 hectares and spreading to 500 hectares.

[46] Fire-fighting equipment such as slashers, beaters, rake-hoes and others are purchased and used for all fires: pristine or invaded. No additional manual equipment would be bought as a result of alien infestation - teams from other areas would supply their own equipment (van Zyl, Marshall, pers. comm., 2002), and in some places such as the George area, beaters are not used at all in fire-fighting (Marshall, pers. comm., 2002). For this reason the cost of such equipment was not included in direct firefighting costs. The once-off purchase of equipment is perceived as a sunk cost. However, in cases where it was thought additional equipment was needed for fighting fires in invaded fynbos, this cost was added to total direct costs.

[47] Fire-fighting teams consist of between 15 and 20 people – usually the number of people working on a nature reserve (van Zyl ,pers. comm., 2002). The opportunity cost of teams fighting wildfires in pristine and alien infested fynbos would be zero, as the policy of reduced prescribed burning would result in teams fighting wildfires instead, where they had previously fought prescribed fires. They would be fighting fires at some stage, and the control of wildfires would be the substitute for the reduction in prescribed burning. However, teams on standby (usually from other reserves or WfW) do incur an opportunity cost in the form of lost productivity, while a fee of R24 per team per day is paid on top of that, in order to have teams on standby. However, teams are immediately placed on standby, irrespective of the alien infestation level of the vegetation burning. Factors other than the alien infestation level, including the risk of damage to infrastructure and orchards, are more important considerations (Gentle, pers. comm., 2002). It is important to note that the smaller the fire, the higher the fire-fighting cost per hectare, and therefore the impact per hectare.

[48] Sometimes the interval varies between 6 to 8 hours. These food packages are specifically designed to re-hydrate firefighters. For this reason it is important that distributors stick strictly to these hours (Gentle, pers. comm., 2002).

Table 4.3 A summary of the mop-up costs for a fire in natural fynbos, and fynbos with a 50-100% infestation level.

People	Total hours*	Rate/h (R)	Overtime (R/h)	Special overtime (R/h)	Cost (R)
NATURAL FYNBOS					
Workers	630	3.75	4.98	6.26	3302.89
Specialists (e.g. high altitude)	0	5.63	7.48	9.40	0
Supervisors	31	6.88	9.15	11.48	298.18
Managers/ Fire bosses	8	11.88	15.80	19.83	132.87
		Cost per parcel (R)			
Food parcels	84	22			1839.75**
TOTAL COST					**5573.69**
50 – 100% INFESTED FYNBOS					
Workers	2058	3.75	4.98	6.26	10789.45
Specialists (e.g. high altitude)	0	5.63	7.48	9.40	0
Supervisors	83	6.88	9.15	11.48	798.34
Managers/ Fire bosses	12	11.88	15.80	19.83	200
		Cost per parcel (R)			
Food parcels	269	22			5920.75**
TOTAL COST					**17707.85**
NET FIRE BENEFIT per fire					**12134.16**
NET FIRE BENEFIT per fire (R/ha)					**24.27*** **

* This is the average of the total hours of mop-up as provided by the fire experts.
** This cost is calculated by dividing the total number of hours by 8 hours (food parcels are distributed every 8 hours) and then multiplying this with the cost per food parcel.
*** The net fire benefit is divided by the size of the fire – in this case 500ha – in order to derive the cost per hectare in Rands.

The net fire benefit is determined by subtracting the direct cost of fires in natural fynbos from the direct cost of fires in fynbos with a 50 – 100% infestation level. The difference in cost of two fires, both starting at areas less than 50ha, under similar conditions, and spreading to an area of approximately 500ha, is R12 134.16 more in 50 –100% infested fynbos than in pristine fynbos. This equates to a cost of about R24 per hectare.

4.6.1.3 The problem of estimating ecological fire costs

Ecological damage is an indirect cost associated with fires in alien-invested fynbos (Euston-Brown, 2000; Swanepoel, van Zyl and Martens, pers. comm., 2002). These costs include the loss of biodiversity, dam siltation, and erosion (Euston-Brown, 2000). The presence of aliens transforms the predominant fynbos fire regime consisting of warm, fast surface fires, that quickly burn through the fynbos, to fires that burn intensely but at a slower pace, causing damage to the fynbos as fires burn into the ground[49] (Moore, pers. comm., 2002). This has a negative effect on biodiversity in the fynbos biome, as most species need surface fires for seed reproduction and germination, but intense fires kill these seeds. Fynbos can also be out-competed by aliens at the regrowth stage, as alien trees are fast growers, and more alien trees would grow after fires as their seeds are also stimulated by fires (Cowling, 1992).

Soil erosion increases as a result of wildfires in alien-infested areas, because roots of these species smoulder and burn holes in the ground (van der Merwe, pers. comm., 2002; Moore, pers. comm., 2002). Soil erosion costs include that of rehabilitation of areas (Rautenbach, pers. comm., 2002). These costs are site-specific and can only be estimated once in-depth site analyses have been undertaken (Erasmus, pers. comm., 2002). As could be expected, there is disagreement on the relative impact of fires on soil in fynbos infested with alien species versus pristine fynbos. Some people argue that alien species do not increase erosion (Weitz, pers. comm., 2002). A study done on a WfW monitoring plot in the Kleinmond area (which was approximately 85% infested with *Pinus Pinaster)* showed no extra soil damage after a wildfire (Holmes, 2001).

The study done by Euston-Brown (2000) on the effect of wildfires on soil erosion in alien, cleared and pristine fynbos vegetation after fires at Fish Hoek and the Cape Peninsula, indicated differently. The degree of heating of surface soils is higher in alien-infested fynbos vegetation, and the most erosion and soil loss occurred in alien vegetation and areas recently cleared of alien vegetation[50]. The latter occurrence suggests that WfW activities can aggravate the soil erosion problem. WfW is currently addressing the situation by looking at alternative clearing methods, such as the removal of cleared biomass and the immediate rehabilitation of cleared areas (Knipe and Marais, pers. comm., 2002). The course of soil erosion also depends on other factors, which need further research (Euston-Brown, 2000). These factors include vegetation type, soil type and the influence of fire severity on the water repellency of soils.

Dam siltation increases when soil erosion occurs, because the topsoil, which is the most fertile soil type, is washed into dams (van der Merwe, pers. comm., 2002). The cost of siltation caused by wildfires cannot readily be determined, because this cost cannot be distinguished from siltation costs originating from other sources (de Wet, pers. comm., 2002).

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[49] Although fires in alien vegetation regularly burn in the crowns of trees high above the ground, these trees can fall over and burn further on the ground. The heat is also conducted to the stems of burning trees.

[50] This erosion was due to the water repellency and the greater depth of the non-repellent layer on the surface of the soil.

It was deduced that further research was needed on the nature of the fire impact in different vegetation zones, before economic valuations could contribute to knowledge on the costs of soil movement due to fires.

4.6.1.4 Implication of the fire benefit at the relevant WfW sites

The Kouga, Tsitsikamma, PE Driftsands and Albany WfW sites are situated within the fynbos biome. Direct fire management costs increase by an estimated R24 per hectare as a result of a 50 – 100% alien infestation level. The average infestation levels at these sites vary between 1 – 20%, and at infestation levels below 50% there are no additional fire-fighting costs. All these sites have patches where alien infestation levels are estimated at above 50%[51], suggesting a fire benefit. No rate-of-spread component was included, as the fire benefit only becomes apparent at relatively high infestation levels (above 50%). The estimated fire benefit for the WfW sites where fynbos is the predominant vegetation, is shown in Table 4.4.

Table 4.4 The fire benefit for WfW sites where fynbos is the predominant vegetation

Site	**Fire benefit (R/ ha)**	**Ha with dense infestation levels ***	**Fire benefit (R)**
PE Driftsands	24.27	3200	77 664
Tsitsikamma	24.27	26 073	63 2791.70
Kouga	24.27	77	1 868.79

* Infestation levels above 75% (Hosking *et al.*, 2002).

The threat of damage to property and infrastructure is pronounced at all three sites. Commercial forests are established in Tsitsikamma, the city of Port Elizabeth is situated near the PE Drifsands site, and the Langkloof fruit orchards are situated near the Kouga site.

Another facet of wildfires is that they stimulate the germination of alien seeds in seedbanks under the ground. For this reason, a wildfire serves the same purpose as a first follow-up operation after the clearing of alien vegetation, where seed germination of alien vegetation is stimulated through prescribed fires and then pulled out by hand. Unfortunately, wildfires are unplanned events, and if follow-up operations are not carried out on areas burned during a wildfire within 2 years, follow-up costs of alien eradication could increase to R6000/ha (Moore, pers. comm., 2002).

[51] The density classes as recorded by the WfW project managers do not correlate with that of fire managers: fire managers estimated fire benefits at levels of 50 to 100%, while density classes are recorded as moderate when between 25 to 75%, and dense above a level of 75%.

4.6.2 Grassland

4.6.2.1 Method

The same method as the one described for fynbos areas was followed in the determination of the net fire benefit of the WfW programme for grasslands. Experts on grassland fires, such as foresters and plantation managers, were asked to comment on the difference in direct costs of fire-fighting in natural grassland as opposed to grasslands infested with alien trees and plants. The opinion of four experts on the matter was solicited.

These experts were presented with two scenarios, to cost a wildfire running through pristine grasslands under high-risk conditions, and a wildfire running through 50 – 100% infested grassland area under the same conditions. No maps were used. A piece of grassland close to some of the Mondi plantations outside Ugie, and a grassland area outside Grahamstown, were used as examples. A fire size of 50 hectares was chosen as a fair average for fire in grasslands (Cobbold, pers. comm., 2002) (see Appendix B).

4.6.2.2 Results

Differences in fire-fighting costs only become apparent at infestation levels at and above 70% (Cobbold, pers. comm., 2002). Pristine grassland fires spread very fast, and the existence of alien species, especially live wattle (the most evident alien invader at the representative sites), will sometimes slow fires down (Butt and Cobbold, pers. comm., 2002). It takes more heat to ignite live wattle than grasslands, with the result that the speed of a fire decreases once it hits the wattle stands. This slowing can provide fire fighters with an opportunity to put in a backburn, thereby reducing fire damage, but backburns have legal implications (Cobbold, pers. comm., 2002). Given this role played by the wattles, it is deduced that fire management costs in alien-infested grasslands do not increase above what they would be in pristine conditions. However, there are other factors that can drive up direct costs and complicate the fighting of fires (Cobbold, pers. comm., 2002).

The dangers of fighting fires in alien-infested grasslands are more pronounced than under the pristine grassland equivalent. In pristine grassland, visibility and accessibility to fires are not a problem, but they are in alien infested grasslands: visibility is greatly reduced and the threat of human injury from falling branches is heightened (Cobbold and Butt, pers. comm., 2002).

In total, the direct management costs associated with fires in grasslands which are 50 – 100% infested with alien species are higher than those in natural grasslands, because such fires are more labour-intensive, engage more resources (equipment)[52] and water (from the fire brigade),

[52] Sometimes only beaters are used to put out fires in pristine grasslands.

and take longer to kill than pristine grassland fires. The mop-up time is also longer. As a result there is a longer period during which sparks can fly to ignite another fire (sparks can fly more than 500 metres). For this reason every stump must be tended to individually (Cobbold, pers. comm., 2002). Overtime and helicopter costs are the main expenses[53]. Table 4.5 below summarises the contributing factors to direct costs of fire-fighting in natural and infested grassland. The costs are for fires of approximately 50 hectares in size. No rate-of-spread component was included, as the fire benefit only becomes apparent at relatively high infestation levels (above 70%).

[53] Fires in grasslands usually pose a threat to plantations, as the climate is also suited for commercial afforestation.

Table 4.5 A summary of the costs for a fire in natural, and 50-100% invaded grasslands

Description	Total hours	Rate/h (R)	Overtime (R/h)	Special overtime (R/h)	Cost (R)
NATURAL GRASSLANDS					
Workers	550	3.75	N.A.	N.A.	2062.50
Specialists (e.g. high altitude)	0	5.63	N.A.	N.A.	
Supervisors	25	6.88	N.A.	N.A.	172
Managers/ Fire bosses	10	11.88	N.A.	N.A.	118.80
Bakkie unit	30	80	N.A.	N.A.	2400
Helicopter	1.5	21 000	N.A.	N.A.	31 500
Mop-up					
Workers	100	3.75	N.A.	N.A.	375
Supervisors	10	6.88	N.A.	N.A.	68.80
Managers	6	11.88	N.A.	N.A.	71.28
Knapsack sprayers	100	6.50	N.A.	N.A.	650
		Cost per food parcel (R)			
Food parcels	87	22			1911.25**
TOTAL COST					**39329.60**
50 – 100% INFESTED GRASSLANDS					
Workers	400	3.75	4.9875	6.2625	1599
Specialists (chainsaw operators)	10	5.63	7.4879	9.4021	60
Supervisors	25	6.88	9.1504	11.4896	183.35
Managers/ Fire bosses	10	11.88	15.8004	19.8396	126.64
Fire brigade	20	300	N.A.	N.A.	6000
Helicopter*	1.5	21000	N.A.	N.A.	31500
Chainsaws	10				1100
Mop-up					
Workers	650	3.75	4.9875	6.2625	3352.88
Supervisors	32.5	6.88	7.4879	9.4021	307.6
Managers/ Fire bosses	32.5	11.88	15.8004	19.8396	531.1
Fire brigade	32.5	300	N.A.	N.A.	9750
		Cost per food parcel (R)			
Food parcels	145	22			3190
TOTAL COST					**57700.50**
NET FIRE BENEFIT per fire					**18370.90**
NET FIRE BENEFIT per fire (R/ha)					**367.42*** **

N.A. – Not Applicable

* Due to visibility problems, helicopters are not that accurate and effective in stands of wattle as opposed to grasslands. For this reason they would not be used extensively in the fighting of alien invaded grasslands.

** This cost is calculated by dividing the total number of hours (during fire and mop-up) by 8 hours (food parcels are distributed every 6 to 8 hours) and then multiplying this with the cost per food parcel.

*** The net fire benefit is divided by the size of the fire – in this case 50ha – in order to derive the cost per hectare in Rands.

The net fire benefit of the WfW programme in grassland was calculated by subtracting the cost of fighting pristine grassland fires, from grasslands with a 50 to 100% alien infestation level. This benefit is estimated to be R39 329.60 for a fire of 50 hectares. This estimate translates into a net benefit of approximately R367.42 per hectare.

Two qualifications need to be added to this estimate. Firstly, bigger grassland fires would be expected to have lower costs, as an inverse relationship between fire size and fire-fighting costs is evident (the grassland fire benefit is determined for fires of 50ha, while the fynbos fire benefit is for areas of 500ha). Secondly, the role alien trees play in slowing down fires could not be determined in monetary terms.

4.6.2.3 Implication of the fire benefit at the relevant WfW sites

Grassland is the predominant vegetation type at the Ugie and Kat River sites. Differences in fire-fighting costs in pristine grasslands and alien-infested grasslands only become apparent at infestation levels at and above 70%. For this reason the fire benefit could only be determined for areas where the alien infestation is recorded as dense (75% and above).

The fire benefit was calculated as the Rand per hectare difference between pristine and alien invaded grasslands, multiplied by the number of hectares where alien infestation was recorded at above 75%. The fire benefit for the WfW sites where grassland is the predominant vegetation is shown in Table 4.6.

Table 4.6 The fire benefit for WfW sites with grasslands as predominant vegetation

Site	**Fire benefit (R/ ha)**	**Ha with dense infestation levels ***	**Fire benefit (R)**
Albany	367.42	6900	2 535 198
Kat River	367.42	0	0
Pot River	367.42	260	95 529.20

* Infestation levels above 75% (Hosking *et al.*, 2002).

Commercial plantations are found in close proximity to both the Kat and Pot River sites, contributing to the risk of damage as a result of fires in these areas (Cobbold, pers. comm, 2002). In the Ugie area a helicopter is on standby for the duration of the dry months (May to September) to minimise fire damage on Mondi plantations (Butt, pers. comm., 2002). The town of Grahamstown is situated near the Albany site, increasing the risk of damage to infrastructure from fire there.

No rate-of-spread component was included in the determination of the fire benefit over time, because of increased costs only becoming apparent at high infestation levels. Although patches of dense infestation levels were recorded at five of the six sites, these are relatively small in comparison with the total area cleared at most of these sites. The germination of alien seedlings after wildfires would also complicate the prediction of such a rate of spread.

4.7 CONCLUSION

Fire regimes of different vegetation types – taking into account factors like intensity, frequency and season - have been the subject of numerous studies (Bond and van Wilgen, 1996). Alien tree and plant species alter the fire regime of indigenous vegetation through their higher biomass load. However, data on the cost of such fires has been lacking.

This chapter values the direct fire management costs of wildfires in fynbos and grassland in their pristine condition, and contrasts it with the same vegetation with an alien infestation level of between 50 and 100%. The difference in direct fire-fighting costs between the two scenarios was deemed to constitute the fire benefit of the WfW programme. The predominant indigenous vegetation types present at the representative WfW sites in this study are fynbos and grasslands.

The relative alien infestation level at all study sites varies between 1% and 10%. However, the fire benefit only becomes a factor at infestation levels at and above 50% for fynbos, and above 70% for grasslands.

From the responses of the fire experts, it was deduced that fire costs during a wildfire would be almost equal for both pristine and infested fynbos. The mop-up costs (after fire care) of wildfires in fynbos with a 50 – 100% infestation level would be higher than in the pristine counterpart. The reason for the latter is that roots of alien species tend to smoulder for a long period underground, and the probability of flare-ups is increased. When direct fire-fighting costs of hired fire management teams are included, the extra cost of mop-up over time in fynbos – and hence the net fire benefit of the WfW programme - is R12 134.46 for a 500-hectare fire site, which translates into approximately R24 per hectare.

There are other costs that were excluded from this estimate. These costs include expenses incurred by other role players, such as private landowners and farmers[54].

Possible ecological costs such as loss of biodiversity, erosion, and siltation of dams were also excluded from the calculations.

[54] Some costs such as cellphone calls and transport are always underestimated (Moore, pers. comm., 2002).

The direct fire-fighting costs of a wildfire in grasslands with a 50 – 100% infestation level was estimated to be R367.42 per hectare higher than they would be in pristine veld. The increased use of labour and equipment during and after fires contributes to this cost difference. Other costs, such as those of other role players' inputs in direct fire-fighting management were excluded from this estimate[55].

[55] A member of the WfW's Economic Development and Resource Economics panel suggested that the fire benefit in general (including risks to infrastructure) could be refined through computer modeling (such as the BEHAVE model), as these models predict the behaviour of fires and include danger indices, which would be helpful in the determination of damage costs.

CHAPTER 5
VALUING BIODIVERSITY BY MEANS OF THE CONTINGENT VALUATION METHOD

5.1 INTRODUCTION

The Convention of Biological Diversity defines biological diversity as “the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems” (Gaston & Spicer, 1998:2). Biological diversity (biodiversity) comprises the variety of life in all its elements and complexities (Gaston & Spicer, 1998:1). The elements of biodiversity are listed in Table 5.1 below.

Table 5.1 The elements of biodiversity

Ecological diversity	**Genetic diversity**	**Organismal diversity**
Biomes	Populations	Kingdoms
Bioregions	Individuals	Phyla
Landscapes	Chromosomes	Families
Ecosystems	Genes	Genera
Habitats	Nucleotides	Species
Niches		Subspecies
Populations		Populations
		Individuals

Source: Gaston & Spicer, 1998:3.

The idea that biodiversity can be valued is a contentious one - mainly because there is uncertainty over quantifying it at an ecological level. If biodiversity could be unambiguously defined and ecologically measured, valuation would be less of a problem. The loss could be measured, and valuation could proceed.

Most ecological measures of biological diversity centre around two components: the number of species (species richness) and the degree of difference between species (Gaston & Spicer, 1998:5). The former is the most widely used, and has become the common currency of biodiversity discourse (Gaston & Spicer, 1998).

Biodiversity is necessary for the functioning of ecosystems. All living organisms, including humans, depend on these systems for their survival. Ecologists have imperfect information on species and ecological processes. For this reason, current indicators of biodiversity do not offer enough information for the establishment of a necessary level of species richness, without which living organisms cannot survive (Barbier, Burgess and Folke, 1994:18).

For these reasons, analysts are forced to rely on indirect ways to measure and value biodiversity (Hanley and Spash, 1993). There are two types of values/benefits which may be derived from biodiversity: use and non-use values. These values are not mutually exclusive (Field, 1997).

The protection of biodiversity has ecological, economic, and moral implications. The main ecological benefits of biodiversity are essential services to maintain life support systems and natural material for current and future use (Huntley, 1991; Barbier, Burgess and Folke, 1994). Empirical studies show that certain species within an ecosystem - so-called “keystone species” - dictate the processes necessary for ecosystem functioning (Huntley, 1991; Barbier, Burgess and Folke, 1994). Without keystone species, an ecosystem cannot be sustained (Barbier, Burgess and Folke, 1994).

Economic implications regarding biodiversity preservation centre around its influence on the welfare of current and future generations. Matters of inter- and intra-generational equity are the focus points (Barbier, Burgess and Folke, 1994). Humans have a responsibility towards conserving biodiversity, as it enables ecosystems to yield them direct (e.g. food) and indirect services (e.g. clean water). This responsibility ties in with the moral grounds for preserving biodiversity, which focus on the aesthetic value of nature (Barbier, Burgess and Folke 1994).

This chapter proposes that the information problem with respect to the nature of the biodiversity benefit be overcome by taking people’s preferences towards indigenous vegetation as a proxy for their preferences towards biodiversity. WfW’s contribution towards biodiversity relates to its facilitation of indigenous tree growth and improved ecosystem functioning through the eradication of alien plant species.

5.2 LEVELS OF BIODIVERSITY

The use of species as a measure of biodiversity has led to the division of biodiversity into three levels. These levels are alpha, beta and gamma diversity.

Alpha diversity refers to the number of species within a habitat. An alpha rarity would be a species that is uncommon within a community. Loss of genetic diversity within small communities is perceived as the biggest threat at this level of biodiversity (Huntley, 1991).

Beta diversity deals with species turnover between habitats and habitat specificity (the number of habitats and the turnover of species between them). A species that is a beta rarity is found in a small part of the habitat, a “habitat specialist” (Huntley, 1991). Beta diversity can be protected by setting aside areas where such biodiversity appears, and keeping them intact (Huntley, 1991).

Gamma diversity refers to the turnover of species within a region. Species in this group are restricted within biogeoclimatic boundaries (Huntley, 1991; van Kooten & Bulte, 2000:280), but are difficult to separate in morphological and ecological terms. Gamma diversity can be protected through the construction of many small reserves, in order to include all endemic species (expensive) (Huntley, 1991), or through the protection of species across ecological gradients (Marais, pers. comm., 2003).

Changes in the number of individuals of a species, or in the number of sites or habitats for a threatened species, are crucial indicators of biodiversity.

5.3. THE VALUE OF ENVIRONMENTAL RESOURCES

5.3.2 Valuing environmental goods

Environmental goods are often also public goods (Turner, Pearce and Bateman, 1993). Markets for most environmental goods do not exist, which means that data on values and prices are not directly available. For this reason, the "market value" of an environmental good has to be estimated indirectly.

Various techniques have been developed to estimate values for these goods. Methods aimed at pricing units of environmental goods attempt to capture the marginal value to society. In order to determine the total current value of an environmental resource, the demand function must be estimated. If the good is fundamental to existence (such as biodiversity) the demand function would be of such a nature that the total value would be infinite[56].

5.3.2 Valuing biodiversity

The value of an environmental good is made up of use and non-use values. Use values arise from actual use of the environmental resource (Pearce and Moran, 1994: 18). Non-use or passive-use values relate to the preservation value of an environmental asset, and are divided into option, bequest and existence values.

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[56] This can be demonstrated with the water and diamond paradox, where the marginal value of diamonds might be very high when compared with that of water, because it is a scarce resource. However, water is vital to human existence, resulting in an infinite total value, as people would pay an infinite price for it as its availability tended towards zero (the demand curve would never cross the Price-axis). The total value of diamonds, on the other hand, will be low when compared with that of water, as it is not vital to human existence (Parkin, 2000).
In the case of biodiversity, it is argued that it cannot be valued as the sum of the individual components, as the total value of the whole exceeds that of the aggregate value of the individual components. When valuing biodiversity, one should keep in mind the value of the total restored ecosystem. Some members of WfW's Economic Development and Resource Economics panel feel that biodiversity, in terms of the Working for Water programme, can be translated as the provision of a source of stable vegetation cover that will protect mountain catchment areas in the long term, as alien invasion leads to catchment degradation after several fire cycles and fundamental changes to the hydrological regime over years.

Use values are divided into consumptive and non-consumptive types. There are a number of consumptive and non-consumptive use values generated by biodiversity (Huntley, 1991; Gaston and Spicer, 1998 and Turner, Pearce and Bateman, 1993). Consumptive use refers to the actual use of the environmental good, such as the use of indigenous vegetation for medicinal purposes[57]. The fynbos biome has a consumptive use as a source of products such as thatch, rooibos tea, honey bush tea, herbs for medicinal purposes, grazing, and cut flowers (Bond, 1993). Non-consumptive use refers the indirect use of an environmental asset, such as game viewing. The non-consumptive use of biodiversity also relates to the value of ecosystems as the "web of life", providing an infrastructure for ecological processes necessary for survival. This infrastructural value of biodiversity is difficult to quantify, not least because a minimum level of ecosystem functioning is crucial for human survival, but its total value is limitless (Gaston and Spicer, 1998:80; van Kooten & Bulte, 2000).

The option value relates to people's willingness to pay to retain future use or access to a natural resource (Pearce and Moran, 1994 19-20; Turner, Pearce and Bateman, 1993: 113, van Kooten & Bulte, 2000:121). Bequest value is the willingness to pay for the conservation of an environmental resource for the potential use and benefit of future generations (Turner, Pearce and Bateman, 1993: 113, Gaston and Spicer, 1998:82). Existence value (intrinsic value) is the value derived from knowing that a resource exists, even though a person might never enjoy consuming it. This value may arise from feeling a moral obligation towards protecting habitats and species from extinction.

Option, bequest and existence values are extremely difficult to identify separately in practice (Pearce and Moran, 1994:20).

Policymakers face many difficulties in their decisions to preserve biodiversity in general, and individual species specifically. This difficulty is demonstrated by the Endangered Species Act of 1973[58]. This Act was designed to overcome the market failure of unpriced social benefits

[57] In the USA, approximately one quarter of all medical prescriptions are based on plant or microbial products. They serve as ingredients for industrial materials, recreational harvesting (such as hunting and fishing) and eco-tourism all over the world (Gaston and Spicer, 1998:77). Indigenous vegetation is of particular interest to some tourists who visit an area in order to experience the indigenous flora, and the fauna that goes with it. The fynbos biome is perceived as a biodiversity "hotspot" (Buckle, pers. comm., 2002), meaning that the indigenous trees and plants within this biome are endemic, and cannot be found elsewhere in the world. Some tourists to South Africa incur huge travel costs to see the flowers in Namaqualand, for instance.

[58] Critics of this Act have pointed out that ecosystems – rather than species – ought to be conserved, as ecosystems have intrinsic value in that they enhance species survival (Gardner, Brown and Shogren, 1998). This, once again, refers back to the central question of the conceptualisation of biodiversity.

Metrick and Weitzman (1998) put forward a model for biodiversity preservation, where a ranking system was used to determine the optimum level of biodiversity, by ranking species in order of importance. They used the example of a Noah's Ark, where decisions needed to be made on which species to take on board and which to leave behind. This ranking system relied on four variables: the utility derived from the species, the survivability of the species, its provided by these species. It does not rank endangered species from most important to least important, and therefore takes no account of budget constraints. By implication, all species on the list have the same infinite value, and are placed beyond the reach of the real world of economic trade-offs (Gardner, Brown and Shogren 1998). In the real world people and governments faces budget constraints.

Environmental economics attempts to place the quality and quantity of biodiversity that can be conserved within the budget constraint framework. This approach may recommend that some species be allowed to become extinct if the social costs of protecting them exceed the benefits.

5.3.3 Methods available for the valuation of biodiversity

Methods for valuing environmental resources can be divided into two categories: those aimed at estimating the demand curve, and those that are not (Turner, Pearce and Bateman, 1993: 115). Demand curve approaches make use of observations of behaviour in existent markets, or survey responses in theoretical markets (Callan and Thomas, 1996)[59].

The value of an environmental good can be elicited by asking people to express their preferences for the good in monetary terms. This approach is known as the Contingent Valuation Method (CVM). In the use of CVM, surveys are employed to determine what people would be willing to pay for an environmental good/quality if a hypothetical market for it existed (Callan and Thomas, 1996:238). It is “contingent” because a hypothetical market for the environmental good is created, and the results are dependent on the realism of the hypothetical market situation sketched. It is the most widely used of the expressed preference approaches, and has numerous advantages (Tietenberg, 2000, Goodstein, 2002). These are as follows: respondents can express their preferences, use and non-use values can be captured, and it can be related to a wide spectrum of environmental goods (Callan & Thomas, 1996). Its weaknesses are discussed in section 5.3.4.3.

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distinctiveness, and the cost of preserving it. The utility of a species is divided into direct utility (e.g. commercial), and indirect utility derived from an increase in overall diversity because the contribution of a specific species is protected. The distinctiveness of a species relates to the closeness of other species belonging to the same family. The survivability of a species concerns its probability of survival with and without conservation measures, and the expected overall gain of conserving the species was calculated by multiplying the change in survival probability with conservation measures with the sum of direct utility and diversity value (Metrick and Weitzman, 1998). This gain was then contrasted to the cost of conserving the species, taken as an opportunity cost.
Metrick and Weitzman (1998) admitted that these four variables would be difficult to identify and quantify in the real world, but they should at least be considered as a rough guideline for the ranking of species. Their inclusion of a budget constraint (cost of preserving the species) is an important move towards the reconciliation of economics and the environment (biodiversity), as it highlights the real problem of limited funds available for the preservation of biodiversity. Environmental problems cannot be detached from other problems in society, and compete with other problems for funding (Gowdy and Carbonell, 1999).

[59] The demand curve approach taken was one aimed at valuing consumer surplus (Turner, Pearce and Bateman, 1993: 115).

In principle, the demand curve for environmental goods can be generated through the use of revealed preferences methods such as the Travel Cost Method (TCM) and the Hedonic Pricing Method (see Appendix E). Travel costs incurred to undertake a trip to a site can be used to determine the willingness to pay a price for the environmental goods at the site (Callan and Thomas, 1996).

The Hedonic Price Method (HPM) is founded on the assumption that the value of a good or service can be broken down into parts for each of the characteristics it possesses. The unit value of each part is called the “implicit” or “hedonic” price. House values are often used as a basis to conduct HPMs. The price of a house is broken down in terms of its features, e.g. number of rooms, location, noise level, and proximity to amenities such as schools (Callan and Thomas, 1996).

5.3.4 The Contingent Valuation Method (CVM)

The CVM has been refined many times since its inception in 1952. It has been used extensively in the United States of America for the determination of values of environmental goods and services. In South Africa, it has been used in water-pricing studies, *inter alia* (Turpie, Winkler, Spalding-Fecher and Midgley, 2002).

5.3.4.1 Reasons for the choice of CVM to value biodiversity at the six sites

The CVM was used to determine people’s preferences for biodiversity at the six representative WfW sites. The CVM has been subject to criticism for its valuation of environmental resources in general, and biodiversity in particular. Biodiversity is known for its substantial non-use component (Gaston and Spicer, 1998). Non-use values (such as existence value) can be captured through contingent valuation procedures, as both user and non-user respondents are asked for their WTP values (Gaston and Spicer, 1998). Respondents are informed about all impacts of biodiversity and its broader importance for all living organisms.

This degree of specificity of information cannot be duplicated using the Hedonic Pricing (HPM) or Travel Cost Methods (TCMs). The biggest hurdle to overcome when using Contingent Valuation is the provision of sufficient correct and easily comprehensible information to respondents (Gaston and Spicer, 1998).

A big problem with valuing biodiversity is that it does not have neat geographical definitions and boundaries. Biodiversity is a complex concept, but if it can be ‘unpacked’ into understandable chunks of information in a realistic manner, then it becomes amenable to Contingent Valuation.

This study proposes that biodiversity can be unpacked, in this case, as people's preference for indigenous vegetation.

5.3.4.2 Steps of the Contingent Valuation Method

Because of its suitability to capturing a wide range of values of environmental goods and services, researchers often prefer the CVM over TCM and HPM (Callan and Thomas, 1996).

A CVM consists of three steps (Field, 1997:138).

Firstly, the questionnaire must be constructed using the following guidelines:

(a) The good/service to be valued must be defined.

(b) The importance of the environmental good to be valued needs to be explained in simple terms.

(c) The WTP question needs to be devised. A hypothetical request for payment of a service from the natural resource must closely resemble that of a real market. The way in which the payment for the good will be raised, the bid vehicle, must be specified. This can be via a tax, trust fund, entrance fee, or utility bill. Care must be taken in the selection of the bid vehicle, as it can affect the WTP or WTA responses (Callan and Thomas, 1996:238). In general, a neutral (non-controversial) bid vehicle should be chosen. Additional information should be provided on whether all consumers would pay a fee, the way in which the fee would be paid, and the way in which the decision to proceed with the project or policy would be made.

(d) The sample population must be specified[60].

(e) A representative and adequate sample selection should be made.

(f) An internal test of the CV for validity should be devised. This is usually done in the form of a comparison between an estimated WTP function and one done *a priori*.

Secondly, the questionnaire must be administered. Surveys can be done telephonically. This is an inexpensive way of administering a survey, but is inadequate for this case, because the concepts are complex and sometimes difficult to explain over the telephone. Alternatively, mail surveys can be undertaken. Although this is relatively inexpensive and avoids interviewer bias, it takes time to collect responses, the response rate is usually low, and there may be information biases in the responses. Personal interviews are the best way of gathering information, because concepts can be explained at length, and respondents can be enticed to participate. As a result, the non-response rate is usually low. However, it is time-consuming and is more expensive.

[60] This includes everyone that would be affected by a change in the environmental good in question, i.e. both users and non-users.

Respondents can be approached in different ways in order to elicit their WTP or WTA. These include:

1. *A bidding game*, where an amount is put on the table, and respondents must either agree or disagree on the amount and subsequent amounts until the maximum WTP is reached.
2. *Open-ended questions* leave the choice of an amount to the respondent. *A closed-ended referendum* provides a single payment, which the individual must either accept or reject.
3. *Payment cards* require the respondent to choose his/her WTP from cards listing a range of values.
4. *Auctions*, whereby either a maximum amount is given and respondents must bid lower than the given amount, or a minimum price is given, and respondents must increase the bid until the highest value is reached.
5. *Take-it-or-leave-it offer*. In this case, individuals are asked whether they would be willing to pay a specified amount for the environmental good or service in question.

Thirdly, the data is analysed. An average bid is estimated, using all the responses acquired. A median bid is also specified, as some responses may distort the results, e.g. outliers and protest bids of zero. The WTP or WTA is used to determine a bid curve, where WTP/WTA represents the dependent variable, and gender, age, education, income and so on, are independent variables.

WTP = f(Yi, Ei, Gi)
where
G = gender
Y = income
E = education

Bid curves are used to determine whether results are consistent with economic theory. A benefit aggregation is then undertaken, to ensure that the sample fully represents the population affected by the decision made on the environmental good. The population must include everybody whose utility and welfare will be affected by the decision.

The “total” current value of a specific quantity of an environmental good is the product of the average WTP and the total number of people affected by the addition or subtraction of the good or service. Problems of bias arise if the sample does not represent the population.

The average WTP amount must also be adjusted for the time period over which the benefits of the project will accrue. For this purpose, discounting is used to determine the present value of a benefit stream over time.

5.3.4.3 Problems associated with CVM

Although the CV method is widely used, it has also been the subject of considerable criticism (Field, 1997: 138). Problems associated with the CVM include:

- *Information provision and acceptance*. Interviewers try to provide sufficient information to assist respondents in determining their true willingness to pay value, but people have a limited capacity to understand and comprehend new knowledge (which is often the case with CVM, as people are confronted with new information) and assign a value to it at the same time. People have little or no experience with this type of questionnaire, and often find it extremely difficult to assign a value to an environmental good (Ortolano, 1997: 137). If insufficient information is provided, or if the questions seem unrealistic to the respondent, this person's WTP will differ from the true WTP value (Callan and Thomas, 1996:239). Information about budget constraints is often not clearly understood by respondents, leading to mental account bias. Mental account bias occurs because of the complex decision-making process involved in contingent valuations, and its hypothetical nature. Respondents need to decide how much they would be willing to spend on the environmental good or service. Then they must make a budget trade-off, and decide how much less they will spend on other goods and services in order to spend more on the environmental good (Hanley and Spash, 1993; Ortolano, 1997: 137).

  Respondents are also not always informed on the availability of substitutes for the environmental good in question. This information is important, as it must be taken into account in the WTP decision. If close substitutes are available, with which respondents can satisfy their demand, their WTP may be lower than under circumstances where no substitutes are available (Tietenberg, 2000).

- *Free rider problem (Strategic bias).* Respondents have an incentive to understate their true WTP, in order to "free ride" (Callan and Thomas, 1996:239).

- *Survey instrument-related bias.* If predefined ranges of values are used to elicit WTP responses, these values can influence the respondent's revealed preferences (starting point bias). This bias occurs when a bidding game is used, and the starting point is perceived as being the closest value resembling the "correct" amount. One reason for this has to do with impatience of respondents to get the interview over. The choice of a bid vehicle (method of payment) can also affect the values provided (Callan and Thomas, 1996:239). The bid vehicle should be as close as possible to the payment method envisaged (Ortolano, 1997:136). Interviewer bias[61], erroneous sampling procedures and processes, incorrect layout, and the wrong wording of questions, are other typical survey instrument-related problems.

- *Part-whole bias (embedding bias).* People tend to put similar values on a part of an asset and the whole asset, because of the way they allocate their budget (Bateman and Willis, 1999:258). The problem is that similar values are given for the protection of, for instance, one conservation project, and all conservation projects in general, as people tend not to separate the parts from the whole.

- *WTA vs WTP.* People generally feel the cost of a loss (WTA) more severely than a benefit or gain, thus WTA may be higher than WTP. With WTP, respondents need to allocate their budget with their limited income, while there is no budget constraint with WTA, because the payment comes from other sources (Field, 1997).

- *Inconsistency with rational choice behaviour*. Rational choice requires that more of a good be preferred to less. However, in CVM studies, people's WTP values do not necessarily increase as the quantity of the good increases (Ortolano, 1997: 136).

5.3.4.4 Specific problems in the use of CVM for determining the value of biodiversity

The use of CVM in the determination of preferences for the preservation of biodiversity has some additional problems. A study done by Spash and Hanley (1995) concluded that a significant proportion of respondents refused to make trade-offs between biodiversity and other goods. They came to the conclusion that the CVM fails as a method for determining values of biodiversity, because of widespread lexicographic preferences in the population. Individuals with lexicographic preferences refuse to make trade-offs between an increase/decrease in biodiversity and losses/gains in income. They have a WTA that is infinite, and a WTP that entails the total budget, because they want welfare to remain at its existing level. For this reason, utility functions for these individuals are similar to perfect complements. As a result, these people have only two WTP

[61] Interviewer bias is of particular importance in CV, as a substantial number of CVs are done using personal interviews (Schultz, Pinazzo, Cifuentes, 1998). In a CVM study done in Costa Rica, it was discovered that local Costa Ricans had a higher WTP than tourists, partly because most of them had no prior experience with this kind of survey, and felt that they had to provide a high value in order to keep the interviewers content. This is a problem commonly found in developing countries (Schultz, Pinazzo, Cifuentes, 1998).

values: zero, in protest against a decrease in the guarantee of the right of the environmental good to survive; or the respondent's whole budget, as individuals refuse money trade-offs for a decrease in the availability of the environmental good.

Individuals with lexicographic preferences believe that particular species must be protected, irrespective of the cost to society or the utility derived from the species. They are not willing to accept any kind of compensation in order to keep their welfare constant as the level of biodiversity decreases. Willingness-to-pay methods cannot be used if people are not willing to trade the good in question (Ortolano, 1997: 118).

Spash and Hanley argued that the general public was uninformed about biodiversity, raising doubt as to the reliability of their stated preferences. This exposes the real problem with the use of CVs in valuing biodiversity - the information problem. The information problem is more relevant in explaining people's inability to value biodiversity than lexicographic preferences. The main issue regarding biodiversity valuation is that when it is referred to as a whole, it is a necessity, and ordinary people would allocate their whole budgets to preserve it. To do anything else would be irrational, because we cannot exist without the ecosystem.

However, that is not what is typically meant by "valuing biodiversity". We are usually talking about small changes in status – in our case very small changes. Whether there is, or is not, a change in the biodiversity status, human existence will scarcely be affected – certainly not threatened. Allocating one's whole budget to prevent a reduction in biodiversity is not a credible thing for rational people to do in this case. For this reason, WTP methodology remains highly relevant as a measure of choice (stated choice).

5.4 BIODIVERSITY IN TERMS OF PEOPLE'S PREFERENCE FOR INDIGENOUS VEGETATION AT THE WFW SITES

Approximately 10% of all plant species in the world are found on less than 1% of its surface – in Southern Africa. South Africa is the only country to host one of the world's six floral kingdoms in its totality (Cape Floral Kingdom). For this reason, it plays an important role as custodian of the world's biodiversity (Low and Rebelo, 1996). With this biodiversity comes a responsibility - that of conservation. Conservation is the wise use of natural resources in order to keep them intact for current and future generations. The Rio Convention recommends that at least 10% of every vegetation type be reserved for pristine or near pristine use (Low and Rebelo, 1996). In South Africa, this recommendation has only been realised in nature reserves and conservation areas.

However, other uses, such as recreation, tourism, and some kinds of harvesting, are well-suited to conservation in its pristine form. The danger is that a vegetation type can never be reinstated in its pristine form after transformation has occurred (Low and Rebelo, 1996).

The Eastern Cape hosts 7 of the 8 biomes found in South Africa, with 29 Acocks veld types and 6164 plant species present in the province. This makes it the second richest province in terms of plant biodiversity, after the Western Cape (Low and Rebelo, 1996). The WfW programme makes an important contribution to conserving this biodiversity.

For the purpose of the contingent valuation, biodiversity is taken to be synonymous with people's preference for indigenous vegetation. The marginal increase in biodiversity (indigenous vegetation) as a result of WfW activities at the six WfW sites in the Eastern and Southern Cape was valued.

5.4.1 Albany

The predominant vegetation types in the Albany region are Eastern Cape Thicket and grassy fynbos (Low and Rebelo, 1996). Eastern Cape Thicket extends over 2% of South Africa, but 66% of South Africa's Eastern Cape Thicket is found in this province. About 9% of the Eastern Cape consists of this vegetation type. However, only 2% is conserved at present (as opposed to at least 10% recommended by the Rio Convention). Over 51% has already been transformed by agricultural and urban land-use practices. The Eastern Cape is known for hosting a substantial diversity of species, many endemic to a certain locality, such as the "Albany hotspot". Eastern Cape Thicket can be found in river valleys through the Eastern Cape to KwaZulu-Natal, and in the eastern parts of the Western Cape (Low and Rebelo, 1996).

Although a number of nature reserves preserve Eastern Cape Thicket, it is threatened by the intensive farming of livestock, such as ostrich, and Angora and Boer goats (Low and Rebelo, 1996). For this reason it is important that this vegetation type be protected in the Eastern Cape (where most of South Africa's Eastern Cape Thicket is found).

Grassy fynbos comprises 0.5% of South Africa, and 3% of the Eastern Cape. It is established in the Baviaanskloof, the Zuurberg Mountain, and between Steytlerville and Grahamstown. However, 97% of all grassy fynbos is found in the Eastern Cape relative to the whole of South Africa. Approximately 16% is conserved in South Africa, and 17% in the Eastern Cape, while humans have transformed a relatively small 3%. This vegetation type is used for water catchment, grazing (although fynbos is a poor source of nutrition) and hiking trails (Low and Rebelo, 1996).

5.4.2 Kat River

Afromontane (natural) forests and grasslands are the major vegetation types in this area. The forest biome, comprised of Afromontane, Sand and Coastal forests, covers less than 0.25% of Southern Africa's land surface, making it the smallest biome on the subcontinent. Afromontane forests inhabit 0.5% of South Africa, with 48% of it growing in the Eastern Cape. An estimated 2% of the Eastern Cape's vegetation is made up of natural forests. Approximately 44% of these forests have been changed through agricultural practices. Natural forests are used for timber, firewood and muti. About 18% of indigenous forests are conserved in South Africa, the best known being those established in the Tsitsikamma region. Forests are also found along south-facing mountain ridges from KwaZulu-Natal to the Western Cape, as these slopes are high rainfall areas (Low and Rebelo, 1996). In the Eastern Cape, Afromontane forests are established in the Amatole mountains and Tsitsikamma, but bits of forests growing on southern facing slopes are also established throughout the province, as forests tend to grow in patches. Approximately 7% of forests are conserved in this province.

Indigenous forests appeal to tourists because of their rarity and splendour. However, alien plant invaders threaten them. Conserving patches of forest will not be sufficient for its preservation, as forest conservation aims at managing crucial processes - which require the protection of fauna (mammals and birds for seed dispersal) and gene flow (Low and Rebelo, 1996).

Grasslands cover the high plateau in South Africa, but can also be found in inland areas in KwaZulu-Natal and the Eastern Cape, and lower-lying areas in South Africa. They are the foundation for dairy, beef and wool production. The biggest pressure on grasslands is urbanisation, which has already altered up to 75% of the biome. The grassland biome has a substantial biodiversity, rated second after the fynbos biome (Low and Rebelo, 1996).

Moist upland grassland – the specific type of grasslands located in the Eastern Cape – occupies about 72% of the province. It inhabits 3% of South Africa, and 19% of the Eastern Cape. Most types of grasslands are poorly conserved. About 3% of moist upland grasslands are conserved in South Africa, mostly in KwaZulu-Natal, while 0.2% is conserved in the Eastern Cape. Generally speaking, these grasslands are well maintained in the Eastern Cape, except in the Transkei region, where heavy overgrazing occurs (Low and Rebelo, 1996).

5.4.3 Pot River

Moist upland grassland inhabits the Pot River area. The importance of this vegetation type for biodiversity is discussed in section 5.4.2. The whole Pot River site is situated on privately owned land, which is used for agricultural activities, mainly livestock farming.

5.4.4 Kouga

Grassy and mountain fynbos are the predominant vegetation types within the Kouga region. The Cape Floral Kingdom consists of five biomes (fynbos, renosterveld, Thicket, forest, and Succulent and Nama Karoo). It is of particular importance because of its "biodiversity hotspot" status as the smallest Floral Kingdom in the world, and the only one found within the borders of a single country. The Cape Floral Kingdom is renowned for its richness in plant species, measured at 8700 species, 68% of which are endemic. It covers an area of less than 6% of South Africa, but accounts for more than a third of its plant species. It is interesting to note that the fynbos biome – consisting of the fynbos and renosterveld vegetation types[62] - contributes most to the floral diversity. If the other vegetation types were included, endemism would increase to 80%, the highest on any subcontinent (Low and Rebelo, 1996).

About 1700 species within the Kingdom are listed as threatened with extinction to some extent. This threat underlines the exceptional character of fynbos, with its narrow local distributional range. The fynbos biome is exposed to urbanisation, but alien tree and plant invaders pose a more serious threat to its existence and diversity. The incorrect use of fire[63] also contributes to the danger of biodiversity loss (Low and Rebelo, 1996).

Approximately 26% of mountain fynbos – the most widespread vegetation type of the fynbos biome - is conserved in South Africa, while 49% is conserved within the Eastern Cape. Approximately 11% has been transformed through human use. The economic significance of mountain fynbos lies in its recreational value for ecotourism, hiking, mountaineering, and mountain biking[64]. It also has value as a source of water. Wildflowers, rooibos and honey bush tea and thatching reeds are harvested from mountain fynbos areas (Bond, 1993).

Mountain fynbos can be found between the Cape Fold Belt stretching from Nieuwoudville in the Western Cape to close to Port Elizabeth in the east (Low and Rebelo, 1996).

5.4.5 PE Driftsands

Dune Thicket, grassy fynbos and renosterveld cover the PE Driftsands area. South and South-west coast renosterveld make up 1% of South Africa, with the Eastern Cape contributing 13% of this. One per cent of the Eastern Cape is occupied with South and South-west coast renosterveld. Renosterveld is characterised by many *geophytic* species, and the soil fertility is

[62] These two vegetation types have different ecological systems. Whereas renosterveld used to host large mammals and is fairly fertile, fynbos has poor soils that cannot sustain such animals, but it is host to a substantial number of endemic plant, amphibian, insect, reptile, bird, and animal species (Low and Rebelo, 1996).
[63] This includes fires that occur too frequently, or in the wrong season (Low and Rebelo, 1996).

[64] The Kouga region is marketed as a district featuring five biomes, unspoiled beaches, dune fields, and pristine wilderness areas, with world-standard surfing (Engen, 2002).

high. This is one of the reasons why large mammals populating the fynbos biome frequent renosterveld. However, only the Bontebok, Mountain Zebra and Leopard have not become extinct in the fynbos biome[65], while the Bluebuck and Quagga have become totally extinct. On the other hand, the high fertility makes it a prime candidate for agricultural uses – especially for grazing and cereal growing (Low and Rebelo, 1996).

Almost 32% of South and South-west coast renosterveld has been altered, while 1% of it is protected in South Africa and the Eastern Cape. Most nature reserves occur in the transitional zone between fynbos and Thicket, and do not preserve renosterveld as such. This is a far cry from the guideline of 10% provided by the Rio Convention (Low and Rebelo, 1996).

South and South-west coast renosterveld inhabits other areas, such as close to Humansdorp, the eastern parts of the Little Karoo, and Albertinia to Riversdale (Low and Rebelo, 1996).

Dune Thicket occupies 0.3% of South Africa, with 18% of all South Africa's Dune Thicket established in the Eastern Cape. Dune Thicket vegetation makes up 0.4% of the Eastern Cape. About 25% has already been altered through human intervention. It is used for firewood and crop growing. Dune Thicket is established along the coastal strip from the Western Cape up to KwaZulu-Natal. Although it is fairly well conserved in some areas (14% in South Africa), it is threatened by coastal resort development and alien invasion. Almost 7% is preserved in the Eastern Cape province. Dune Thicket is also established in the Western Cape and KwaZulu-Natal (Low and Rebelo, 1996).

Grassy fynbos also inhabits the PE Driftsands area, which is discussed in section 5.4.1.

The Port Elizabeth area is also known as the "Sunshine Coast", extending along the coast of Algoa Bay. The Madiba Bay project, planned at an estimated cost of R212 million (*Die Burger*, 19 November, 2002) is situated in the PE Driftsands area. It is designed as a coastal tourist attraction, including Madiba Bay resorts, Madiba Bay Safari World, Big Five, Sea World, Agri World, Edu World and an African Village Theme Park. Its mission is to enhance domestic and international tourism, empower disadvantaged communities, and complement existing tourism practices. Tourists will be able to view attractions of the Eastern Cape on a small scale. The idea is to showcase the natural beauty and diversity of the province to tourists, for instance elephants in their natural habitat. This venture is marketed on the back of the Eastern Cape's biodiversity.

[65] Many species have been reintroduced within conservation areas (Low and Rebelo, 1996).

For this reason, it is important to protect the indigenous vegetation for tourists and local residents alike.

5.4.6 Tsitsikamma

Afromontane forests and mountain fynbos are the dominant vegetation types established in this region. The Tsitsikamma area is world-renowned for its indigenous forests, mountains, rivers, waterfalls, and high cliffs overlooking the sea (Engen, 2002). For this reason, the loss of indigenous vegetation could well have a negative impact on the tourism industry in this region.

This region is marketed to tourists as an adventure centre, featuring activities such as blackwater tubing, kloofing, bridgewalking (Bloukrans), bungeejumping (Bloukrans as the highest bungeejump in the world), abseiling, bushcamping, scuba diving, tree-swinging, and mountain biking. Many of these activities depend in part on the presence of indigenous vegetation.

5.5 RESEARCH DESIGN

5.5.1 Population and sample

Right from the onset it was realised that a full CV would not be feasible within the time frame and resources available for this study. For this reason, only pilot studies were attempted. In order to acquire a sample of the population at the six WfW sites selected, a target population was defined and the sampling size, together with the sampling process, was determined.

1. Target population: users and non-users of biodiversity at the six sites. These groups were sub-divided into tourists and local residents (including farmers and farmworkers) at the time the survey was conducted.
2. Elements: household heads (no gender specified).
3. Sampling unit: households.
4. Sampling frame: a list of the following institutions was used to identify the target population – local municipalities, the Department of Nature Conservation, Parks Board, and Eastern Cape Tourism.
5. Sample size: the pilot study sample sizes were set as follows:

Tsitsikamma: 30

Kouga: 30

PE Driftsands: 60

Albany: 33

Kat River: 34

Ugie: 32

The people whose views were to be solicited were randomly selected by the interviewers.

5.5.2 Knowledge and information

The term "biodiversity loss" was not referred to, in the survey. There were two reasons for this: there was no loss or gain of species that could be identified, and pre-pilot trials showed that there was confusion amongst the public over the meaning of the term.

- The concept "biodiversity" was unpacked/redefined in terms of the indigenous vegetation found at every site. The questionnaire translated into layman's terms the biodiversity implications of WfW activities for every site.

- *Responsibility of payment towards biodiversity preservation:* Household heads were required to respond on behalf of their households, as it was assumed that they would be responsible for contributing on the household's behalf towards biodiversity preservation through WfW activities.

- *The nature of the public good:* Eradication of alien tree and plant species by WfW would ensure that the biodiversity status was maintained, if not enhanced. In almost all cases indigenous vegetation was to be restored.

- *Conditions for the protection of biodiversity and payment for it:* WfW activities remove alien vegetation and restore indigenous vegetation. Residents and tourists were asked to contribute financially towards the continuation of these activities. Residents were asked to pay a fee similar to municipal service levies, while tourists were asked to pay a tourist levy. The respondents were told that the nearest local municipality would administer these funds.

5.5.3 Factors affecting willingness to contribute

The goal of the survey was to evaluate residents and tourists' valuation of the selected indigenous vegetation restoration programmes (as WfW projects). The survey included questions on the following household variables:

- *Knowledge of respondent.* Two questions on the WfW programme were asked, in order to determine respondents' familiarity with the programme, and environmental matters in general (see Appendix D). Specific knowledge about biodiversity was excluded, on the basis that it is a complex concept (Gowdy and Carbonell, 1999). It was hypothesised that respondents with knowledge of the environment would be willing to pay more than uninformed individuals, because of their understanding of the connection between indigenous vegetation and the health of the ecological system.

- *Gender of household head*. Female-headed households were expected to have less disposable income available for payment towards the preservation of biodiversity through WfW clearing activities, as these households typically have only one breadwinner, as opposed to male-headed households, where the wife may also contribute to the income.

- *Educational level of respondent*. Individuals who had attained higher levels of education were expected to be more inclined to pay for the preservation of biodiversity, as they would have more income and knowledge at their disposal.

- *Gross annual income of respondent*. Households with higher incomes were expected to be willing to pay more towards the protection of the environmental resource than low-income households.

- *Worth of fixed property.* Respondents owning more expensive properties or houses were expected to be in a better position to pay for the preservation of indigenous vegetation.

These expectations were used to test the plausibility of the data collected through the contingent valuation. The direction, magnitude and strength of the relationships among variables, were used to test for acceptance or rejection of the hypothesis that the WTP average was a valid estimate for the sample population.

5.5.4 Administration of survey

Personal interviews were used to conduct the survey. Interviewers were asked to ensure that concepts were understood, while non-responses would be lower. Photographs of different vegetation types were used in the administration of the questionnaire, to point out differences between vegetation types (see Appendix D1).

5.5.5 Questionnaire

In the pre-coded questionnaire (see Appendix D), the vegetation types prevalent at every site (both indigenous and alien), together with photographs of each, were presented to respondents. The nature of the vegetation change was described with and without WfW programme. Each vegetation type was described, and its significance within South Africa was explained, in order to reduce information bias. Care was taken to avoid preferential treatment of indigenous vegetation, by not listing it as a first option.

Respondents were reminded of substitutes available for the indigenous vegetation, by listing other nearby areas where the same vegetation occurred, and also other closely related vegetation types and their location.

The willingness to pay question was linked to the possible future event of an increase in alien vegetation up to a point where indigenous vegetation would be totally compromised, and biodiversity at that location would be compromised. Respondents were informed that the alternative to indigenous vegetation was alien vegetation. A payment card was used, where respondents were prompted to choose the value that represented their willingness to pay. In this way, starting point bias was reduced (Hanley and Spash, 1993).

In the questionnaire, the bid vehicle (method for payment) was described as a municipal levy on locals, and a tourist levy on tourists. These bid vehicles were seen as neutral and realistic. Money raised through the municipal service and tourist levies was to be used to provide funds for WfW activities.

In order to pay for the preservation of indigenous vegetation, sacrifices had to be made. The interviewers reminded respondents that they had to operate within their respective budget constraints, and that spending more on the preservation of indigenous vegetation implied spending less on all other goods and services. This reminder was given to reduce mental account bias. No specific question was asked on what individuals would sacrifice in order to be able to make the payment specified.

Embedding bias (Field, 1997) was reduced by asking respondents their willingness to pay for WfW activities at the specific site, WfW activities in South Africa, and Conservation projects in South Africa, respectively. This served as a reminder that their willingness to pay for WfW activities at one site did not include their payment for other important environmental resources.

The questionnaire was pretested using a pilot study, in order to streamline, revise and clarify questions. Owing to the complex nature of contingent valuation questions, it was considered to be of the utmost importance that the questions be made as user-friendly as possible. The target time taken to administer the questionnaire was set at a limit of about 10 minutes.

Three interviewers administered the questionnaire during November 2002. One enumerator was used for the Ugie, Kat River and Albany sites (a black male residing in this area), and two enumerators were used for the remaining sites (senior black female economics students).

5.6. EMPIRICAL ANALYSIS AND DISCUSSION

The sample size was too small to draw conclusions about the population, but big enough to show possible population characteristics. It was expected that respondents would have a low WTP, as the Eastern Cape is a poor province (www.pimss.co.za), and people's willingness to pay values for indigenous vegetation would be low. WfW field staff were also skeptical about the likely WTP responses. A description of the empirical model and the data analysis of the results of the surveys undertaken at each of the six sites follows.

5.6.2 The responses, the model and the data

a) Invalid responses

An important methodological matter in CVMs concerns invalid responses. These can be in the form of protest bids (WTP values of zero), or very high WTP values, which cannot be paid owing to budget constraints (outliers). These responses were included in the calculation of a mean willingness to pay, because of the small sample size. The exclusion of invalid responses is, in any case, statistically incorrect (Carson, 1991). Owing to the use of personal interviews in this study, there were no non-responses.

b) Empirical model

An analysis of the factors impacting on the willingness to pay and the construction of an empirical model was carried out, using the information from all the sites combined (n=219). The following equation describes the model:

$$Y = \sum_{i=1}^{n} \beta i X i + \varepsilon$$

Where Y = WTP (dependent variable)

X = factors believed relevant to explaining WTP (independent variables)

β = vector of n parameters

ε = disturbance term

c) The independent variables

The independent variables (explanatory variables) and their representation in the sample are listed in Table 5.2.

Table 5.2 Proportions of sample responses – selected variables

Variable	Classes	All sites combined	Sites					
			PE	Albany	Kat River	Pot River	Tsitsikamma	Kouga
Reason why in the area	Resident	75.4%	98.3%	54.5%	50%	87.5%	43.3%	97.6%
	Farmer/ worker	4.1%	1.7%	0%	8.8%	9.4%	3.3%	3.3%
	Tourist	20.5%		45.5%	41.2%	3.1%	53.3%	
	Total	100%	100%	100%	100%	100%	100%	100%
Familiarity with WfW RSA	Yes	41.1%	20%	39.4%	44.1%	62.5%	23.3%	76.7%
	No	58.9%	80%	60.6%	55.9%	37.5%	76.7%	23.3%
	Total	100%	100%	100%	100%	100%	100%	100%
Familiarity with WfW in area	Yes	45.7%	45%	30.3%	29.4%	62.5%	26.7%	83.3%
	No	54.3%	55%	69.7%	70.6%	37.5%	73.3%	16.7%
	Total	100%	100%	100%	100%	100%	100%	100%
Preference for vegetation **	Commercial plantations	76.2%	81.7	93.9%	100%	37%	53.3%	76.7%
	Invasive plants growing wild	12.7%	25.4%	0%	0%	11.5%	16.7%	13.3%
	Indigenous	58.5%	75%	6.3%	0%	74.1%	93.3%	96.7%
	Total	100%	100%	100%	100%	100%	100%	100%
Gender	Male	49.1%	50.8%	39.4%	21.9%	50%	66.7%	66.7%
	Female	50.9%	49.2%	60.6%	78.1%	50%	33.3%	33.3%
	Total	100%	100%	100%	100%	100%	100%	100%
Household size	1	21.9%	26.7%	30.3%	25.9%	9.4%	24.1%	10.3%
	2-4	56.2%	53.3%	51.5%	70.3%	53.1%	69%	44.8%
	5-6	15.7%	11.5%	18.2%	0%	28.1%	6.9%	31%
	7+	6.2%	8.5%	0%	3.8%	9.4%		13.9%
	Total	100%	100%	100%	100%	100%	100%	100%
Educational level	Less than matric	7.5%	1.7%	6%	3.2%	3.2%	3.3%	33.6%
	Matric	20%	31.7%	6.1%	3.2%	19.4%	20%	30%
	Post matric	72.5%	66.6%	87.9%	93.6%	77.4%	76.7%	36.4%
	Total	100%	100%	100%	100%	100%	100%	100%
Income (R)	0 – 24 000	20%	18.4%	31.3%	6.7%	12.5%	23.4%	34.5%
	24 001 – 120 000	58.3%	63.3%	65.6%	50%	78.2%	43.3%	55.2%
	> 120 001	21.7%	18.3%	3.1%	43.3%	9.3%	33.3%	10.3%
	Total	100%	100%	100%	100%	100%	100%	100%
Worth – fixed property (R)*	1 – 100 000	55.6%	33.3%	79%	81%	59.1%	36.6%	78.9%
	100 001 – 150 000	19.4%	30.8%	15.8%	19%	18.2%	13.3%	13.8%
	150 001 – 250 000	13.8%	20.5%	0%	0%	22.7%	16.7%	13.8%
	250 001 +	11.3%	15.4%	5.3%	0%	0%	33.3%	3.4%
	Total	100%	100%	100%	100%	100%	100%	100%

* Respondents renting were included in the bracket in which their annual rent would fall.
** This percentage shows the number of people that ranked that specific category as their first choice of preferred vegetation.

Approximately 20% of all respondents (all sites) were tourists (n = 46), while 80% (n = 173) were residents (either in town or farmers/farm workers). More than half the sample (58.9%) was unfamiliar with the WfW programme in South Africa. The gap between respondents familiar and unfamiliar with the WfW programme at the specific sites was narrower, with 45.7% being familiar and 54.3% being unfamiliar with it. If questions 2 and 3 of the questionnaire (on familiarity with the programme in South Africa and the specific site respectively) were combined, the percentage of respondents who replied affirmatively to both questions was 31.1%, indicating that a minority of respondents were well informed about the WfW programme. The Kouga and Pot River sites deviated from this trend, in that more than 50% of the respondents knew about the programme. A possible explanation for this deviation is that both sites are situated in close proximity to small towns, and the headquarters for the programme at these sites are located in these towns.

If all the respondents at all the sites are combined, 77.6% of respondents ranked commercial plantations as their first choice of vegetation. Many respondents remarked that, although they liked indigenous vegetation, they preferred plantations because of the employment prospects associated with them. They recognised the commercial potential of indigenous vegetation in the form of ecotourism, and fynbos as a biodiversity hotspot, but argued that the job implications of commercial afforestation were greater. The Pot River area is home to substantial afforestation industry.

Only 13.7% of respondents awarded first place on their preference list to alien trees and plants growing wild. About 60% of respondents ranked indigenous vegetation as their first preference. Undoubtedly, there is an inconsistency between this result and the one that 77.6% of respondents' first choice was for commercial plantations. Many respondents gave commercial forests and indigenous vegetation the same ranking.

The household size ranged between 1 and 16 people, with 56.2% of households being between 2 and 4 persons. About 21.9% of respondents were single households, while 6.2% consisted of more than 7 people.

The educational level of respondents was high on average: 20% had a matric qualification and 72.6% had tertiary qualifications in the form of diplomas, degrees or post-graduate degrees. The presence of universities close to the sites could have played a role in this response characteristic[66].

[66] Specifically Rhodes University in Grahamstown (Albany), the University of Port Elizabeth (PE Driftsands) and Fort Hare in Alice (near Kat River).

The majority of respondents (58.2%) earned between R24 000 – R120 000 per year, while 20.2% earned less than R24 000 per annum. About 21.6% had an income of more than
R120 000 per year. The age of respondents varied from 18 to 67 years. The average age was 40 years. Table 5.3 shows the statistics of the factors used to explain the WTP in the empirical model.

Table 5.3 Statistics of selected responses

Statistics	All sites	PE Driftsands	Pot River	Kat River	Albany	Kouga	Tsitsikamma
Age (years)							
Mean	39.8	33.98	39.4	41.1	52.8	40	36
Standard. deviation	29.8	12.44	10.21	10.3	71	10.4	10.5
Minimum	18	19	23	27	21	18	22
Median	35.5	30.5	37	38.5	36	40	34
Maximum	67	65	60	62	65	67	63
Household size (number)							
Mean	3.2	3.4	3.9	2.5	2.6	4.6	2.6
Standard. deviation	2.3	2.8	1.9	1.6	1.5	2.9	1.2
Minimum	1	1	1	1	1	1	1
Median	3	3	3.5	2	2	4	3
Maximum	16	16	8	9	6	13	5
Income (R)*							
Mean	92 000	78300	77440	114200	54560	64970	185140
Standard. deviation	93 180	56780	45300	62640	40850	73780	141350
Minimum	6000	6000	6000	6000	6000	6000	6000
Median	90000	90000	90000	90000	42000	42000	135000
Maximum	360 000	180000	180000	180000	180000	360000	360000
Worth of fixed property (R)							
Mean	114440	154620	102950	56190	64210	82930	173670
Standard. deviation	103300	98540	62710	39530	80230	82530	142430
Min	10000	10000	10000	10000	10000	10000	10000
Median	75000	125000	75000	35000	35000	75000	162500
Max	350000	350000	200000	125000	350000	350000	350000

* Although these questions were asked as categories, the numerical values were used for analysis purposes.

Table 5.3 indicates that the mean age of respondents for all the sites was 40 years. The PE site recorded the youngest mean age (34) and the Albany site the oldest (52). The median age was 36 for all the sites combined, and varied between 30 and 40 for the individual sites.

The mean household size for all the sites combined was 3. A minimum household size of 1 was recorded at every site, while the PE Driftsands site recorded the biggest household size of 16, with the Kouga site not far behind at 13.

The mean income level was measured at R92 000 for all the sites combined. The PE, Pot River, Albany and Kouga sites recorded lower mean income levels than this, while the Tsitsikamma and Kat River sites had income levels higher than the combined mean. A maximum income of R360 000 was recorded at the Tsitsikamma and Kouga sites. The minimum income at all the sites was R6000. The median income was substantially lower for all the sites combined, and for the separate sites. For all the sites combined, as well as for the PE Driftsands, Pot and Kat River sites, the median income level was R90 000. At the Kouga and Albany sites, the median income level was R42 000, while it was R135 000 at the Tsitsikamma site. The median income provides a better reflection of the prevailing income level at the sites, and is more in line with average income levels in the Eastern Cape, as determined by Household Surveys (www.pimss.co.za).

The average worth of fixed income for all the sites combined was R114 440. The minimum worth of fixed property considered separately at all the sites, and all the sites combined, was R10 000, while the maximum worth was R350 000. Only the Pot and Kat River sites had maximum levels below this, at R200 000 and R125 000 respectively. In relation to the worth of fixed property owned by them, the income levels provided by the respondents were fairly high.

d) The dependent variable

The average willingness to pay per site (as the dependent variable) is described in Table 5.4 below.

Table 5.4 The average willingness to pay per Rand per site

Site	**Sample size**	**Mean WTP (R)**	**Standard deviation of WTP (R)**	**Minimum WTP (R)**	**Median WTP (R)**	**Maximum WTP (R)**	**95% Low (R)**	**95% High (R)**
PE	60	76.58	272.77	0	5	1500	6.12	147.05
Pot River	32	68.12	135.25	0	35	750	19.36	116.89
Kat River	34	111.76	75.05	0	150	350	85.58	137.95
Albany	33	75.76	68.35	0	75	350	51.52	99.99
Kouga	30	304.83	1391.92	0	5	7500	-224.63	834.29
Tsitsikamma	30	80	153.75	0	35	750	22.59	137.41
All sites combined	219	111.54	532.43	0	15	7500	40.46	182.61

From Table 5.4 it is clear that the mean WTP at the Albany, Pot River, Tsitsikamma and PE Driftsands sites was lower than the mean WTP for all the sites combined. The mean WTP for the WfW programme at the Kouga and Kat River sites was, however, higher than the combined mean WTP. The mean WTP for the Kouga area was the highest. In the Kouga area, most respondents were familiar with the Working for Water programme in South Africa (76.7%) and 83.3% knew about the activities of the local Kouga Working for Water programme. This contrasts with 41.1% of the respondents at the combined sites level who knew about the WfW programme in general (i.e. at all 6 sites), and 45.7% who were familiar with the WfW in their area.

The mean WTP was the lowest in the Pot River area. It is a poor part of South Africa, with a high unemployment rate (approximately 34%) and high dependency ratio, where 42% of the population is under the age of 15 (www.pimss.co.za)[67].

The majority of respondents (79.8%) were prepared to pay a levy towards the preservation of indigenous vegetation through continued WfW activities. About 42.2% were prepared to pay between R1 and R50, while 15.1% were willing to pay between R51 to R100, and 22.5% were prepared to pay more than R101 a year. About 20.2% of the respondents were not willing to pay anything towards the preservation of indigenous vegetation. Table 5.5 provides a breakdown of the willingness-to-pay attitudes at the six sites.

Table 5.5 Number of respondents' willingness to pay per payment class at the six sites (%)

Site	**R0**	**R1 – R50**	**R51 – R100**	**R101 +**
PE Driftsands	26.7	55	6.7	11.7
Albany	6.1	33.3	39.4	21.2
Kat River	11.8	17.6	5.9	64.7
Pot River	31.3	31.3	18.8	18.8
Kouga	20.7	65.5	3.4	10.3
Tsitsikamma	20	43.3	23.3	13.3

e) Results and discussion

Using the Chi-Square Test of significance, it was determined that several variables were insignificant factors of people's willingness to pay for the preservation of indigenous vegetation (p–value < 0.05). These included: reason for being in the area; familiarity (knowledge) with the WfW programme in general (South Africa) and at the specific site; age, household size and gender. The level of education was also not a meaningful explanatory variable. The respondents' taste for indigenous vegetation and their level of income, however, were meaningful indicators of

[67] The purpose of this study was to estimate selected non-water benefits for the sites investigated by Hosking *et al.* (2002). The existence of alien tree and plant species have certain impacts on rural people's creation and diversification of livelihoods, be that through employment benefits or through environmental factors (rural communities in general have stronger bonds to resources). For this reason a member of WfW's Economic Development and Resource Economics panel suggested that the selection of sites for future CVs should reflect the diversity of resource users and non-users.

their willingness to pay. The analysis of the significant variables is shown in the Analysis of Variance table below.

Table 5.6 Analysis of variance (ANOVA) of significant variables affecting willingness to pay for preservation of indigenous vegetation (n=210*)

Variable	Mean Squares	D.F.	F-stat	p-value
Taste for vegetation	30.16	2.202	8.740	0.0002
Level of education	8.75	2.202	2.54	0.0818
Income	10.5	2.202	3.04	0.0498

* This sample size differs from the total sample size (n=219) as some responses were missing and were automatically omitted from calculations by the statistical programme.

A regression analysis of the impact of the explanatory variables is shown in Table 5.7.

Table 5.7 Regression of factors affecting willingness to pay for preservation of indigenous vegetation (n=169*)

Independent variable	Dependent variable Money contribution (Rand) $R^2 = 0.2188$; F-stat = 7.562; p-value = 0.000			
	Coefficient	Std error	t-statistic	p-value
Taste for plantations	3.16	0.111	4.53	0.00
Taste for indigenous vegetation	2.34	0.1314	2.81	0.01
Level of education: lower than Grade 12	-0.54	0.2156	-1.25	0.21
Level of education: Grade 12	-0.69	0.1149	-1.41	0.16
Income	1.00**	0.0059	2.08	0.04

* This sample size differs from the total sample size (n=219) as some responses were missing and were automatically omitted from calculations by the statistical programme.
** Categorical values were used for the income variable, and not numerical values.

The respondents' taste for a vegetation type was significant in explaining their willingness to contribute money towards WfW activities. Respondents with a preference for commercial plantations were prepared to pay R3.16 more than respondents who ranked invasive alien plants and other vegetation as their first choice. Respondents who ranked indigenous vegetation as their first choice were prepared to pay R2.34 more for the preservation of indigenous vegetation than those who preferred alien plants growing wild, and other vegetation types. The difference in WTP between respondents who ranked indigenous vegetation first, and those who ranked commercial plantations first, was unanticipated. It could be attributed to respondents' arguments that, although they realize that indigenous vegetation was important from a conservationist perspective, commercial plantations created work for them.

Respondents with an educational level below Grade 12 and those who had a Grade 12 qualification were prepared to pay R0.54 and R0.69 more for the preservation of indigenous vegetation than respondents with a tertiary qualification. We expected the educational level and willingness to pay of respondents to be positively correlated. One possible reason for the inverse relationship of these two variables is that respondents with higher educational levels were better equipped to understand their budget constraint, and would therefore be more realistic in their valuation of indigenous vegetation.

The income variable also indicated a positive relationship: for every R12 000 increase in income, respondents were willing to pay R1 for WfW activities at the specific site.

5.6.2 The value of indigenous vegetation

As stated before, respondents' taste for biodiversity was equated, in the survey, to their preference for indigenous vegetation. To calculate the total value that people would be willing to pay to preserve indigenous vegetation, the mean willingness to pay per site was multiplied by the total sample population[68]. The latter was estimated to be the total number of household heads residing in the local municipal area in which the site is situated. The tourist population was not included in the calculation of a total value, as the proportion of tourists to locals was small, and the regression analysis indicated that the reason for being in the area (local or tourist) was not a significant explanation for people's willingness to contribute to the WfW programme for the preservation of indigenous vegetation.

The Eastern Cape is divided into district municipalities, and these are further divided into local municipalities, which may include a number of towns in close proximity to each other. The total population from local municipalities was used to determine the total WTP[69]. The calculations are shown in Table 5.8.

Table 5.8 The average and total value (benefit) of preference for indigenous vegetation over alien vegetation

Site	Local municipality*	Number of households*	Mean WTP (R)	Total WTP (R)	WTP per hectare (R/ha)
PE Driftsands	Nelson Mandela Metropole Municipality	220 000	76.58	16 847 600	1 936.51
Albany	Makana/ Grahamstown	16 300	75.76	1 234 888	108.32
Kat River	Nkonkobe	28 635	111.76	3 200 247.6	2 675.79
Pot River	Elundini	29 279	68.12	1 994 485.48	4 070.38
Kouga	Kouga	14 605	304.83	4 452 042.15	28.06
Tsitsikamma	Greater Plettenberg Bay area	15 516	80	1 241 297.78	9.64

*Source: www.pimss.co.za. Household sizes are provided per municipality, except for the municipalities in which the Albany and Tsitsikamma sites are situated. For the Tsitsikamma site, the average household size (estimated at 4.5 people in the Eastern Cape) was used (www. pimss.co.za). No population figures existed for the Albany/Makana municipality. For this reason the population figures for Grahamstown and surrounding area were used, instead of municipality figures.

[68] No rate-of-spread component was included in the determination of the biodiversity benefit. The alien infestation level at which ecosystems would cease to function is difficult to estimate - uncertainty over it at an ecological level still exists.
[69] This sample population will have to be re-examined in follow-up work, should this be done (see recommendations).

The possible biodiversity benefit of the WfW programme may be substantially higher than the fire and agricultural benefits at five of the six sites (see Table 5.8). It may also be higher than the water yield benefit calculated by Hosking *et al.* (2002). The biodiversity benefit at the PE Driftsands site was R1936 per hectare, as opposed to the per-hectare water yield and agricultural benefits of zero. At this site, the per-hectare biodiversity benefit was estimated to be 80 times the size of the fire benefit. At the Tsitsikamma site, where the lowest WTP per hectare results of all the sites were recorded, the biodiversity benefit was 0.4 times that of the fire benefit, while the agricultural benefit was zero. The per-hectare biodiversity benefit at the Kat River site was R2675, and 105 times that of the fire and agricultural benefits respectively. For the Pot River site, the per-hectare agricultural benefit was 13 times lower than the biodiversity benefit. When comparing the per-hectare fire and biodiversity benefits at this site, the fire benefit was 11 times smaller than the biodiversity benefit, while the water yield for this site was zero (Hosking *et al.*, 2002).

The WTP per hectare at the Kouga site was R28.06, which is higher than the fire benefit of R24.27 per hectare, and the agricultural benefit of zero. The Albany site is the only area where the biodiversity benefit per hectare (R108.32) was lower than the per-hectare agricultural (R178.95) and fire (R367) benefits.

These results were derived from pilot studies, and should be seen as giving insight into the potential value of the population's preference of indigenous vegetation. The small sample size limits us in the confidence with which conclusions can be drawn about the population, and the surveyors expressed concern about possible part-whole bias problems. The samples of the CVs were random, but not representative of the total population residing in the area of the project sites, implying that the sample was not normally distributed. For this reason, the calculation of the total willingness to pay as a product of the average willingness to pay and the population, may well not reflect their true willingness to pay[70].

Expectations were that the WTP would be low, but the results revealed that this could be the biggest benefit of the WfW programme, as WTP values elicited were, in fact, high. Our concern is that, bearing in mind that the unemployment rate for the Eastern Cape was 54.5% in 1999, and 70.7% of households lived below the minimum living level (www.pimss.co.za), this might be an overestimation of the population's true WTP.

[70] A member of WfW's Economic Development and Resource Economics panel felt that, as the bias would mostly be upward, the true WTP figures could be closer to half of that estimated in this study.

5.7 CONCLUSION

Gowdy and Carbonell (1999) suggest that biodiversity should be conserved for three main reasons: ecologically, for the limitation of climatic change and preservation of ecosystems; economically, as a future source of agricultural and pharmaceutical industries, eco-tourism, productivity of forests and the value in aesthetics; and philosophically, because every species has a right to exist, or to be preserved for future generations. However, like everything else, promoting biodiversity is subject to budget constraints, and the costs associated with promoting it need to be weighed up against the benefits.

Biodiversity, in the sense of the WfW programme, entails the preservation of areas for indigenous vegetation growth. The results of the CVs done at each site are derived from pilot studies, and should be seen as giving insight into the potential value of the population's preference for indigenous vegetation. The small sample size and concern over possible part-whole bias problems limit what conclusions we can draw about the sample population's preference for indigenous vegetation, and thus their willingness to pay to preserve it. Expectations were that the WTP would be low. However, the WTP at all the sites were higher than expected. The results revealed that, at many WfW programme sites, this could potentially be the biggest benefit of them all. For this reason, one could argue that the Working for Water programme could, at some sites, be renamed the Working for Biodiversity programme.

At five of the six sites, this benefit was substantially higher than the water and non-water benefits already estimated. At the PE Driftsands site, the biodiversity benefit amounted to R1936 per hectare, as opposed to the per-hectare water yield and agricultural benefits of zero. The per-hectare biodiversity benefit was 80 times the size of the fire benefit. The per-hectare biodiversity benefit at the Kat River site was 105 times that of the fire and agricultural benefits respectively. For the Pot River site, the per-hectare biodiversity benefit was R4070, as opposed to a water yield benefit of zero (Hosking et al., 2002), an agricultural benefit of R819 and a fire benefit of R367. The per-hectare biodiversity benefit at the Kouga site was higher than the estimated fire and agricultural benefits. Only at the Albany site was this pattern reversed, with a higher fire and agricultural than biodiversity benefit.

CHAPTER 6
THE COST BENEFIT ANALYSIS

6.1 INTRODUCTION

This chapter applies cost benefit methodology to the six WfW sites. The net incremental benefit as a result of the programme is the difference between the base case (without the programme) and the project case (with the programme).

Benefits and costs are expressed at 2001 price levels, i.e. the base year is 2001. The project period was set at 100 years, and a horizontal distributional weighting (that between different people) of 1 was assumed for all costs and benefits.

A social discount rate of 10.1%, - as calculated by Hosking *et al.* (2002), was used, although this rate was lowered in a sensitivity analysis to allow for intergenerational and sustainability considerations, as discussed in Chapter 2.

6.2 METHODOLOGY

In order to assess the feasibility of a project, its benefit stream must be weighed up against its cost stream. These two streams cover the project's lifetime (Callan and Thomas, 1996). The cost benefit approach is widely used in environmental economics to determine the viability of projects or investments (Turner, Pearce, and Bateman, 1993: 93). It has its roots in neoclassical economic theory (Conningarth economists, 2002).

Three decision-making criteria are typically used to determine the feasibility of a project - Net Present Value (NPV), the Benefit Cost Ratio (BCR), and the Internal Rate of Return (IRR).

The NPV of a project is its discounted benefits minus its discounted costs (Turner, Pearce, and Bateman, 1993:97). In order for a project to be accepted, the NPV must be positive (Conningarth economists, 2002).

The formula for the NPV is:

$$NPV = \sum_{t=0}^{n} \frac{B_t - C_t}{(1+r)^t}$$

where

NPV = Net Present Value

Bt = Benefit in year t

Ct = Cost in year t

(1 + r) = Factor by which difference in Bt and Ct is discounted.

r = Discount rate

0 = Present or base value

n = Duration of project in years

The IRR is defined as the discount rate at which the present value of benefits of a project is equal to the present value of costs, i.e. the rate at which the NPV of the project equals zero (Rosen, 1995).

$$\sum_{t=0}^{n} \frac{B_t - C_t}{(1+r)^t} = 0$$

In order to be deemed viable, the IRR needs to exceed the applicable discount rate r. There are instances in which multiple IRR values exist. This occurs when the net benefit profile switches many times between positive and negative (Conningarth economists, 2002).

The BCR is defined as the ratio of the present value of the benefit stream to the present value of the costs:

$$BCR = \frac{\sum_{t=0}^{n} \frac{B_t}{(1+r)^t}}{\sum_{t=0}^{n} \frac{C_t}{(1+r)^t}}$$

In order to be accepted, the BCR must exceed unity (Conningarth economists, 2002).

If more than one of these criteria are used, the results may conflict with each other (Hosking, *et al.*, 2002). For instance, the IRR could be positive, but the BCR negative or less than unity. Distribution weights other than unity would be used if one wished to incorporate horizontal equity considerations into the CBA. Unincorporated factors (those left out) should be acknowledged (explicitly) (Conningarth economists, 2002).

6.3 THE COST OF ALIEN TREE AND PLANT CLEARING AT THE SIX PROJECT SITES

Initial clearing, together with intensive follow-up operations and maintenance for approximately 5 to 10 years, makes up the cost of clearing. Actual costs sustained at the six representative sites, as well as cost forecasts made by managers, were used in the determination of the costs of the programme (see Hosking *et al.*, 2002). These costs were adjusted to 2001 price levels, as shown in Table 6.1.

Table 6.1 Cost of clearing, follow-up operations and maintenance for the six WfW project sites in 2001 prices

Treatment	Tsitsikamma (R/ha)	Kouga (R/ha)	Port Elizabeth Driftsands (R/ha)	Albany (R/ha)	Kat River (R/ha)	Pot River (R/ha)
Initial (clearing)	1306	2 431	2 801	2 579	1 522	1517
1st follow-up	423	423	740	793	888	1 163
2nd follow-up	262	211	423	381	476	740
Maintenance (1st year)	148	53	211	180	270	106
Maintenance (2nd year)	69	21	74	148	116	53
Maintenance (3rd year)	26	21	21	74	63	0
Maintenance (4th year)	16	21	21	63	0	0
Maintenance (5th year)	0	21	21	53	21	32
Maintenance (6th year)	16	0	21	21	0	0
Maintenance (7th year)	0	0	0	21	21	0
Maintenance (8th year)	16	0	0	21	0	32

Source: Hosking *et al.,* (2002).

6.4 THE BENEFITS OF CLEARING ALIEN TREE AND PLANT SPECIES AT THE SIX PROJECT SITES

6.4.1 Water benefit

Primary and secondary benefits are realised through the WfW programme. Increased water yield is measured in cubic metres per hectare per year (Hosking *et al.,* 2002). The increased water yield benefit is depicted in Table 6.2, at prices adjusted to 2001 levels.

Table 6.2 Net incremental water yield (m^3/ha) per fire cycle for the six selected sites in 2001 prices

Fire cycle (years)	Tsitsikamma	Kouga	Port Elizabeth Drifsands	Albany	Kat River	Pot River
	Water yield (m^3/ha)	Water yield (m^3/ha)	Water yield (m^3/ha)	Water yield (m^3/ha)	Water yield (m^3/ha)	Water yield (m^3/ha)
1	34.06	7,65	66.81	1502.77	707.02	1110.93
2	102.18	22.98	200.46	1516.57	751.21	1143.28
3	170.30	55.95	376.63	1525.75	795.39	1175.64
4	283.16	106.58	558.87	1534.94	751.21	1197.21
5	424.33	154.53	692.51	-	-	-
6	539.24	198.83	795.78	-	-	-
7	637.32	242.14	880.83	-	-	-
8	723.50	285.43	965.88	-	-	-
9	801.47	329.39	1038.77	-	-	-
10	872.87	375.36	1093.45	-	-	-
11	938.94	429.66	1148.11	-	-	-
12	1001.33	473.95	1202.79	-	-	-

Source: Hosking *et al.,* 2002.

6.4.2 Non-water benefits

The objective of the current study was to incorporate into the CBA three non-water benefits: increase in biodiversity valued with reference to people's taste for indigenous vegetation, a more extensive valuation of the gain in agricultural output, and the decrease in fire-fighting costs. Other non-water benefits, such as flood control, the decrease in soil erosion, social development and poverty alleviation, fire-risk reduction, and improvement in water quality, were not included, and would be expected to add to the benefit profile.

For each site, the applicable non-water benefits were estimated in 2001 prices. The benefit stream of Hosking *et al.* (2002) consisted of the net incremental water yield benefit (R/cubic metre) and the livestock benefit. The incremental water yield benefit was included as per the Hosking et al. (2002) calculations (adjusted to 2001 price levels). The livestock benefit calculated by Hosking *et al.* (2002) was adjusted to 2001 price levels, and this benefit was extended to include all possible agricultural benefits and not just livestock. The agricultural benefit was adjusted for each land use's share of production.

6.4.2.1 Non-water benefits at the six project sites

(i) PE Driftsands

The PE Driftsands site falls within an urban area. For this reason, no agricultural benefit of potentially productive land could be established. The incremental water yield benefit was also zero in this case (Hosking *et al.*, 2002). The fire benefit was deemed applicable only to areas where alien infestation exceeded 50%. The density classes established according to average alien infestation levels by Hosking *et al.* (2002) did not correlate with the density classes established according to fire benefits. In the Hosking *et al.* (2002) study, a class of moderate density consisted of an alien infestation level of between 25% and 75%, while the fire benefit becomes evident in indigenous fynbos with an alien infestation level of over 50%. The Hosking *et al.* (2002) density figures were nonetheless used, as they were the only source which provided this type of information. Approximately 3200 hectares of land at the PE Driftsands site have an infestation level above 75%, and the fire benefit was determined for these hectares. The fire benefit would be realised every 12 years on the relevant hectares, in accordance with the prevalent fire cycle.

The biodiversity benefit was assumed to increase over the project's span in proportion to the land cleared by WfW teams (the total area would only be cleared after 17 years). Hosking *et al.*'s (2002) estimation of the percentage of land cleared per year was used for this calculation.

The decision-making criteria relevant to this site, as calculated from the applicable costs and benefits, are shown in Table 6.3.

(ii) Albany

For the Albany site, the incremental water yield benefit calculated by Hosking *et al.* (2002) was expanded to include the net benefit of potentially productive land (see Chapter 3), the fire benefit in grasslands (see Chapter 4), and the biodiversity benefit (see Chapter 5). The potentially productive land benefit was calculated as a percentage of the total amount of land cleared (30%), as not all land was used for this activity. The fire benefit in grasslands becomes applicable at alien infestation rates of 75% or above, and, while the average alien infestation at this site was estimated at between 5.1% and 10%, approximately 6900 hectares have an infestation level of above 75%. The fire benefit was determined for these hectares, and would accrue every four years, as per the fire cycle.

The biodiversity benefit would only be realised in full after 19 years. From years 1 to 18, this benefit would grow in line with the proportion of land cleared by WfW as estimated by Hosking *et al.* (2002). In the case of Albany, increased livestock farming was the only productive land benefit envisaged. Livestock farming in the area is of an extensive nature. If responsible farming practices were followed, no biodiversity would be lost with grazing. For this reason, both the biodiversity and livestock benefits could both be accommodated on the total area cleared. As with the biodiversity benefit, the agricultural benefit would increase every year as more areas were cleared. The total agricultural benefit would only be realised from year 19 onwards. The decision-making criteria for WfW activities at the Albany site, as calculated from the benefits and costs, are shown in Table 6.3.

(iii) Kat River

For the Kat River site, the net benefit of potentially productive land (see Chapter 3), together with the fire benefit in grassland (see Chapter 4), and the biodiversity benefit, were added to the incremental water yield estimated by Hosking *et al.* (2002). No fire benefit could be realised, as the average alien infestation for the project area was 1.1 – 5%, and no infestation over 75% was evident. The increase in indigenous vegetation, water yield and livestock capacity constituted the benefit stream flowing from WfW activities.

The biodiversity benefit would be realised after 17 years on the total area cleared (Hosking *et al.*, 2002). Between years 1 and 17, this benefit would grow in line with the proportion of land cleared by WfW teams. It is assumed that livestock farming of an extensive nature (grazing) and indigenous vegetation present could co-exist without any vegetation loss (in this case grasslands, which is well-suited to accommodate grazing). For this reason, both benefits could be realised on cleared land. In the case of the Kat River site, though, no horticultural activity could be established, owing to the high water consumption of suitable crops.

Table 6.3 depicts the decision-making criteria for WfW activities as calculated from the combined benefits and costs.

(iv) Kouga

The benefit stream of the Kouga project site was estimated by combining the net benefit of potentially productive land (see Chapter 3), the fire benefit (see Chapter 4), the biodiversity benefit, and the incremental water yield (R/cubic metre) (Hosking *et al.*, 2002).

About 77 of the total 158 678 hectares of the project area have an infestation level above 75%. A reduced fire benefit would therefore be realized every twelve years on this land, per the normal fynbos fire cycle.

The biodiversity benefit would increase each year as the proportion of land cleared by WfW expands. These proportions were estimated by WfW managers (Hosking, *et al.,* 2002). The total biodiversity benefit, as determined in Chapter 5, would be realised in year 20. Between years 1 to 19 this benefit would increase by the increase in the proportion of land cleared. The same applied to the calculation of the agricultural benefit over the 19 years of clearing. The agricultural benefit consisted of the livestock benefit only. Increased deciduous fruit farming was ruled out as an option because of its substantial water use, which would negate the water yield benefit calculated by Hosking *et al.* (2002). If responsible farming practices were followed on cleared areas, both the biodiversity and increased livestock farming benefits could be realised.

The costs and benefits are depicted in Table 6.3.

(v) Pot River

In order to estimate the net benefit of the WfW programme at the Pot River site, the incremental water yield (R/cubic metre) (Hosking *et al.*, 2002) was added to the net benefit of potentially productive land (see Chapter 3), the fire benefit (see Chapter 4), and the biodiversity benefit (see Chapter 5). The fire benefit was estimated for the hectares where alien infestation levels exceeded 75% (260 hectares). This benefit would occur every 4 years as per the fire cycle in grassland vegetation.

The productive land benefit determined consisted of horticultural and livestock components. As with the previous sites, responsible livestock farming at the Pot River site was assumed to co-exist with the indigenous vegetation, with no biodiversity loss. Both benefits would increase over time in line with the proportion of land cleared, as set out by the WfW managers. The 490 hectares identified would be cleared in 4 years.

The horticultural component of the agricultural benefit would transform the indigenous vegetation, and could therefore not co-exist with the indigenous vegetation (biodiversity benefit). The biodiversity benefit (R4070 per hectare) is substantially higher than the horticultural benefit (R450 per hectare). In terms of opportunity costs, the preservation of indigenous vegetation would be the preferred land use for cleared areas. For this reason, the horticultural component was removed from the net benefit stream. Only the livestock component was included in the productive land benefit stream.

The decision-making criteria for the WfW project at the Pot River site, as determined from the costs and benefits, are depicted in Table 6.3.

(vi) Tsitsikamma

For the Tsitsikamma site, the fire benefit of fynbos (see Chapter 4) and the biodiversity benefit (see Chapter 5), were added to the incremental water yield estimated by Hosking *et al.* (2002). The productive land benefit was estimated at zero. A fire benefit could only be determined for areas where infestation levels exceeded 75% (as per density classes established by Hosking *et al.* (2002)). Approximately 26 073 hectares were classified as having dense infestation (above 75%), and this was used for the estimation of the fire benefit.

The total area branded for clearing would only be realised after 19 years. The total biodiversity benefit would thus only become applicable in year 20. Between years 1 and 19, the biodiversity benefit would increase in proportion to the number of hectares cleared every year (Hosking *et al.*, 2002).

Table 6.3 depicts the decision-making criteria for WfW activities as calculated from the combined benefits and costs.

6.5 DECISION-MAKING CRITERIA RESULTS AT THE SIX WFW PROJECT SITES

Table 6.3 below summarises the results of the decision-making criteria applied to the cost benefit profiles of the project sites. It depicts the results of three CBAs. Firstly, the results of the decision-making criteria, as constructed by Hosking *et al.,* (2002) are displayed. The revised CBA including the potentially productive land and fire benefits is then shown (labelled CBA 2). Finally a second revised CBA is shown – one which includes the impact of the biodiversity benefit (labelled CBA 3).

Table 6.3 Summary of CBA results

			Sites					
CBA	**CBA used**	**CBA criteria**	**PE Driftsands**	**Albany**	**Kat River**	**Pot River**	**Kouga**	**Tsitsikamma**
1	**Hosking *et al.* (2002)**	**NPV (R)**	-14 674 240	-15 232 753	-1 031 609	-1 446 624	-33 854 196	-31 757 404
		IRR (%)**	0	1.13	3.60	-3.14	7.25	5
		BCR	0	0.21	0.43	0.03	0.75	0.54
2	**Revised decision criteria including agric. and fire benefits**	**NPV (R)**	-15 407 671	-9 058 614	-1 109 142	-1 034 188	-35 950 176	-32 765 901
		IRR ** (%)	Undefined*	4	4	1	7	5
		BCR	0.01	0.56	0.42	0.21	0.74	0.55
3	**Revised decision criteria including agric., fire and biodiversity benefits**	**NPV (R)**	67 721 069	-3 046 798	16 767 386	16 137 316	-18 244 864	-26 875 031
		IRR (%)**	202	8	Undefined*	Undefined*	9	6
		BCR	5.37	0.85	9.82	13.3	0.74	0.63

* An undefined value indicates that no sign change occurs during the whole benefit cost stream. In these cases there are only benefits, and no costs (positive values).
** The estimated social discount rate of 10.1% was used.

None of the CBAs yielded positive results where only the productive land and fire benefits were incorporated. A combination of these projects into a regional cost benefit profile yielded a NPV of –R95 325 696 and a BCR of 0.62. It is deduced that the findings of Hosking *et al.* (2002) remain valid even if the agricultural and fire benefits are incorporated. As argued by Hosking *et al.* (2002), only at lower discount rates and with a lower cost structure (30% cost reduction) would this result change – the Kouga and Tsitsikamma sites would become economic propositions for the WfW programme.

When the preference for indigenous vegetation was added to the revised cost benefit profile (including the agricultural and fire benefits), the picture changed significantly. With the inclusion of this benefit, the PE Driftsands, Pot River and Kat River sites became efficient. The magnitude of the NPV values for these sites was high. As a result, if the project was redefined in terms of the sum of all the subprojects, the NPV increased to R52 459 077, and the BCR increased to 1.14.

6.6 SENSITIVITY ANALYSIS

A sensitivity analysis was undertaken to establish the worth of the programme under lower social discount rates (as argued in Chapter 2) of 8.1% and 5.1% respectively. The revised benefit cost profile, including the productive capacity of land, fire and biodiversity benefits, was used in this sensitivity analysis. The results are shown in Table 6.4.

Table 6.4 Sensitivity results of the second revision (CBA 3 - including biodiversity benefit) with varied discount rates

Site	Criterion	Discount rate	
		8.1%	**5.1%**
PE Driftsands	NPV (R) BCR	98 375 471 6.49	198 877 302 9.75
Albany	NPV (R) BCR	-685 020 0.97	10 286 358 1.34
Kat River	NPV (R) BCR	23 272 525 11.76	44 019 662 17.36
Pot River	NPV (R) BCR	20 895 071 16.02	35 013 169 23.76
Kouga	NPV (R) BCR	9 637 258 0.90	134 531 324 1.36
Tsitsikamma	NPV (R) BCR	-20 087 966 0.77	16 076 402 1.14

With a lower discount rate of 8.1%, the Kouga site becomes efficient. When the discount rate is reduced to 5.1%, all the sites become attractive economic propositions.

6.7 CONCLUSION

The results of the CBA presented in this chapter show that the inclusion of selected non-water benefits has a dramatic effect. With the inclusion of non-water benefits, three of the sites deemed inefficient by Hosking *et al.,* (2003) become efficient. Hosking *et al.,* (2002) argued that only the Kouga and Tistsikamma sites would be efficient if 30% cost savings were realised and lower interest rate levels prevailed. The present analysis has found that the PE Driftsands, Kat River and Pot River sites may possibly be efficient without these savings, and at the current interest rate levels. If a discount rate of 8.1% is applied, the Kouga site also becomes an economically attractive proposition. At a discount rate of 5.1%, all the sites may be efficient.

Of the three non-water benefits incorporated, one stood out as of much greater consequence than the others, namely the biodiversity benefit. The incorporation of the agricultural and fire benefit on their own, did not change the results found by Hosking *et al.*, (2002). The changes found here were primarily due to the inclusion of the biodiversity benefit. Unfortunately, however, little confidence can be attached to the estimate of the biodiversity benefit, because the sample size used was too small.

CHAPTER 7
CONCLUSION AND RECOMMENDATIONS

7.1. CONCLUSION

A cost benefit analysis done by Hosking *et al.* (2002) on six representative WfW sites in the Eastern and Southern Cape (namely PE Driftsands, Albany, Kat River, Pot River, Kouga and Tsitsikamma) indicated that WfW activities undertaken to increase the natural water yield were inefficient at all the sites. These results were based on a real social discount rate of 10.1%. Their conclusion was subject to two qualifications: at a lower discount rate (e.g. 5%) and with cost savings of 30%, both the Tsitsikamma and Kouga projects were efficient. Only the increased livestock farming benefit was included as a non-water benefit in their analysis. The present study has extended that of Hosking *et al.* (2002), by incorporating into the CBAs three non-water benefits at the six sites. The non-water benefits incorporated were: an extension of the scope of the agricultural benefit, the impact on fire-fighting costs of wildfires in alien infested land, and people's preference for indigenous vegetation (as a proxy for biodiversity).

This study has criticised the Hosking *et al.* (2002) study for using too high a discount rate, and drawing conclusions without knowing the values of the non-water benefits. Even though Hosking *et al.* (2002) performed a sensitivity analysis whereby clearing costs were reduced by 30% (which rendered qualified support for the Kouga site), this cost reduction was not generous enough. Arguably, up to 80% of the costs are actually transfers (not costs). The question arises as to whether an even greater cost deduction should not have been made. Labour had few alternative work options, and poverty relief was going to be made anyway.

In the Hosking *et al.* (2002) study, the discount rate was lowered to 8.1% and 5.1%. None of the sites became viable at a rate of 8.1%, but the Tsitsikamma and Kouga sites were efficient at a discount rate of 5.1%. Even 5.1% may be considered a high rate from an intergenerational perspective. The omission of non-water benefits is not of great consequence with respect to the agricultural and fire benefits, but it may well be serious with respect to the biodiversity benefit.

When only the potential productivity of land benefit and the fire benefit were incorporated into the CBA carried out by Hosking *et al.* (2002), none of the sites rendered positive NPVs at a social discount rate of 10.1%. The BCRs were all less than 1, while the IRR values were less than the discount rate. When all the projects were combined into a regional cost benefit profile, the NPV was –R 95 325 696 and the BCR was 0.62.

The inclusion of the biodiversity benefit into the revised CBA had a noteworthy impact on the results. The value of the public's preference for indigenous vegetation was determined through the use of the Contingent Valuation technique. The surveys done were pilot studies only. The sample sizes were very small, and not representative of the total population at every site. The pilot studies suggest that this is a non-water benefit of great potential significance. The revised CBA, incorporating the agricultural, fire, and biodiversity benefits, indicates that the PE Driftsands, Kat River and Pot River sites become efficient options for clearing efforts, even at a discount rate of 10.1%. The combined NPV for all the sites becomes R52 459 077 and the BCR becomes 1.14. If the discount rate is decreased to 5.1%, all the sites become efficient.

7.3 RECOMMENDATIONS

(a) Decisions on where the WfW programme must function should not be made based on the water benefit alone. A prioritisation strategy of where clearing should be undertaken must be put in place.

(b) The preliminary figures emanating from the Contingent Valuation pilot studies done at the six sites indicated that this benefit could be considerable. In-depth CVs should be done at the six sites. A more rigorous questionnaire and sampling process need to be followed.

(c) The social benefit realised through the job creation and poverty alleviation aspect of the WfW programme, needs to be evaluated and incorporated into the CBA. In particular, the implications of poverty alleviation transfers made through the WfW programme need to be taken better account of. The WfW programme is undoubtedly a conduit for transfer payments that are going to be made anyway. The issue needs to be re-examined as to whether allocations of funds from transfer budgets should be costed in the same way as allocations of funds from service-generating budgets.

(d) The extent to which alien infestation contributes to soil erosion and movement due to increased fire intensities after wildfires, needs to be assessed ecologically. Only when the magnitude of ecological damage is established, can an economic valuation be made.

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APPENDIX A: List of fire experts

Manager	**Region**	**Company**	**Years of fire-fighting experience**
Jaco Rheeder	West Coat Region	Western Cape Nature Conservation	10+
Mark Gentle	Hottentots-Holland Area	Western Cape Nature Conservation	10+
Mark Johns	Kogelberg Nature Reserve	Western Cape Nature Conservation	10+
Chris Martens	Overberg Area	Western Cape Nature Conservation	22
Deon Geldenhuys	Walker Bay Nature Reserve	Western Cape Nature Conservation	
Piet van Zyl	Vrolijkheid Nature Reserve	Western Cape Nature Conservation	
Ben Swanepoel	De Hoop Nature Reserve	Western Cape Nature Conservation	7+
Nigel Wessels	Outeniqua Nature Reserve	Western Cape Nature Conservation	12
Tony Marshall	Outeniqua Nature Reserve	Western Cape Nature Conservation	23
Kevin Bates	Director: Parks	Makana Municipality	5+
Ty Cobbold	Ugie	Working for Water	10+
D. Butt	Ugie	Mondi plantations	10+

APPENDIX B: Fire fighting questionnaire

FYNBOS, PRISTINE, UNPLANNED BURNING

HIGH RISK ***

During fire		
People	Amount of people	Person hours
Workers		
Specialists (eg. high altitude)		
Supervisors		
Managers/ Fire bosses		

Equipment	Quantity	R/h
"Bakkie Sakkie"/ Bakkie unit		
Fire brigade		
"Plakke"		
Slashers &"Skoffel pikke"/Spades		
Helicopter		
Other 1: Specify		
Other 2: Specify		
Other 3: Specify		
Other 4: Specify		
Other 5: Specify		
Mop-up teams ("kooltjielyn")		
People	Amount of people	Person hours
Workers		
Specialists (eg. high altitude)		
Supervisors		
Managers/ Fire bosses		
Equipment	Quantity	R/h
"Bakkie Sakkie"/ Bakkie unit		
Fire brigade		
"Plakke"		
Slashers &"Skoffel pikke"/Spades		
Helicopter		
Other 1: Specify		
Other 2: Specify		
Other 3: Specify		
Other 4: Specify		
Other 5: Specify		

*** Temp > 28 C, Humidity medium, Wind > 28km/h

APPENDIX B: Fire fighting questionnaire

FYNBOS, 50 – 100% INFESTATION, UNPLANNED BURNING

During fire		
People	Amount of people	Person hours
Workers		
Specialists (eg. high altitude)		
Supervisors		
Managers/ Fire bosses		

HIGH RISK ***

Equipment	Quantity	R/h
"Bakkie Sakkie"/ Bakkie unit		
Fire brigade		
"Plakke"		
Slashers &"Skoffel pikke"/Spades		
Helicopter		
Other 1: Specify		
Other 2: Specify		
Other 3: Specify		
Other 4: Specify		
Other 5: Specify		
Mop-up teams ("kooltjielyn")		
People	Amount of people	Person hours
Workers		
Specialists (eg. high altitude)		
Supervisors		
Managers/ Fire bosses		
Equipment	Quantity	R/h
"Bakkie Sakkie"/ Bakkie unit		
Fire brigade		
"Plakke"		
Slashers &"Skoffel pikke"/Spades		
Helicopter		
Other 1: Specify		
Other 2: Specify		
Other 3: Specify		
Other 4: Specify		
Other 5: Specify		

*** Temp > 28 C, Humidity medium, Wind > 28km/h

APPENDIX B: Fire fighting questionnaire

GRASSLANDS, PRISTINE, UNPLANNED BURNING

HIGH RISK ***

During fire		
People	Amount of people	Person hours
Workers		
Specialists (eg. high altitude)		
Supervisors		
Managers/ Fire bosses		

Equipment	Quantity	R/h
"Bakkie Sakkie"/ Bakkie unit		
Fire brigade		
"Plakke"		
Slashers &"Skoffel pikke"/Spades		
Helicopter		
Other 1: Specify		
Other 2: Specify		
Other 3: Specify		
Other 4: Specify		
Other 5: Specify		
Mop-up teams ("kooltjielyn")		
People	Amount of people	Person hours
Workers		
Specialists (eg. high altitude)		
Supervisors		
Managers/ Fire bosses		
Equipment	Quantity	R/h
"Bakkie Sakkie"/ Bakkie unit		
Fire brigade		
"Plakke"		
Slashers &"Skoffel pikke"/Spades		
Helicopter		
Other 1: Specify		
Other 2: Specify		
Other 3: Specify		
Other 4: Specify		
Other 5: Specify		

*** Temp > 28 C, Humidity medium, Wind > 28km/h

APPENDIX B: Fire fighting questionnaire

GRASSLANDS 50 – 100% INFESTATION, UNPLANNED BURNING

During fire		
People	Amount of people	Person hours
Workers		
Specialists (eg. high altitude)		
Supervisors		
Managers/ Fire bosses		

HIGH RISK ***

Equipment	Quantity	R/h
"Bakkie Sakkie"/ Bakkie unit		
Fire brigade		
"Plakke"		
Slashers &"Skoffel pikke"/Spades		
Helicopter		
Other 1: Specify		
Other 2: Specify		
Other 3: Specify		
Other 4: Specify		
Other 5: Specify		
Mop-up teams ("kooltjielyn")		
People	Amount of people	Person hours
Workers		
Specialists (eg. high altitude)		
Supervisors		
Managers/ Fire bosses		
Equipment	Quantity	R/h
"Bakkie Sakkie"/ Bakkie unit		
Fire brigade		
"Plakke"		
Slashers &"Skoffel pikke"/Spades		
Helicopter		
Other 1: Specify		
Other 2: Specify		
Other 3: Specify		
Other 4: Specify		
Other 5: Specify		

*** Temp > 28 C, Humidity medium, Wind > 28km/h

APPENDIX C: Map used in expert fire fighting survey – fynbos vegetation

Available on request.

APPENDIX D: The CV questionnaire

ALBANY

<u>Instructions to person administering the questionnaire</u>.

Please tick the appropriate blocks. If the answer is other, please specify the meaning of other (details).

1. Why are you in this area?

Resident - urban	
Farmer/ farm worker	
Tourist	
Other - specify	

2. Are you familiar with the Working for Water Programme?

Yes	
No	

3. Do you know where in this area the Working for Water Programme is clearing alien vegetation?

Yes	
No	

4. Rank your order of preference for the following vegetation: (1 would be most preferred and 4 least preferred)

1.	Commercial plantations (eg. Pine and Gum)	
2.	Invasive plants and trees growing wild, such as Wattle, Pine, Hakea species	
3.	Grassy fynbos and Valley Thicket	
4.	Other - specify	

<u>Fill in the gaps in the person's knowledge – information to the respondent</u>

- The Eastern Cape has 7 biomes (regions classified by vegetation and climate), the highest of all the provinces, and is the home of substantial numbers of animals, plants and other organisms.
- The Working for Water programme clears alien vegetation such as Wattle, Hakea and Eucalyptus species in the Albany area to restore the indigenous vegetation known as grassy fynbos and Valley Thicket: 11 400 hectares with an infestation level of approximately 8% are cleared.
- Grassy fynbos occupies 0.5% of South Africa, with 97% of it growing in the Eastern Cape. Grassy fynbos makes up 4% of the Eastern Cape. Valley Thicket inhabit 2% of South Africa, with 66% of it growing in the Eastern Cape. Approximately 9% of the Eastern Cape's vegetation is made up of Valley Thicket.

- Grassy fynbos is used for grazing, hiking and water catchment - approximately 3% of it has already been lost through human activity. The economic uses of Valley Thicket include goat farming. Humans have transformed approximately 51%.
- Most types of Thickets are poorly conserved: 2% of Valley Thicket is conserved in South Africa. A number of reserves protect this type of vegetation, but it is under threat from poor farming management practices. Valley Thicket can be found in river valleys through the Eastern Cape to KwaZulu-Natal and in the eastern parts of the Western Cape.
- 16% of grassy fynbos is conserved in South Africa. It is established in the Baviaanskloof, Zuurberg mountains and from Steytlerville to Grahamstown.
- The alternative to Valley Thicket and Grassy fynbos is alien vegetation, mostly from Australia. It has been increasing its coverage in South Africa at the expense of the indigenous vegetation.
- This is not about the water impact of aliens in South Africa, but about your preference for a vegetation type.

5. What are you willing to pay per year - in local tourist levies (as a tourist) or would you be willing to pay in local municipal service levies, eg. like a refuse removal charge (as a resident in the area) - for the stated vegetation clearing programme in terms of your preference for the grassy fynbos and Valley Thicket coverage over the alien tree coverage:

Rand	**The Working for Water Programme at this site (budget of R1.95 million in 2002)**	**The Working for Water Programme in South Africa (budget of R 403 million in 2002)**	**Conservation projects in South Africa (budget of R560 million in 2002)**
0			
1-10			
11 - 20			
21 – 50			
51 - 100			
101 - 200			
201 – 500			
501 – 1000			
1001 – 2000			
2001 – 5000			
5001 +			

Remember that financial sacrifices/ a reallocation of money must be made in order to make a payment towards the clearing of alien species.

6. Gender:

Male	Female

7. Age of household head:

---

8. Number of people making up household:

---

9. Educational level of household head:

Less than Std 8/ Grade 10	
Std 8/ Grade 10	
Matric	
Post Matric	
Diploma	
Degree	
Post Graduate degree	

10. Gross Annual pre-tax income of household head:

R

0 – 12 000	
12 001 – 24 000	
24 001 – 60 000	
60 001 – 120 000	
120 001 – 240 000	
240 001 +	

11. Worth of house/ farm:

R

1 – 20 000	
20 001 – 50 000	
50 001 – 100 000	
100 001 – 150 000	
150 001 – 250 000	
250 001 +	

Please note that this is a sensitive issue, but this is an anonymous survey.
It makes a big difference to us!

Questionnaire constructed Ms L.L. du Plessis, Dept. of Economics UPE, in consultation with by Prof. S. G. and Hosking, Mr M. Du Preez.

APPENDIX D1: Pictures shown to respondents during CV survey

1. Fynbos: pristine

www.ecoafrica.com/.../grootwinterhoek/ Fynbos.jpg

2. **Grasslands: pristine**

http://www.ngdc.noaa.gov/paleo/drought/images/grass.jpg

3. Invasive plants growing wild

http://www.wildlifesociety.org.za/images/BKaliens.jpg

4. Commercial plantations

http://www.tpwd.state.tx.us/conserve/wildlife_management/pineywood/images/habitat/plantation.jpg

APPENDIX E: Discussion of the Travel Cost and Hedonic Pricing Methods

E.1 The Travel Cost Method (TCM)

The TCM hinges on the assumption that the costs incurred in visiting a place (eg. a game park) can be related to the value derived from its enjoyment. Ultimately, a demand curve for the environmental good can be constructed, using these utilities/ values derived from using the environmental good. The cost individuals incur for visiting recreation sites (including travel cost, admission fees, on-site expenses and the purchase of equipment needed for consumption) is used as a substitute for the price of the recreational site. Thus the demand is seen as a trip generating function (Turner, Pearce and Bateman, 1993:116; Turner et al., 1993:116).

Two travel cost methods categories can be identified: the zonal travel cost method (or Clawson-Knetsch method) and the individual travel cost method.

The zonal travel cost method starts with a division of the surrounding are to a recreational site into zones of origin, by drawing concentric circles around the site. However, it is usually easier to divide the zones per magisterial or government administrative districts, as the population size of each zone is used to predict the number of trips per person per zone. Multiple regression analysis is used to calculate the trip generating function (TGF), using the following formula:

Vsk = V (Csk, Psk, Sesk) ; S = 1…n

V = the number of trips from zone n to recreation site k

P = population of zone S

SEsk = socio-economic characteristics of the population of each zone (e.g. average income, age and race)

Trips per person per zone constitutes the dependent variable (Vsk/ Psk), and then a demand curve is assessed by increasing the admission fee (which is a proxy for the real price) and looking at the resultant quantity of visits per annum demanded from each zone. The fee/visit mix can then be estimated, based on the visit and travel cost correlation. In most cases, the number of visits decrease as the travel cost increases.

The demand curve drawn for each zone (using the TGF) is used to calculate the consumer surplus, which is represented by the area under the demand curve (Hanley & Spash 1993).

The individual TCM also relies on a TGF, where travel costs (C) predict the number of visits (V) of an individual (j) to a recreational site (k). The travel costs are depicted as:

Cjk = DCjk + TCjk + Afjk; j = 1…n,

Where

DC = distance cost for individual "j". It varies as the distance travelled to visit the site and the cost per kilometre changes.

TC = time costs. This is calculated using the value of the individual's time and the time it takes to travel to the site.

AF = admission fee to recreational site k.

Socio-economic variables are also used to explain movements in demand (Hanley & Spash, 1993:84).

Although the TCM is used regularly in the estimation of values of recreational sites, a number of problems exist regarding its use. These include:

- *Time costs*. The time taken to travel to a recreational site constitutes an additional cost, which needs to be added to all other travel costs. However, the value of time is difficult to measure, and it has been the subject of much research (Rosen 1992:254). A common way to calculate the value of time is through an after tax wage rate. This method is based on the theory of leisure-income choice (Rosen 1992:418), where utility maximising people work up until that point where the value of their leisure is equal to the cost they incur in income foregone, which is their after-tax wage rate. However, two problems are encountered with this approach, the first being that some people are not in the position to choose their work hours and secondly, time uses away from work are not similar (Rosen 1992:254).

- *Distance costs*. The travel cost is the product of the price per kilometre traveled and the distance traveled (in kilometres). However, the cost per kilometre traveled can differ from person to person – some perceive this cost as being only fuel costs, while others include depreciation and insurance. Utility maximization occurs where marginal cost equals marginal benefit of consumption; therefore the choice of which costs are included are paramount for calculation purposes.

- *Multi-purpose trips*. Some users may be visiting the recreational site in question as part of a bigger trip where other sites that fall outside the study area are also visited. Various techniques have been developed to deal with such problems. In some instances people undertaking multi-purpose trips are omitted from the travel cost analysis and a per visit consumer's surplus value is computed, based on the assumption that the multi-purpose trippers do not place a higher value on the recreational site than single purpose visitors. The average consumer surplus is then added across all visitors (Hanley and Spash. 1993:87-88).

- *Existence values*. Existence values cannot be measured using the TCM

E.2 The Hedonic Pricing Method (HPM)

This method relies on the principle in consumer theory that the utility derived from a good is based on its characteristics. The property market is used in most applications of HPM (Turner et al. 1993:120). From consumer choice theory, it flows that the price that people are willing to pay for a property depends on the characteristics of the property, such as position, neighbourhood characteristics and environmental quality, to name but a few.

All factors affecting the explicit price of a property need to be assessed if the HPM is applied (Turner, et al., 1993). A hedonic (implicit) price function is then generated by determining the relationship between an environmental variable and a marketed good with a close relationship to the environmental variable. All other factors perceived as important are then included as explanatory variables in the estimation of the price of the environmental good. For instance, the price of urban houses typically relies on size (for example erf size – Si), neighbourhood characteristics such as proximity to schools (with Nj being the number of schools in the area) and environmental amenities such as noise levels (Ek). This can be expressed in terms of an equation:

$$P_h = P(S_i, N_j, E_k); \qquad [i = 1 \ldots m, \; j = 1 \ldots n, \; k = 1 \ldots l]$$

The ordinary least squares technique is then used to calculate the Hedonic Price of the environmental resource, where the equation is expected to be of a non-linear nature because consumers do not treat the characteristics individually but as part of a package (Rosen 1974:34-41). The implicit price of an individual characteristic can be determined by partially differentiating the Hedonic Price equation. In the case of the price of environmental characteristic E1, for instance, its implicit price can be calculated using:

$$\partial P_h / \partial E_1 = \frac{\partial P(L_j, N_j, E_k)}{\partial E_1}$$

This can be perceived as the market price of environmental good E1 (Hanley and Spash, 1993:76)

At the same time a compensated demand curve is estimated for the environmental quality variable, based on the work done on implicit markets by Rosen (1974). This is done in order to calculate the consumer surplus. As with the TCM, various problems exist with the use of HPM. These include:

- *Excluded variable bias*. An excluded variable that correlates with all or some of the included variables and has a substantial effect on house prices can bias the coefficients of the calculated variables (Hanley and Spash, 1993:79).
- *Multi-collinearity*. If the independent variables included in the Hedonic pricing equation correlate with each other, bias in the coefficient estimates will occur and the confidence coefficient linked to the model will decrease (Hanley and Spash, 1993:79).
- *Expected versus actual characteristics*. In the use of HP to estimate the value of environmental characteristics, current environmental characteristics play a role in the price of houses. However, future foreseen changes in the environmental quality should also be included in order to avoid omitted variable bias.
- *Unrealistic assumptions*. Three conditions need to be met before an accurate value of environmental quality can be determined. The housing market needs to be in equilibrium, while all buyers must have perfect information on air quality levels at every conceivable location. Lastly all consumers must be able to move to a position where utility is maximised.
- *Complexity.* The HPM suggests a high level of statistical expertise in the determination of the relationship between house prices and environmental quality, which renders it user unfriendly (Turner, et al., 1993:120; Callan and Thomas, 1996:250).