Financing active restoration in South Africa: An evaluation of different institutional models

T. Vundla*
ASSET Research, Pretoria. E-mail: thuli.vundla@gmail.com

J.N. Blignaut
Department of Economics, University of Pretoria, Pretoria; South African Earth Observation Network, Pretoria. E-mail: jnblignaut@gmail.com

D.C. Crookes
ASSET Research, Pretoria; Department of Economics, University of Pretoria, Pretoria. E-mail: d_crookes@hotmail.com

* Corresponding author

Abstract

The restoration of natural capital is increasingly becoming important to counter ongoing land degradation. The Natural Resource Management programme of the Department of Environmental Affairs (DEA: NRM) has long been investing in options to improve the effectiveness of active restoration. The aim of this study is to conduct a cost-benefit analysis of two approaches to active restoration at selected sites in KwaZulu-Natal, South Africa. This study compares a barter approach to a financial compensation approach, both of which are used to finance and advance active restoration. The barter system relies on community members to grow various tree seedlings, and they then receive various goods in exchange for the seedlings grown, whereas the financial compensation sources the seedlings from various commercial nurseries. We use a system dynamics model to evaluate the benefits and costs of these restoration approaches. The main finding is that restoration through the reintroduction of indigenous trees contributes a great deal towards increased carbon sequestration, with the barter option marginally cheaper than the nursery option. The model estimates an annual saving of more than R120 000 per annum with the barter approach in terms of the total restoration costs. However, the financial saving is not significant, as the model concludes that the financial compensation approach is more economically attractive considering a broader range of variables. The model estimated the value of water lost to be -R2 929 992.14 for the financial compensation model and -R2 920 412.76 for the barter financing model over 30 years. With the financial compensation model, the rate of clearance was found to be higher, thus translating directly into a greater accumulation of benefits. The lesser losses in water value, coupled with the higher gains in value-added products for the financial compensation model, are the main reason the financial compensation model is the more economically attractive financing approach.

Key words: active restoration; biological invasions; cost-benefit analysis; degradation; system dynamics

1. Introduction

Environmental stressors such as invasive alien plants (IAPs), the conversion of natural areas into transformed agricultural areas, and urbanisation, have long been drivers of environmental degradation. Owing to the rate at which the environment is being degraded and natural capital is being lost, it is in the interest of conservation scientists to find mechanisms and strategies to restore and conserve natural capital. The restoration of natural capital fosters the speedy recovery of an ecosystem's functioning, as well as the goods and services that it provides (see, for example, De Groot *et al*. 2010). There are several studies that have motivated the need for the restoration of natural capital. The studies by Aronson *et al*. (2006) and Clewell and Aronson (2006) are some of the key studies looking at the restoration of natural capital. Clewell and Aronson (2006) highlight and describe five motivations for restoring natural capital, namely technocratic, biotic, idealistic, heuristic and pragmatic. However, they conclude that each of these motivations has its own individual flaws, and thus there is a need for a unified approach to the restoration of natural capital. From a South African perspective, Aronson *et al*. (2006) further motivate the need for the restoration of natural capital. Their study places a greater emphasis on the restoration of natural capital in urban communities, which is supported by De Wit *et al*. (2001) and Elmqvist *et al*. (2015). These studies find that the restoration of natural capital in urban areas is both socially and ecologically beneficial.

There are two main approaches to ecological restoration, namely active and passive. Passive restoration involves the removal of the environmental stressor, thus allowing secondary succession or natural recuperation/recovery to take place (Benayas *et al*. 2008). Benayas *et al*. (2008) further describe active restoration as the management of land by planting and/or weeding to achieve a desired state. Passive restoration is arguably the most commonly implemented approach to restoration in South Africa (Le Maitre *et al*. 2011), mainly because of the high costs associated with active restoration (Gaertner *et al*. 2012), which has been studied widely (De Wit *et al*. 2001; Mudavanhu *et al*. 2016; Vundla *et al*. 2016). De Wit *et al*. (2001) investigated the costs and benefits of black wattle (which is a conflict-of-interest species) in South Africa and found that the costs of not clearing black wattle outweigh the benefits derived from value-added products. In general, the successful implementation of active restoration is limited by the high costs associated with it. Within the context of clearing IAPs, however, the main flaw of passive restoration is the recovery of IAPs, which usually causes a secondary invasion of the same species that was cleared.

There are several added benefits achieved through the implementation of active restoration initiatives. The main benefits include the accelerated restoration of natural capital, enhanced ecosystem functioning and biodiversity. The benefits derived from forest restoration underscore the need for the restoration of forest products. However, the costs of restoring natural capital could be prohibitive. Studies by Holl and Howarth (2000), Milton *et al*. (2003) and Benayas *et al*. (2008) have looked at the various options for financing the high costs associated with restoration. Holl and Howarth (2000), for example, found that funding options depend on various social and ecological contexts in which restoration takes place; Benayas *et al*. (2008) focused on active restoration, with the study suggesting that dense stands of indigenous trees needed to be reforested.

Policy makers are often presented with various options for the implementation of strategies to achieve various tasks. In this case study, two options were available to finance the active restoration of natural capital. Most active restoration projects propagate seedlings in commercial nurseries. However, the cost of this can be exorbitant, thus deeming active restoration unrealistic in heavily degraded sites (Gaertner *et al*. 2012). Bartering, a more socialist market economy, is a long-standing practice that involves the exchange of goods and/or services for anything other than financial compensation (Appadurai 1986). In recent years, significant developments have been made in the bartering approach in industrialised nations, such as in Europe through local exchange and trading systems (LETS). Through this system, member companies are able to barter their services. Further details of LETS can be found in Williams (1996). In addition, bartering has been crucial in countries facing financial crisis. For instance, Cellarius (2000) notes the role played by the bartering of goods such as potatoes to meet people's basic needs and even make them prosper in the face of financial crisis. In Peru, South America, bartering markets have been instrumental in achieving food security and in conserving agricultural biodiversity through promoting natural produce (Argumedo & Pimbert 2010).

In South Africa, the Wildlands Trees for Life programme is a unique approach to financing active restoration that has been adopted by the Wildlands Conservation Trust (WCT). The programme is multifaceted, with the main components including active restoration, soil rehabilitation, and the control of IAPs. For the purpose of this study, only active restoration and the control of IAPs are considered. Through the Trees for Life programme, tree growers from various communities are incentivised to grow seedlings in exchange for various goods. The goods offered include, but are not limited to, food parcels, bicycles and prepaid airtime. The older the planted seedling, the greater the value of goods received. This programme has been important in the alleviation of poverty in marginalised communities in South Africa. The barter goods entail no extra cost to Wildlands, as there are obtained through donations. Thus this study aims to compare the benefits and the costs of two active restoration payment options, namely a conventional nursery with financial compensation, and a bartering system whereby out-growers are compensated with goods rather than with money.

2. Methodology

2.1 Description: KZN restoration sites

The restoration sites for this study are located within the KwaZulu-Natal province, South Africa, and represent both rural and urban sites. The rural sites are located in northern KwaZulu-Natal and are characterised by tribal, communal areas. The urban sites are located within larger local and metropolitan municipalities. Figure 1 shows the location of the restoration sites used in this study (Richards Bay coastal forest (RBCF), Umsunduzi, Tongaat and Dukuduku). Table 1 further highlights some of the key characteristics of each of the sites.

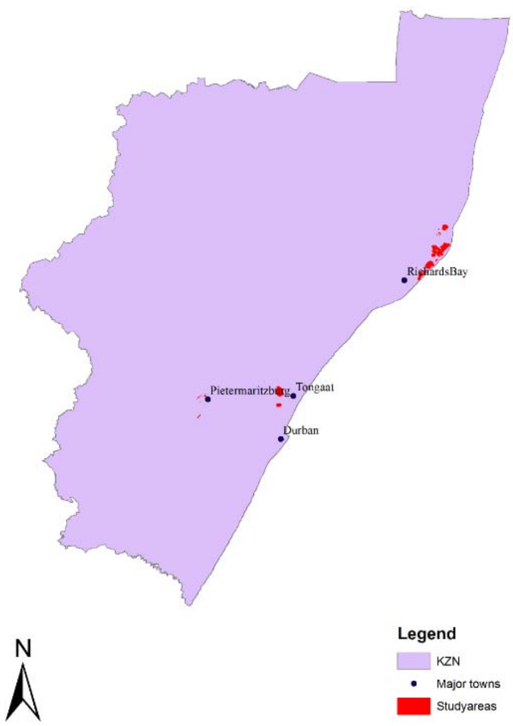

Figure 1: Location of study sites for Wildlands Conservation Trust's active restoration projects

Table 1: Project sites and their respective quaternary catchments and IAPs

Project Sites	Size (Ha)	Quaternary catchment	Proportion	Invading species	Zone	Municipality
Richards Bay coastal forest	4 167.09	W12J	0.13	*Chromolaena ordonata* (Triffid weed)	Rural	uMfolozi
Umsunduzi	63 456.77	U20H, U20J	1	*Cereus jamacaru* (Queen of the night) *Acacia* spp. Wattle spp. *Solanum mauritianum* (Bugweed) *Eucalyptus* species (Gum tree) *Senna didymobotrya* (Peanut butter cassia)	Urban	eThekwini
Tongaat	3 282.75	U30A, U30C	0.05	*Chromolaena ordonata* (Triffid weed) *Senna didymobotrya* (Peanut butter cassia) *Solanum mauritianum* (Bugweed) Wattle spp.	Rural	Ndwedwe
Dukuduku	1 295.53	W32H	0.14	*Psidium gaujava* (Guava) *Melia azedarach* (Syringa) *Eucalyptus* species (Gum trees) *Chromolaena ordonata* (Triffid weed)	Rural	Jozini

2.2 Data collection

This study used both primary and secondary data. Data sources included stakeholder engagements and meetings with the restoration site implementation agency, namely the Wildlands Conservation Trust (WCT), supported by a desktop analysis reviewing the relevant scientific literature.

Figure 2 shows the areas restored at each of the restoration sites from 2013 to 2016, indicating both the areas cleared and the areas planted (Wildlands Conservation Trust [WCT] 2016). There are several indigenous tree species that are used in the Wildlands restoration projects. Table 2 outlines some of the major economic benefits derived from planting these species. The main benefit is fuelwood, especially in rural communities.

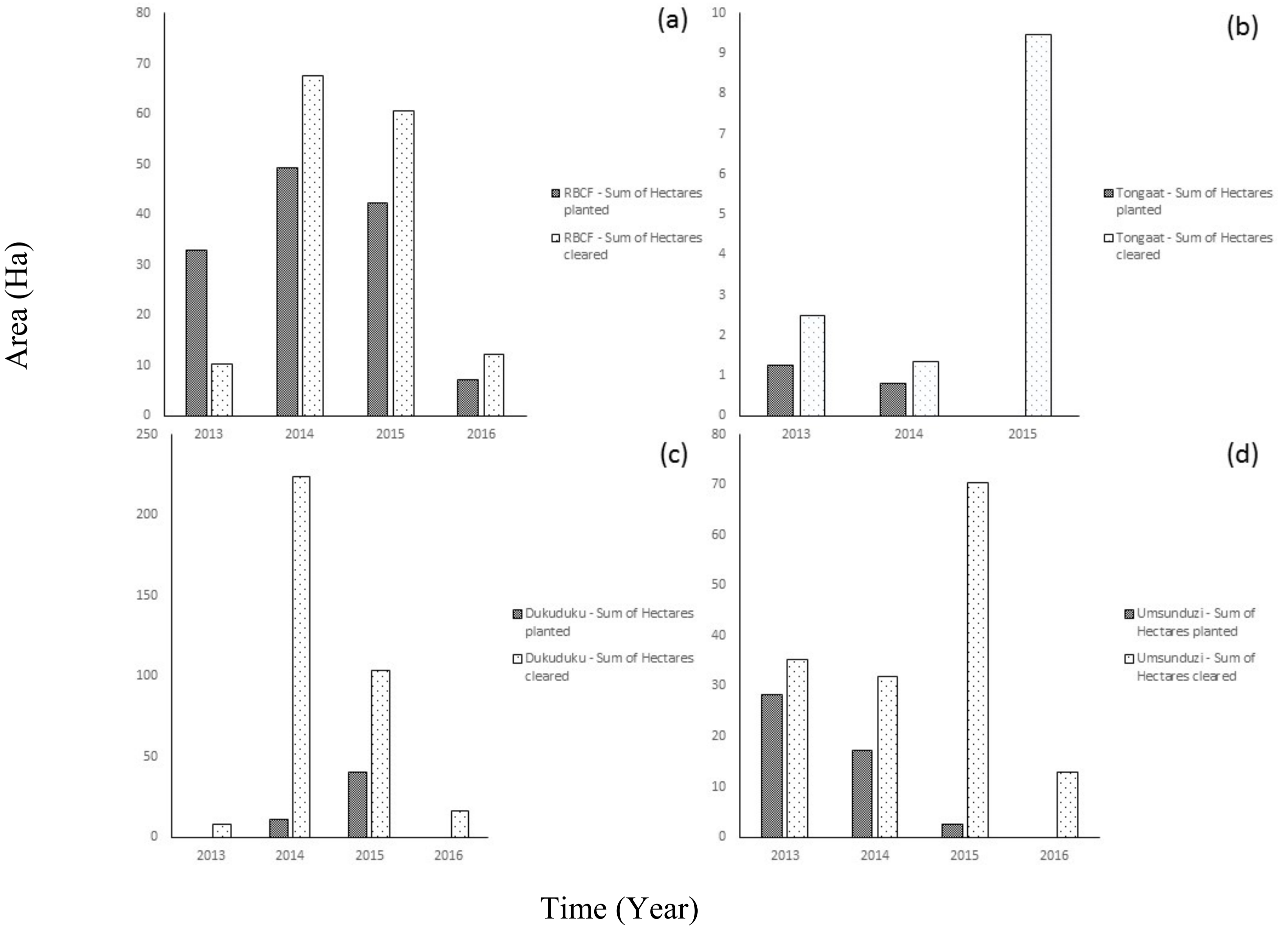

Figure 2: Hectares cleared and planted in the study project areas

Kotzé *et al*. (2010) was used to determine the current extent of invasion for the restoration sites. Since the data in Kotzé *et al*. (2010) is based on the sub-quaternary catchment level, the extent of invasion for this study was estimated as a product of the proportion of the size of the project site (ha) to the respective sub-quaternary catchment(s). For the purposes of this study, only the dominant IAPs were reported for each of the project study sites.

Table 2: Benefits derived from forest products

Species name	Common name	Benefits	Growth from	Distribution	Source
Harpephyllum caffrum	Wild plum	Medicinal	Shrub	Eastern Cape, KwaZulu-Natal	Dlamini (2007)
Syzigium cordatum	Water berry	Medicinal; edible fruit; fuel wood; ornamental	Shrub	Eastern Cape, KwaZulu-Natal	Dlamini (2007)
Erythrina lysistemon	Coral tree	Crafts; ornamental	Wood/tree	North West, Limpopo, Gauteng, Mpumalanga, KwaZulu-Natal and Eastern Cape	Dlamini (2007)
Apodytes dimidiata	White pear	Edible fruit	Wood/tree	Western Cape, Eastern Cape, KwaZulu-Natal and Gauteng	Dlamini (2007)
Various *Ficus* spp.	Fig species	Edible fruit; fuel wood; ornamental	Wood/tree	Eastern Cape, KwaZulu-Natal	Dlamini (2007)
Sclerocarya birrea	Marula	Edible fruit; medicinal; fuel wood; ornamental; fodder and forage	Wood/tree	KwaZulu-Natal, Mpumalanga, Limpopo	Dlamini (2007)
Rauvolfia caffra	Quinine	Medicinal; fuel wood; ornamental	Wood/tree	Eastern Cape, KwaZulu-Natal, Mpumalanga, Limpopo, Gauteng, North-West	Protabase (2016)
Strelitzia nicolai	Wild banana	Edible fruit; ornamental	Shrub	Eastern Cape, KwaZulu-Natal	Protabase (2016)
Acacia xanthoploea	Fever tree	Ornamental	Wood/tree	KwaZulu-Natal	Dlamini & Geldenhuys (2011)
Millettia grandis	Umzimbeet	Timber; firewood; ornamental	Wood/tree	Eastern Cape, KwaZulu-Natal	Protabase (2016)

This information was supported by data sourced from the WCT, some of which is presented in Table 3. Table 3 shows the restoration costs and the person days; since the project-specific costs of restoration were not available for the study, the costs are based on the unit restoration costs as estimated in Nkambule *et al*. (2016) for KZN.

Table 3: Restoration costs, person days and the total number of trees planted for the study project sites

Year	Dukuduku: Costs of restoration (R)	Dukuduku: Person days	RBCF: Costs of restoration (R)	RBCF: Person days	Tongaat: Costs of restoration (R)	Tongaat: Person days	Umsunduzi: Costs of restoration (R)	Umsunduzi: Person days
2013	101 825.19		532 393.80		46 003.27		760 970.00	
2014	1 364 121.86	5 448	1 257 318.00	7 372	9 978.59	2 941	328 590.60	6 917
2015	789 052.52	3 333	880 753.20	8 947	16 212.03	4 183	332 009.90	6 455
2016	204 564.79	320	202 957.70	1 711			26 175.88	4 520
Grand total	**2 459 564.35**	**9 101**	**2 873 422.70**	**18 030**	**72 193.88**	**7 124**	**1 447 746.47**	**19 039**
Total trees planted	**106 569**		**223 116**		**516**		**35 411**	

2.3 System dynamics model

A system dynamics model was developed to investigate the benefits and costs of a barter system (whereby community members acted as out-growers and were compensated by means of previously agreed-upon goods) compared to a conventional nursery system as source of seedlings for active restoration of natural capital. Vensim® was used to conceptualise and analyse the model (Ventana Systems 2007), which consists of seven sub-models. The model was also subjected to structural validation tests. System dynamics modelling applies statistical modelling to constructs that represent an unknown phenomenon based on the various aspects of the system that have been empirically tested. System dynamics modelling is thus able to model various industrial and biological processes without the need for historical data to reveal the relationships between various processes. For this study, a system dynamics model was applied to estimate the benefits and costs of two active restoration payment options. The model used the selected parameters to establish relationships and reveal the nature of the relationships. The section below describes the process that was followed to estimate the costs and benefits of both financing options.

2.3.1 Land-use sub-model

The land-use sub-model (see Figure 3) attempts to capture the social, economic and environmental benefits and costs of restoration. The policy variable for the model was the barter approach vs. a nursery approach. This was quantified as the cost per plant per year. A further cost factor was the number of person days, which were the same for both clearing and planting (restoration). Therefore, the same coefficients were used for both clearing and planting, and all sites have both. For conceptual ease, only the Dukuduku sub-model is presented. The same approach and equations were used for all four sites.

The extent of invasion in the land-use sub-model was increased by the growth and regrowth of IAPs and decreased by clearing. Clearing was affected by the budget, which affects the person days. This relationship and the strength thereof were determined through a series of multiple linear regressions. Selected parameters used in the land-use sub-model are presented in Table 4. The respective equations of the land-use sub-model are presented in Appendix A.

Table 4: Parameters used for the land-use sub-model

Variable	Value	Units	Data Source
Distance to restoration sites	610	Km	WCT (2016)
Annual trips	24	Dmnl	WCT (2016)
Unit cost of transport	4.20	R/km	Automobile Association ([AA] 2016)
Unit plants planted	2072.83	Plant/Ha	WCT (2016)
Good value per plant	6.70	R/plant	WCT (2016)
Spread rates all alien species	0.15	Dmnl/year	Assumption based on Van Wilgen & Le Maitre (2013)
Initial extent of invasion *Melia* spp.	22.656	Ha	Kotzé *et al*. (2010)
Initial extent of invasion guava	282.592	Ha	Kotzé *et al*. (2010)
Initial extent of invasion *Chromolaena*	650.66	Ha	Kotzé *et al*. (2010)
Initial extent of invasion *Eucalyptus*	2356.37	Ha	Kotzé *et al*. (2010)

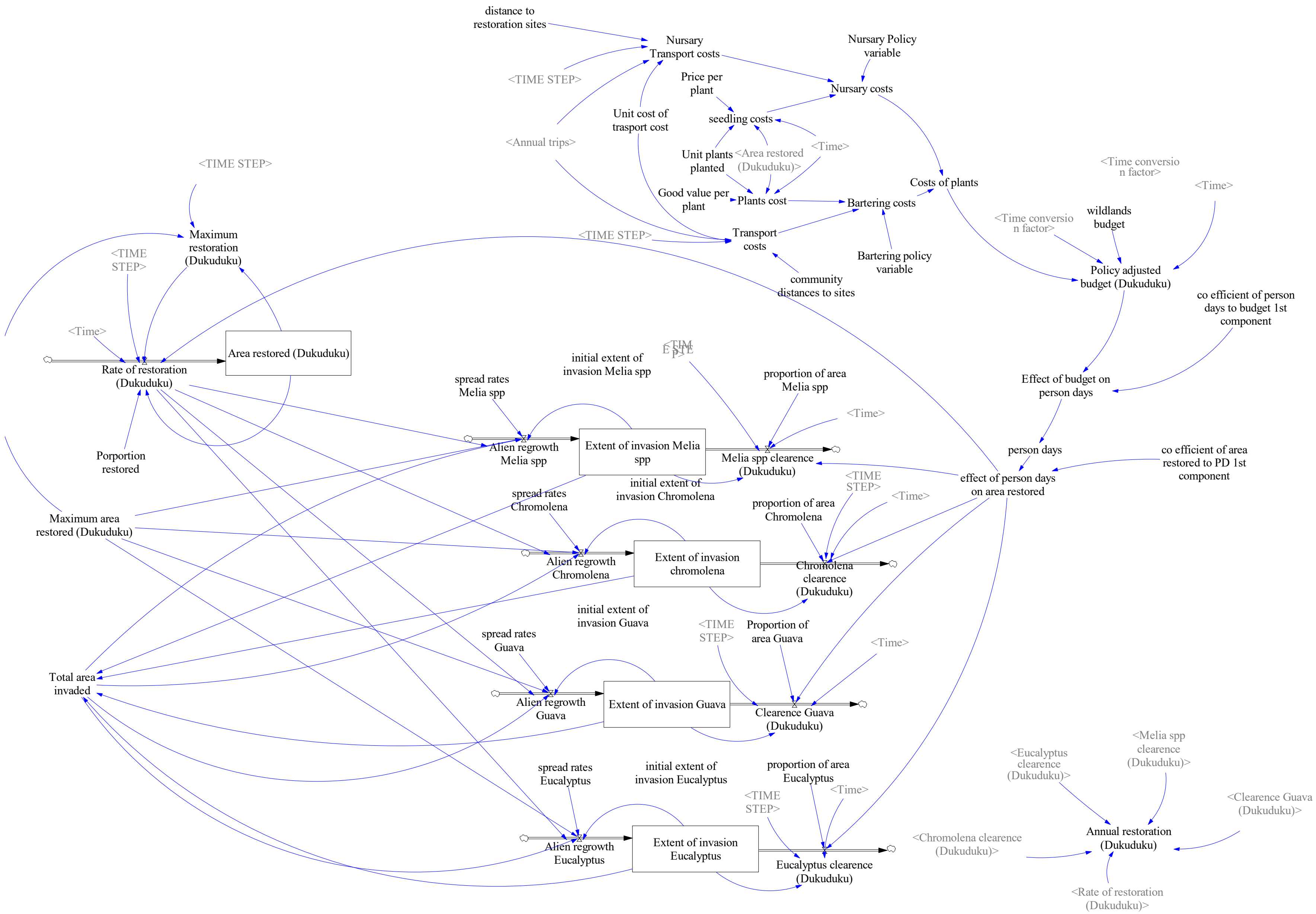

Figure 3: Land-use sub-model (Dukuduku site)

2.3.2 Restoration cost sub-model (Cost)

To estimate additional costs of restoration, the system dynamics model was applied to quantify the unit costs of restoration. The restoration cost sub-model models the restoration costs for each of the project sites, as well the combined total restoration cost. This includes clearing and planting. The schematic representation of the restoration cost sub-model is shown in Figure 4. The unit restoration cost was estimated by the budget divided by the annual clearance. The total restoration costs were estimated as a product of the unit restoration cost and the annual clearance. The complete respective equations of the restoration cost sub-model are presented in Appendix A.

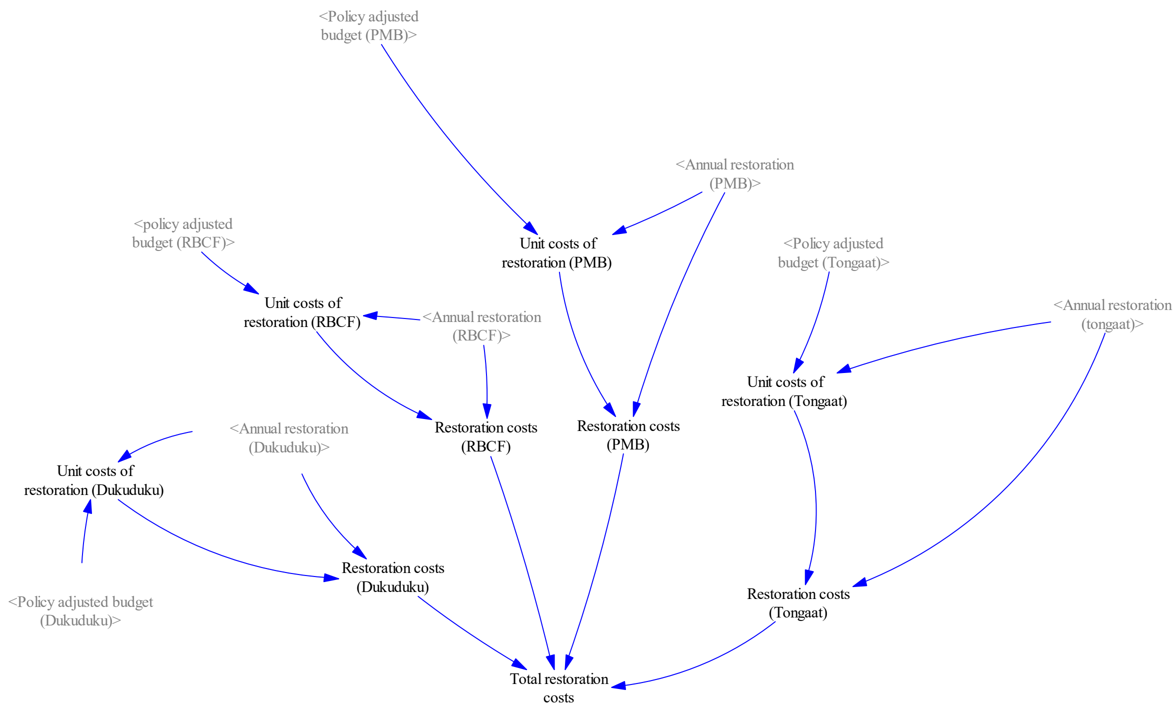

Figure 4: Restoration cost sub-model

2.3.3 Value-added products sub-model (Benefit)

The value-added products (VAPs) sub-model estimates the net income that would be derived from the conversion of IAP biomass into VAPs. The sub-model is shown in Figure 5. For the current study sites, VAPs could only be derived from Eucalyptus and Wattle species. Approximately 20% of the cleared biomass of both Eucalyptus species and Wattle species was converted into timber production, while 80% was channelled into charcoal production, based on Nkambule *et al*. (2016). The VAPs were further corrected for losses and were then multiplied by the corresponding prices to yield their total revenue. The parameters used in the value-added sub-model are shown in Table 5.

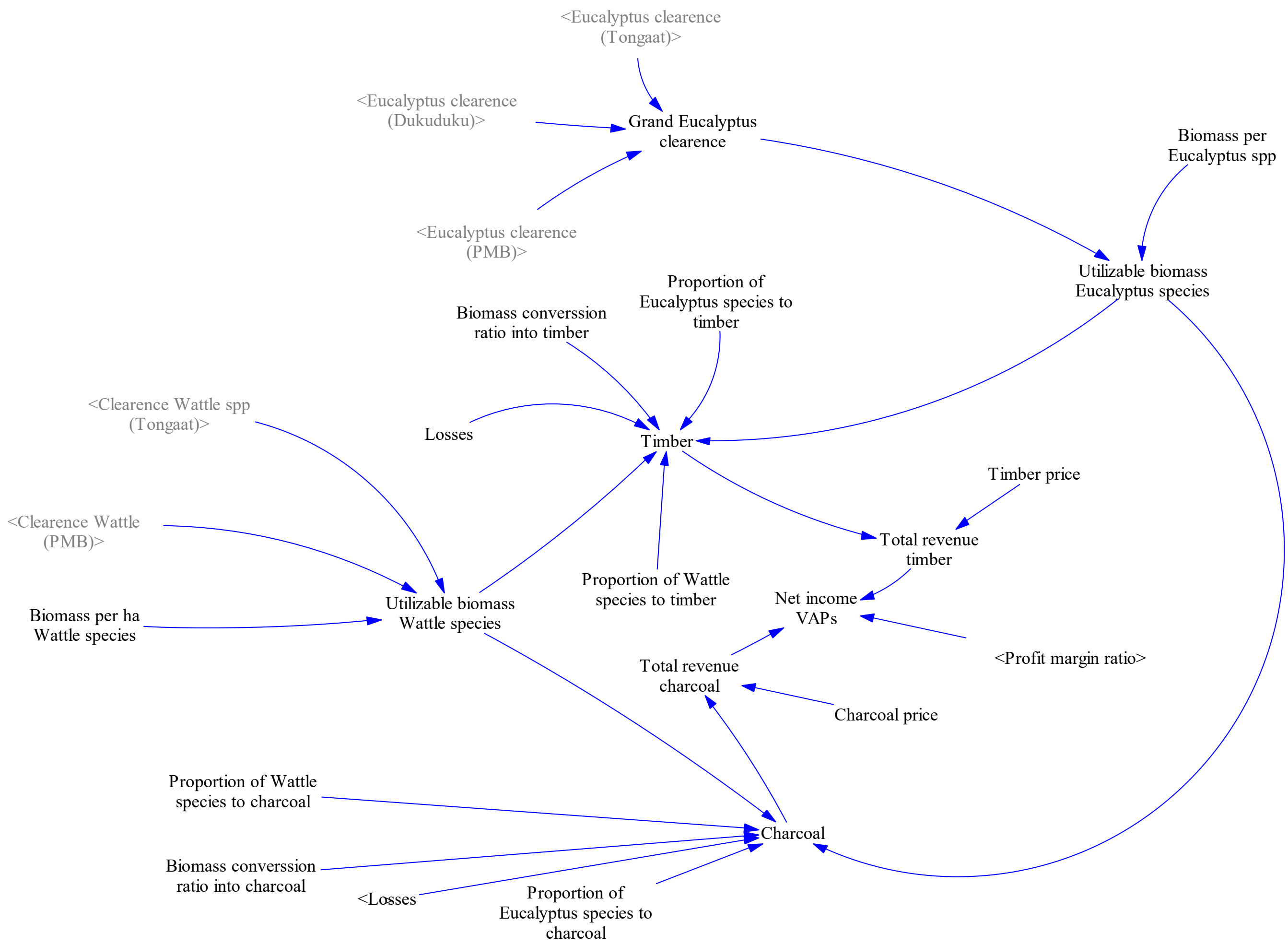

Figure 5: Value-added products sub-model

Table 5: Parameters used in the value-added products sub-model

Variable	Value	Units	Data source
Biomass conversion ratio into charcoal	0.8	ton/ton	Pers. Comm. (Private producer)
Biomass conversion ratio into timber	0.5	ton/ton	Pers. Comm. (Private producer)
Biomass per ha Wattle species	45	Dmnl	Pers. Comm. (Private producer)
Charcoal price	2 700	R/ton	Pers. Comm. (Private producer)
Conversion factor	1	Dmnl	Assumption
Discount rate	0.06	Dmnl	Assumption based on suite of values used by government
Losses	0.8	Dmnl	Assumption
Proportion of Eucalyptus species to charcoal	0.8	Dmnl	Pers. Comm. (Private producer)
Proportion of Eucalyptus species to timber	0,2	Dmnl	Pers. Comm. (Private producer)
Proportion of Wattle species to charcoal	0.8	Dmnl	Pers. Comm. (Private producer)
Proportion of Wattle species to timber	0.2	Dmnl	Pers. Comm. (Private producer)
Timber price	600	R/ton	Pers. Comm. (Private producer)

2.3.4 Carbon sequestration sub-model (Cleared) (Cost)

This sub-model (Figure 6) was developed to estimate the value of the carbon lost due to the clearing of IAPs. Native species and IAPs act as sinks for carbon, and both plant groups follow similar processes to sequester carbon during photosynthesis, thus making both plant groups important in the carbon process (Leishman *et al*. 2007). By absorbing carbon dioxide, IAPs provide a crucial service by offsetting the impacts of climate change. Carbon sequestration costs can reach up to 280 US$ per tCO_2, thus making natural processes to sequester carbon more cost-efficient (Van Kooten & Sohngen

2007). The clearing of IAPs translates directly into carbon sequestration potential lost. Once cleared, plants no longer offer the services of absorbing CO_2 from the atmosphere, therefore clearing IAPs translates into services lost. This service lost can be quantified through the estimation of the standing biomass of IAPs. The carbon sequestrated by each of the IAPs is a product of the IAP biomass, IAP clearance, percent carbon (i.e. percent oven-dry biomass) and the atomic weight of the carbon dioxide. The net carbon stock removed was estimated as a product of the summed individual carbon sequestrated by each of the IAPs and a factor that corrects for carbon lost. To determine the value of carbon lost, the net carbon removed and the unit price of carbon were multiplied. The parameters used in this sub-model are shown in Table 6.

Table 6: Parameters used in the carbon sequestration sub-model (Cleared)

Variable	Value	Units	Data source
Eucalyptus species biomass	86.51	ton/ha	Mugido *et al*. (2014)
Chromolaena odorata biomass	0	ton/ha	Biomass negligible
Agave species clearance biomass	0	ton/ha	Biomass negligible
Wattle species biomass	59.02	ton/ha	Mugido *et al*. (2014)
Melia species	45.	ton/ha	Mugido *et al*. (2014)
Senna didymbotyr	0	ton/ha	Biomass negligible
Lantana camara biomass	0	ton/ha	Biomass negligible
Other species biomass	45	ton/ha	Mugido *et al*. (2014)
Cereus jamacaru biomass	45	ton/ha	Mugido *et al*. (2014)
Solanum mauritianum biomass	0	ton/ha	Biomass negligible
Guava species biomass	0	ton/ha	Biomass negligible
A factor correcting for net carbon	0.5	Dmnl	Assumption
Unit price of carbon	120	R/ton	National Treasury (2013)
Atomic weight of the carbon dioxide	3.6667	Dmnl	
Percent carbon	0.45	Dmnl	Mugido *et al*. (2014)

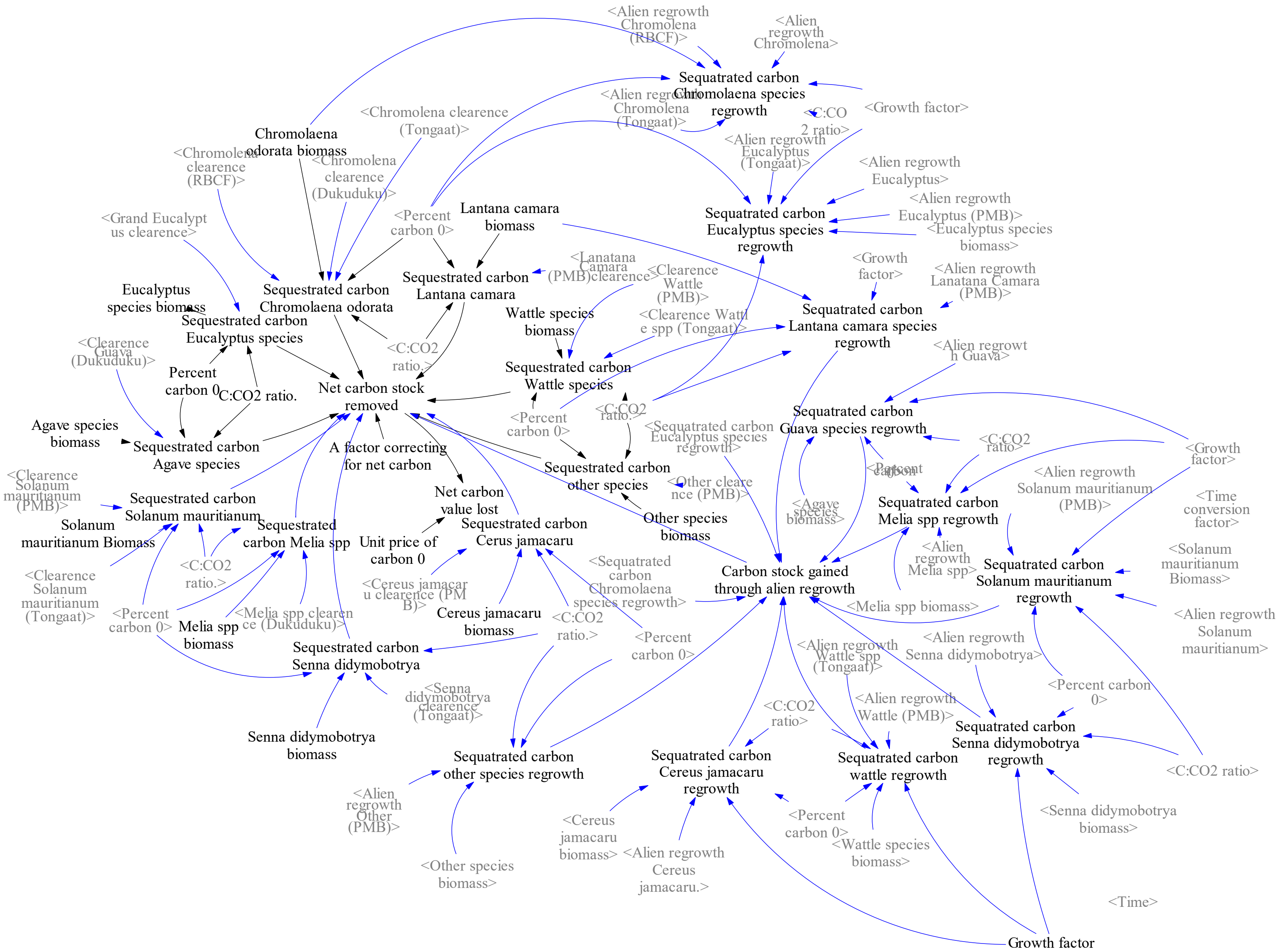

Figure 6: Carbon sequestration sub-model (Cleared)

2.3.5 Carbon sequestration sub-model (Restored) (Benefit)

The value of carbon restored was estimated using a similar method as for carbon lost. Through actively planting indigenous trees, the stock of carbon following clearing in the study area increases. Figure 7 shows the carbon sequestration model for active restoration. To account for the growth rate, growth has been modelled at 4.5 ton/ha/year over a ten-year period to a maximum of 45 ton/ha, based on the findings of Mugido *et al*. (2014).

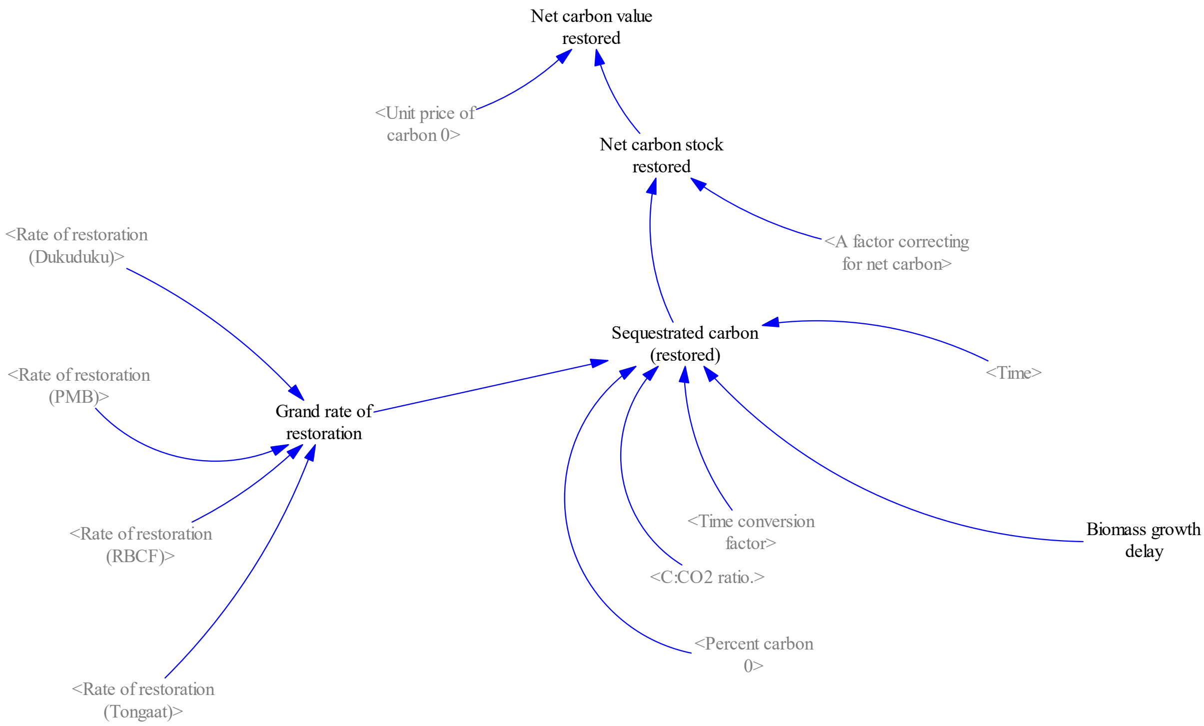

Figure 7: Carbon sequestration sub-model (Restored)

2.3.6 Water saved sub-model (Benefit)

The water saved sub-model sought to estimate the water lost due to invasion. Clearing initiatives would result in water saved, while regrowth would result in a loss of water. In the event that water saved through clearing was less than the water consumed by invasion, the model will yield negative results. The water reduction was derived from Le Maitre *et al*. (2015). The values in Le Maitre *et al*. (2015) are presented in m^3/year. This was converted using the conversion rate of 1 mm/year being equivalent to 10 m^3/ha/year, based on Le Maitre *et al*. (2015). The structure of the water saved sub-model is shown in Figure 8, and the parameters used are given in Table 7. The water consumption by the IAPs is a summation of their water use, which is a product of the individual IAPs' water reduction per hectare and the area that was cleared. The IAPs' water consumption, coupled with the unit value of water, yields the IAPs' water value saved.

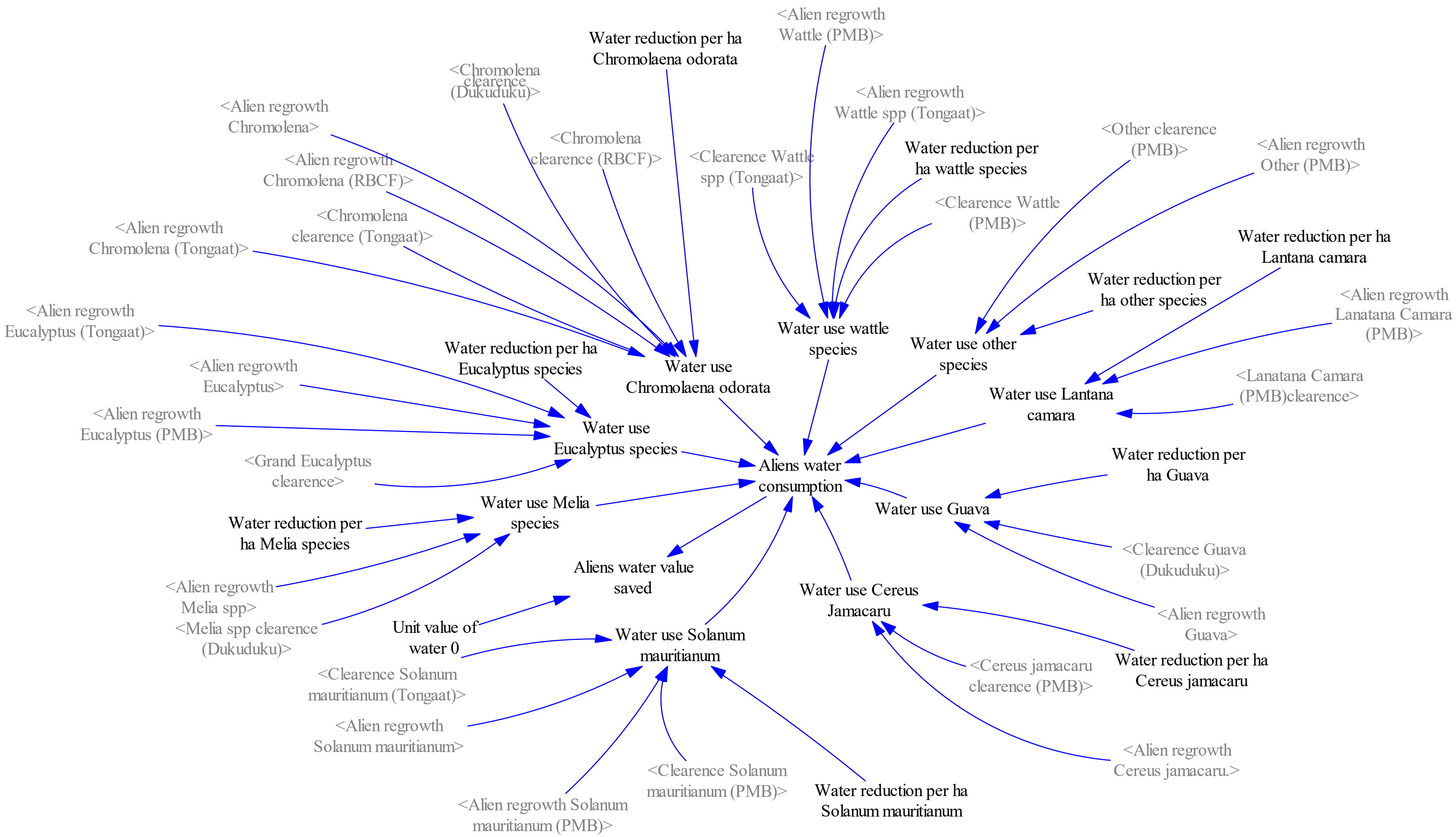

Figure 8: Water saved sub-model

Table 7: Selected parameters used in the water saved sub-model

Variable	Value	Units	Data Source
Water reduction per ha *Chromolaena odorata*	10 200	m^3/ha	Le Maitre *et al.* (2015)
Water reduction per ha Eucalyptus species	14 320	m^3/ha	Le Maitre *et al.* (2015)
Water reduction per ha Wattle species	12 060	m^3/ha	Le Maitre *et al.* (2015)
Water reduction per ha *Lantana camara*	9 650	m^3/ha	Le Maitre *et al.* (2015)
Water reduction per ha *Solanum mauritianum*	9 450	m^3/ha	Le Maitre *et al.* (2015)
Unit value of water	2	R/m^3	Assumption based on agricultural value of water

2.3.7 Economic sub-model

To determine the economic value of restoration, the economic sub-model estimated the net income from restoration and the cumulative NPV. The structure of this model is shown in Figure 9. The net income from restoration was estimated as a summation of the net income from VAPs, value of water saved and value of net carbon gained, less the value of net carbon lost (from clearing the plants) and less the total clearing cost. For estimating the cumulative NPV, the present value factor was applied to the net income.

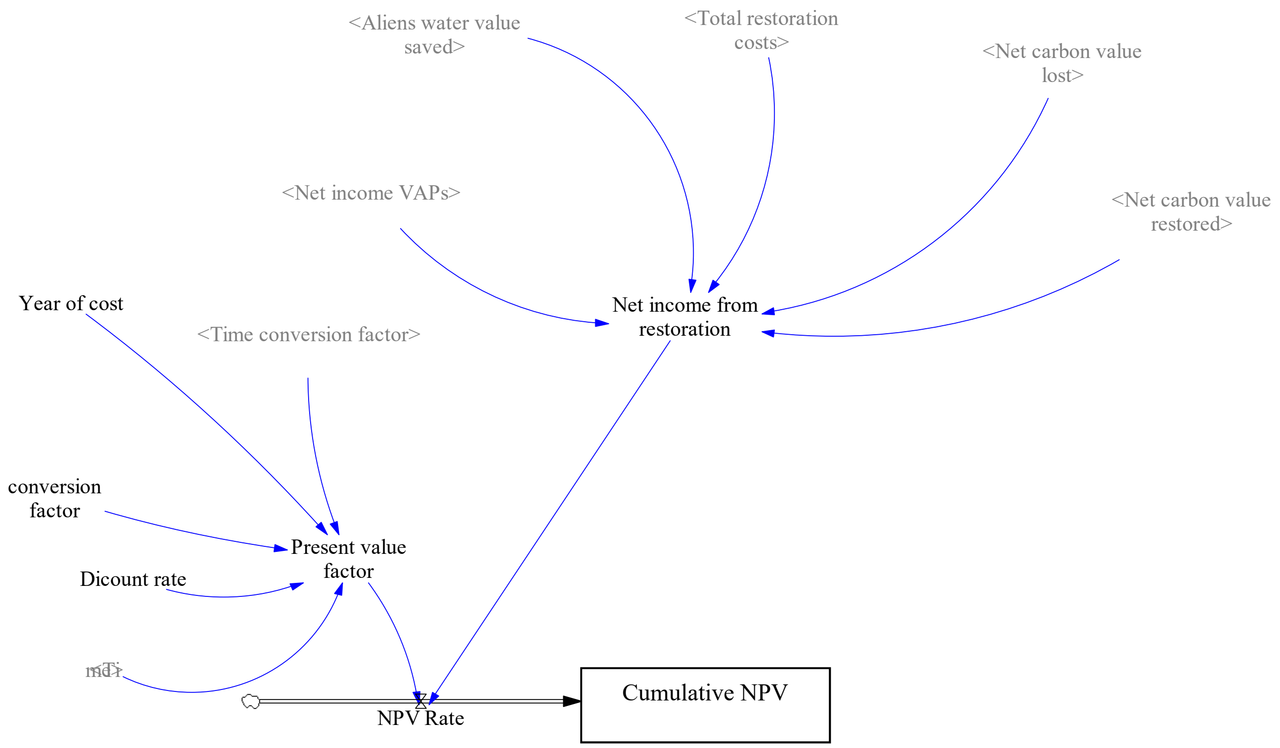

Figure 9: Economic sub-model

3. Results and discussion

The system dynamics model developed for this study was used to compare two approaches to active restoration in the WCT project restoration sites. This study focuses on i) the water saved from the clearing initiative, ii) the carbon stock balance and iii) the total restoration costs. To assess these, three scenarios, characterised by various IAP spread rates and clearing interventions, were explored. Table 8 presents a summary of these scenarios. The scenarios include a 'do nothing' scenario (where there is no intervention from 2008 onwards), a barter scenario and a financial compensation scenario.

Table 8: Scenarios investigated

Scenario name	Clearing investment (i.e. budget)
Do nothing	No intervention in restoration sites
FinComp	Active restoration with financial compensation for seedlings
Barter	Active restoration with good bartering for seedlings

The model estimates the value of water saved from clearing IAPs. This is estimated as water is reduced due to invasion, which was used to quantify water saved through clearance. Owing to the fact that it is the same areas that are cleared and restored, with only the policy variable changing, the model found minor differences in the water value saved between the financial compensation model and the barter model. The mean value of water lost to invasion is -R2 929 992.14, -R2 920 412.76 and -R7 172 225.23 over a period of 30 years for the barter, the financial compensation and the 'do nothing' scenarios respectively. The net income from VAPs (wattle and eucalyptus) was estimated to be a mean of R794 117.44 and R797 742.20 over 30 years for the barter and financial compensation scenarios respectively. Table 9 below shows the main findings of the model.

While the results highlight the value of water saved as a result of clearance, they also quantify the impacts of IAPs on water resources, which allows for more informed decision making. The value of water saved forms the highest portion of the net income from restoration. The net income also includes the VAPs and the carbon restored. This study did not investigate the impact of re-investment in restoration through a co-finance option. However, several studies (Mudavanhu *et al*. 2016; Nkambule *et al*. 2016; Vundla *et al*. 2016) have investigated this and found that a co-finance option would increase the rate of restoration and, ultimately, the NPV of restoration initiatives. In the study areas considered here, the majority of the IAPs, such as *Lantana camara*, do not have sufficient biomass to be viable for VAPs, driving up the restoration costs and lowering the economic returns.

Table 9: Summary of model findings

Variable	Units	FinComp	Do nothing	Barter
Water saved	R/year	-2 920 412.76	-7 172 225.23	-2 929 992.14
Net income VAP	R/year	797 742.20	0	794 117.44
Net carbon value lost	R/year	157 832,40	-252 907,00	142 938,53
Net carbon value restored	R/year	1 112 661,01	0	720 825.73

The developed system dynamics model estimates the value of the carbon lost due to clearing IAPs at a mean of R-428 307,05 per annum for the 'do nothing' scenario, which translates into a net carbon benefit from not clearing the IAPs. The model further estimates an average carbon loss of R407 625.76 and R410 187.71 per annum for the barter and financial compensation scenarios respectively. The model also estimates the value of carbon that is restored through active planting to be an average of R720 825.73 and R1 112 661.01 for the barter and the financial compensation scenarios respectively.

There is a growing concern regarding methods to reduce the effect of global warming (Noble *et al*. 2000). As plants are known carbon sinks because of carbon fixing during photosynthesis, attempts to increase carbon sinks are made through the use of terrestrial vegetation (Noble *et al*. 2000; Stoffberg *et al*. 2010). Noble *et al*. (2000) define carbon sinks as a process that removes CO_2 from the atmosphere. This study shows that, at the rate at which indigenous vegetation is planted, the carbon stock that would be lost due to clearing will be offset by the planting of indigenous vegetation. The WCT reforestation projects clearly show that actively planting indigenous vegetation would increase the economic returns. These carbon estimates, however, are an underestimation, as the growth rate has not been considered. According to Nowak *et al*. (2002), there are several factors that affect carbon sequestered and stored, including growth rate, tree species, size at maturity, and life span. These have not been considered for this study. Future studies looking into the estimation of carbon sequestration rates of both indigenous and IAP species should take these factors into consideration.

The main aim of this study was to compare the costs and benefits of two restoration approaches, namely a conventional nursery approach with financial compensation, and a bartering approach whereby consumer goods are exchanged for services provided. We therefore compared the restoration costs per site, and also in total, for these two approaches. There are very small differences in the restoration costs at three of the four sites (Figure 10, see a, c & d). Yet, small as the difference may be, for the RBCF site, for example, the difference adds up to R47 990.75 per year, as shown in Table 10. A greater difference is found at the Tongaat site, where the financial compensation approach is almost three times more than the barter approach. However, when compared to the other three sites, the Tongaat study area has much lower restoration costs. The smaller scale of the Tongaat project might be the main reason for this difference. The impact of scale warrants further investigation.

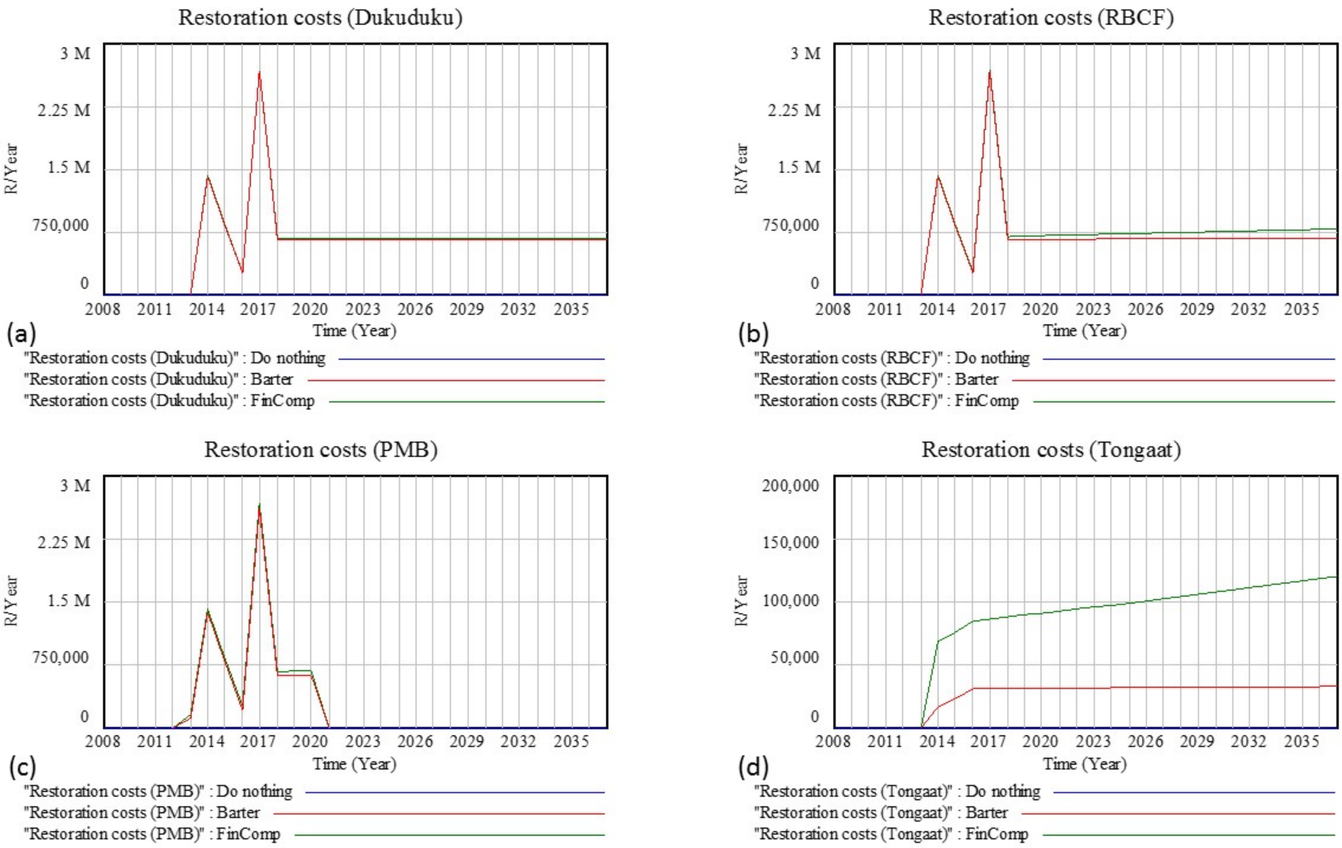

Figure 10: The restoration costs for Dukuduku (a), Tongaat (b), Umsunduzi (c), and the Richard Bay coastal forest (d)

The mean overall restoration costs for all four sites is R2 174 980.17 and R2 387 935.83 for the barter approach and financial compensation approach respectively. The temporal trend of the total costs is shown in Figure 11. A summary of the costs and savings is provided in Table 10.

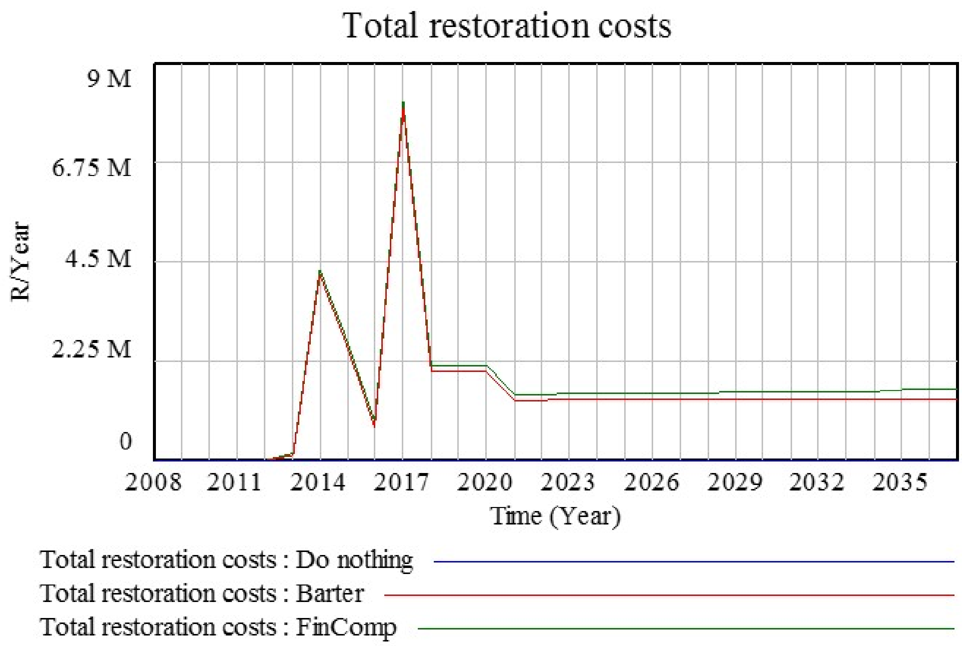

Figure 11: Total restoration costs across all the projects sites

Table 10: Summary of restoration costs an annual savings

Project name	**Mean restoration cost (R/year) (Barter)**	**Mean restoration costs (R/year) (Financial compensation)**	**Annual savings with barter system (R/year)**
Dukuduku dune forest	616 007.93	624 878.33	8 870.4
Tongaat	24 375.20	79 355.31	54 980.10
Umsunduzi (PMB)	232 224.3.	244 603.74	12 379,40
RBCF	619 938.80	667 929,55	47 990.75
Total	1 492 546.29	1 616 766.93	124 220.64

The annual savings with the barter approach do not translate into a higher cumulative NPV and higher net income from restoration, as seen in Figure 12. The higher NPV for the financial compensation approach improves the financial attractiveness of this approach compared to the barter approach.

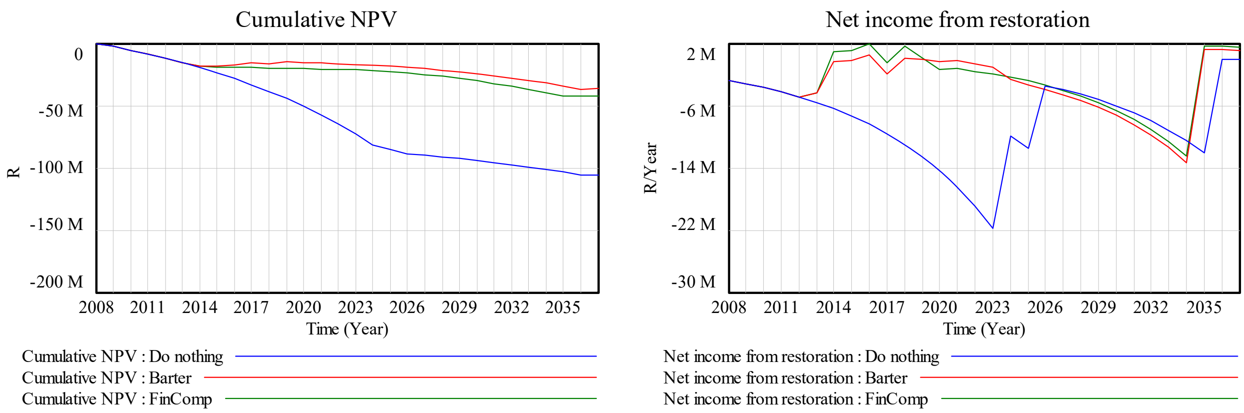

Figure 12: The cumulative NPV (a) of the restoration financing approach and (b) the net income from restoration

4. Conclusion

The restoration of natural capital through afforestation and clearing adds significant economic value to the restored natural environment. There are several benefits that economists are yet to fully valuate. However, the variables that are quantifiable provide significant cause for investment in the restoration of natural capital. In addition, current restoration programmes not only offer the conservation of natural capital, but also significant socio-economic benefits associated with the restoration of natural capital, such as job creation. Investing in the restoration of forest natural capital opens up opportunities for forest-related products. In particular, non-timber forest products (NTFPs) have been found to play a crucial role in many rural livelihoods. Mugido (2016) further states that NTFPs have a major influence in the fight against the impact of poverty on rural communities.

The main finding of this study shows that, with small-scale clearance, the value of water saved through clearing operations is significant. In addition, the benefits of active restoration are significant in the realisation of the full economic returns of restoration. This is evident from the carbon value that is added as a result of active restoration. Active planting of indigenous vegetation facilitates forest regeneration. There is also a great social benefit, which this study has not quantified, derived from the barter approach. The social impact of the barter approach is far greater than that of the financial compensation approach. Further investigations can be done to quantify the direct and indirect social benefits of the barter approach, particularly in rural areas.

Afforestation projects, such as the WCT project, are costly, and thus there is also always a need to investigate the options available to decision makers to reduce the costs of control. The barter approach is shown to reduce the costs of restoration; however, the extent of this reduction is site specific. The findings of this study suggest that there is greater value in the barter approach to smaller restoration projects compared to the financial compensation approach, with the mean saving being estimated at R124 220.64 per annum, although this does not translate into a higher NPV for this approach. From a cost perspective, and excluding the social benefit of the barter approach, the barter approach would be preferable. However, the economic evaluation in this study shows that the financial compensation approach would yield higher economic returns when compared to the barter approach. Thus, this study recommends more investment in active restoration to be directed towards barter compensation, rather than financial compensation, with a stronger motivation in rural small-scale initiatives.

Acknowledgements

The authors would like to extend their gratitude to the Department of Environmental Affairs (DEA) and the Working for Water programme, for funding this research; and to the Wildlands Conservation Trust, for the provision of the necessary IAP data. A special thanks is given to SAEON, for housing the research team.

References

Appadurai A, 1986. The social life of things: Commodities in cultural perspective. Cambridge: Cambridge University Press.

Argumedo A & Pimbert M, 2010. Bypassing globalization: Barter markets as a new indigenous economy in Peru. Development 53(3): 343–9.

Aronson J, Clewell AF, Blignaut JN & Milton SJ, 2006. Ecological restoration: A new frontier for nature conservation and economics. Journal for Nature Conservation 14: 135–9.

Automobile Association (AA), 2016. Rates calculator. Retrieved from https://www.aa.co.za/on-the-road/calculator-tools/rates-calculator/ (Accessed 15 January 2017).

Benayas JMR, Bullock JM & Newton AC, 2008. Creating woodland islets to reconcile ecological restoration, conservation, and agricultural land use. Frontiers in Ecology and the Environment 6: 329–36.

Cellarius A, 2000. "You can buy almost anything with potatoes": An examination of barter during economic crisis in Bulgaria. Ethnology 1: 73–92.

Clewell AF & Aronson J, 2006. Motivations for the restoration of ecosystems. Conservation Biology 20: 420–8.

De Groot RS, Alkemade R, Braat L, Hein L & Willemen L, 2010. Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecological Complexity 7: 260–72.

De Wit M, Crookes D & Van Wilgen B, 2001. Conflicts of interest in environmental management: Estimating the costs and benefits of a tree invasion. Biological Invasions 3: 167–78.

Dlamini CS, 2007. Towards the improvement of policy and strategy development for the sustainable management of non-timber forest products: Swaziland: A case study. Stellenbosch, University of Stellenbosch.

Dlamini CS & Geldenhuys CJ, 2011. The potential impacts of national, regional and international policies and legislation on the sustainable forest management for NTFPs: A Swaziland case study. Journal of Agricultural Science and Technology B1: 297–310.

Elmqvist T, Setälä H, Handel SN, Van der Ploeg S, Aronson J, Blignaut JN, Gómez-Baggethun E, Nowak DJ, Kronenberg J & De Groot R, 2015. Benefits of restoring ecosystem services in urban areas. Current Opinion in Environmental Sustainability 14: 101–8.

Gaertner M, Nottebrock H, Fourie H, Privett SD & Richardson DM, 2012. Plant invasions, restoration, and economics: Perspectives from South African fynbos. Perspectives in Plant Ecology, Evolution and Systematics 14: 341–53.

Holl KD & Howarth RB, 2000. Paying for restoration. Restoration Ecology 8: 260–7.

Kotzé I, Beukes H, Van den Berg E & Newby T. 2010. National invasive alien plant survey. Report No. GW/A/2010/21, Agricultural Research Council, Institute for Soil, Climate and Water, Stellenbosch, South Africa.

Leishman MR, Thomson VP & Cooke J, 2010. Native and exotic invasive plants have fundamentally similar carbon capture strategies. Journal of Ecology 98: 28–42.

Le Maitre DC, Gaertner M, Marchante E, Ens EJ, Holmes PM, Pauchard A, O'Farrell PJ, Rogers AM, Blanchard R & Blignaut JN, 2011. Impacts of invasive Australian acacias: Implications for management and restoration. Diversity and Distributions 17: 1015–29.

Le Maitre DC, Gush M & Dzikiti S, 2015. Impacts of invading alien plant species on water flows at stand and catchment scales. AoB Plants 7: plv043.

Milton SJ, Dean WRJ & Richardson DM, 2003. Economic incentives for restoring natural capital in southern African rangelands. Frontiers in Ecology and the Environment 1: 247–54.

Mudavanhu S, Blignaut JN, Nkambule N, Morokong T & Vundla T, 2016. A cost-benefit analysis of using Rooikrans as biomass feedstock for electricity generation: A case study of the De Hoop nature reserve, South Africa. South African Journal of Economic and Management Sciences 19: 788–813.

Mugido W, 2016. The contribution of non-timber forest products to rural livelihoods and their price determination in different agro-ecological zones of South Africa. PhD thesis, Rhodes University, Grahamstown. South Africa.

Mugido W, Blignaut JN, Joubert M, De Wet J, Knipe A, Joubert S, Cobbing B, Jansen J, Le Maitre D & Van der Vyfer M, 2014. Determining the feasibility of harvesting invasive alien plant species for energy. South African Journal of Science 110: 1–6.

National Treasury, 2013. Carbon tax policy paper: Reducing greenhouse gas emissions and facilitating the transition to a green economy. Pretoria: National Treasury.

Nkambule NP, Blignaut JN, Vundla TS, Mudavanhu S & Morokong T, 2016. The society-wide costs and benefits of invasive alien plants in Northern Zululand. Unpublished manuscript.

Noble I, Bolin B, Ravindranath N, Verardo D & Dokken D, 2000. Land use, land□use change, and forestry. Cambridge: Cambridge University Press.
Nowak DJ, Stevens JC, Sisinni SM & Luley CJ, 2002. Effects of urban tree management and species selection on atmospheric carbon dioxide. Journal of Arboriculture, 28: 113–22.
Protabase, 2016. Species database. Retrieved from https://www.prota4u.org/database/ (Accessed 30 August 2017).
Stoffberg GH, Van Rooyen M, Van der Linde M & Groeneveld H, 2010. Carbon sequestration estimates of indigenous street trees in the City of Tshwane, South Africa. Urban Forestry & Urban Greening 9: 9–14.
Van Kooten GC & Sohngen B, 2007. Economics of forest ecosystem carbon sinks: A review. International Review of Environmental and Resource Economics 1: 237–69.
Van Wilgen BW & Le Maitre DC, 2013. Rates of spread in invasive alien plants in South Africa. Stellenbosch: Council for Scientific and Industrial Research.
Ventana Systems, 2007. Vensim user's guide Version 5. Boston: Ventana Systems, Inc.
Vundla T, Blignaut JN, Nkambule N, Morokong T & Mudavanhu S, 2016. The opportunity cost of not utilising the woody invasive alien plant species in the Kouga, Krom and Baviaans catchments in South Africa. South African Journal of Economic and Management Sciences 19: 814–30.
Wildlands Conservation Trust (WCT), 2016. Database for reforestation project. Hilton: Wildlands Conservation Trust.
Williams CC, 1996. The new barter economy: An appraisal of local exchange and trading systems (LETS). Journal of Public Policy 16: 85–101.

Appendix A: Model equations

Description	Formula/value	Unit
Nursery transport costs	(Distance to restoration sites*Unit cost of transport cost/TIME STEP)*Annual trips	R/year
Seedling costs	Price per plant*Unit plants planted*ZIDZ(Area restored (Dukuduku), Time)	R/year
Costs for plant cost	Good value per plant*Unit plants planted*ZIDZ(Area restored (Dukuduku), Time)	R/year
Nursery costs	(Seedling costs+Nursery transport costs)*Nursery policy variable	R/year
Bartering costs	(Transport costs+Plants cost)*Bartering policy variable	R/year
Cost of plants	Bartering costs+Nursery costs	R/year
Policy adjusted budget (Dukuduku)	Costs of plants+(wildlands budget(Time/Time conversion factor))	R/year
Effect of budget on person days	Coefficient of person days to budget 1st component*Policy adjusted budget (Dukuduku)	PD/year
Person days	Effect of budget on person days-443.51	PD/year
Alien regrowth *Melia* spp.	Extent of invasion *Melia* spp.*spread rates *Melia* spp.	Ha/year
Melia spp. clearance (Dukuduku)	MIN((effect of person days on area restored+ 5.3431)*proportion of area *Melia* spp., Extent of invasion *Melia* spp./TIME STEP)	Ha/year
Alien regrowth *Chromolaena* (Dukuduku)	Extent of invasion *Chromolaena**spread rates *Chromolaena*	Ha/year
Chromolaena clearance (Dukuduku)	MIN((effect of person days on area restored+ 5.3431)*proportion of area *Chromolaena*, Extent of invasion *Chromolaena*/TIME STEP)	Ha/year
Alien regrowth Guava (Dukuduku)	Extent of invasion Guava*spread rates Guava	Ha/year
Alien regrowth Eucalyptus (Dukuduku)	Extent of invasion Eucalyptus*spread rates Eucalyptus	Ha/year
Eucalyptus clearance (Dukuduku)	MIN((effect of person days on area restored+ 5.3431)*proportion of area Eucalyptus, Extent of invasion Eucalyptus/TIME STEP)	Ha/year
Eucalyptus clearance (Dukuduku)	MIN((effect of person days on area restored+ 5.3431)*proportion of area Eucalyptus, Extent of invasion Eucalyptus/TIME STEP)	Ha/year
Rate of restoration (Dukuduku)	MIN((effect of person days on area restored+ 5.3431)*Proportion restored, Maximum restoration*Proportion restored)	Ha/year
Annual restoration (Dukuduku)	*Chromolaena* clearance (Dukuduku)+Clearance Guava (Dukuduku)+Eucalyptus clearance (Dukuduku)+*Melia* spp. clearance (Dukuduku)+Rate of restoration (Dukuduku)	Ha/year
Maximum restoration	MAX(((Area restored (Dukuduku)-Maximum area restored)/TIME STEP), 4167.09)	Ha/year
Unit costs of restoration (Dukuduku)	(Policy adjusted budget (Dukuduku)/(Annual restoration (Dukuduku)))	R/ha
Restoration costs (Dukuduku)	Annual restoration (Dukuduku)*Unit costs of restoration (Dukuduku)	R/year
Unit costs of restoration (RBCF)	(Policy adjusted budget (RBCF)/(Annual restoration (RBCF)))	R/ha
Restoration costs (RBCF)	Annual restoration (RBCF)*Unit costs of restoration (RBCF)	R/year
Unit costs of restoration (PMB)	(Policy adjusted budget (PMB)/(Annual restoration (PMB)))	R/ha
Restoration costs (PMB)	Annual restoration (PMB)*Unit costs of restoration (PMB)	R/year
Unit costs of restoration (Tongaat)	(Policy adjusted budget (Tongaat)/(Annual restoration (Tongaat)))	R/ha
Total restoration costs	Restoration costs (Dukuduku)+Restoration costs (PMB)+Restoration costs (RBCF)+Restoration costs (Tongaat)	R/year
Water use *Chromolaena odorata*	Water reduction per ha *Chromolaena odorata**(*Chromolaena* clearance (Dukuduku)+*Chromolaena* clearance (RBCF)+*Chromolaena* clearance (Tongaat))	m^3/year
Water use wattle species	Water reduction per ha Wattle species*(Clearance Wattle (PMB)+Clearance Wattle spp. (Tongaat))	m^3/year
Water use other species	Water reduction per ha other species*Other clearance (PMB)	m^3/year
Water use Guava	Clearance Guava (Dukuduku)*Water reduction per ha Guava	m^3/year
Water use *Cereus jamacaru*	*Cereus jamacaru* clearance (PMB)*Water reduction per ha *Cereus jamacaru*	m^3/year

Water use *Solanum mauritianum*	Water reduction per ha *Solanum mauritianum**(Clearance *Solanum mauritianum* (Tongaat)+Clearance *Solanum mauritianum* (PMB))	m^3/year
Water use Agave species	Water reduction per ha *Melia* species**Melia* spp. clearance (Dukuduku)	m^3/year
Water use Eucalyptus species	Water reduction per ha Eucalyptus species*Grand Eucalyptus clearance	m^3/year
Aliens' water consumption	Water use *Chromolaena odorata*+Water use Eucalyptus species+Water use Wattle species+Water use other species+Water use Agave species+Water use *Lantana camara*+Water use *Cereus Jamacaru*+Water use Guava+Water use *Solanum mauritianum*	m^3/year
Aliens' water value saved	Unit value of water 0*Aliens' water consumption	R/year
Grand Eucalyptus clearance	Eucalyptus clearance (Dukuduku)+Eucalyptus clearance (PMB)+Eucalyptus clearance (Tongaat)	Ha/year
Utilisable biomass Eucalyptus species	Biomass per Eucalyptus spp.*Grand Eucalyptus clearance	Ton/year
Timber	(Utilisable biomass Eucalyptus species*Proportion of Eucalyptus species to timber*Biomass conversion ratio into timber*Losses)+(Utilisable biomass Wattle species*Proportion of Wattle species to timber*Biomass conversion ratio into timber*Losses)	Ton/year
Utilisable biomass Wattle species	Biomass per ha Wattle species*(Clearance Wattle (PMB)+Clearance Wattle spp. (Tongaat))	Ton/year
Charcoal	(Utilisable biomass Wattle species*Proportion of Wattle species to charcoal*Biomass conversion ratio into charcoal*Losses)+(Utilisable biomass Eucalyptus species*Proportion of Eucalyptus species to charcoal*Biomass conversion ratio into charcoal*Losses)	Ton/year
Total revenue timber	Timber*Timber price	R/year
Net income VAPs	(Total revenue charcoal+Total revenue timber)*Profit margin ratio	R/year
Total revenue charcoal	Charcoal*Charcoal price	R/year
Sequestrated carbon *Solanum mauritianum*	*Solanum mauritianum* biomass*(Clearance *Solanum mauritianum* (PMB)+ Clearance *Solanum mauritianum* (Tongaat))*Percent carbon 0*C:CO2 ratio	Ton/year
Sequestrated carbon Guava species	Guava species biomass*Clearance Guava (Dukuduku)*Percent carbon 0*C:CO2 ratio	Ton/year
Sequestrated carbon Agave species	Guava species biomass*Clearance Guava (Dukuduku)*Percent carbon 0*C:CO2 ratio	Ton/year
Sequestrated carbon Eucalyptus species	Eucalyptus species biomass*Grand Eucalyptus clearance*Percent carbon 0*C:CO2 ratio	Ton/year
Sequestrated carbon *Chromolaena odorata*	*Chromolaena odorata* biomass*(Chromolaena clearance (Dukuduku)+ *Chromolaena* clearance (RBCF)+*Chromolaena* clearance (Tongaat))* Percent carbon 0*C:CO2 ratio	Ton/year
Sequestrated carbon *Lantana camara*	*Lantana camara* biomass**Lanatana camara* (PMB)clearance*Percent carbon 0*C:CO2 ratio	Ton/year
Sequestrated carbon Wattle species	Wattle species biomass*(Clearance Wattle (PMB)+Clearance Wattle spp. (Tongaat))*Percent carbon 0*C:CO2 ratio	Ton/year
Sequestrated carbon *Cereus jamacaru*	*Cereus jamacaru* biomass**Cereus jamacaru* clearance (PMB)*Percent carbon 0*C:CO2 ratio	Ton/year
Sequestrated carbon *Melia* spp.	*Melia* spp. biomass**Melia* spp. clearance (Dukuduku)*Percent carbon 0*C:CO2 ratio	Ton/year
Net carbon stock removed	(Sequestrated carbon Agave species+Sequestered carbon *Chromolaena odorata*+Sequestered carbon Eucalyptus species+Sequestered carbon *Lantana camara*+Sequestered carbon other species+Sequestered carbon *Solanum mauritianum*+Sequestered carbon Wattle species+Sequestered carbon *Melia* spp.+Sequestered carbon *Solanum mauritianum*+ Sequestrated carbon *Cereus jamacaru*)*A factor correcting for net carbon	Ton/year
Net carbon value lost	Unit price of carbon 0*Net carbon stock removed	R/year
Grand rate of restoration	Rate of restoration (Dukuduku)+Rate of restoration (PMB)+Rate of restoration (RBCF)+Rate of restoration (Tongaat)	Ha/year
Sequestrated carbon (restored)	Plant Biomass*Grand rate of restoration*Percent carbon 0*C:CO2 ratio.	Ton/year
Net carbon stock restored	Sequestrated carbon (restored)*A factor correcting for net carbon	Ton/year
Net carbon value restored	Net carbon stock restored*Unit price of carbon 0	R/year

Net income from restoration	(Net income VAPs+Aliens' water value saved+Net carbon value restored)-(Total restoration costs+Net carbon value lost)	R/year
Present value factor	((Conversion factor+Discount rate)^Year of cost(Time/time conversion factor))	Dmnl
NPV rate	Net income from restoration/Present value factor	R/year