COSTS AND BENEFITS OF ERADICATING ALIEN INVASIVE VEGETATION FROM THE UPPER REACHES OF THE MHLATUZE CATCHMENT

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Submitted in partial fulfillment of the
requirements for the degree of
Master of Social Science (Economics)
in the
School of Business
University of Natal

Pietermaritzburg
December 2001

PREFACE

The work described in this thesis was carried out in Kwa-Zulu Natal during the period January 2000 to December 2001, under the supervision of Jessica Schroenn of the School of Business, University of Natal, Pietermaritzburg campus.

The thesis represents original work by the author and has not been submitted in any form, in part or in whole, to any other University. Where use has been made of the work of others, it has been duly acknowledged in the text.

ACKNOWLEDGEMENTS

I wish to express my appreciation and thanks to the following persons:

- To my supervisor, Ms Jessica Schroenn, for her continued assistance, encouragement, interest and guidance throughout the duration of my research project. I am greatly indebted to Jessica for her general enthusiasm towards the project and academic leadership.
- To my co-supervisor, Dr Nevil Quinn, for his advice and assistance in the funding of my trips to the Mhlatuze River Catchment.
- To Dr Tennassie Nichola and Mr John Banach for their support and invaluable comments during my study.
- To all the private farmers and other stakeholders who were interviewed and who showed an interest in this project. Without their co-operation this study would not have been possible.
- To Mr Brian and Mrs Phyllis Aitken for their kind hospitality whilst I was conducting interviews in the Melmoth Region.
- To Mr James Wood, Dr Martin de Wit and Mr David Le Maitre for their interest and continued assistance during this study.
- To Mr Ben and Mrs Joan Pretorius for their consistent support and encouragement as well as hospitality.
- To my parents for their unconditional pride and belief in me throughout the duration of my studies.

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ACRONYMS

BHN	Basic Human Needs
BCR	Benefit-Cost Ratio
CBA	Cost Benefit Analysis
CSIR	Council for Scientific and Industrial Research
CTC	Central Timber Co-operative
CV	Compensating Variation
CVM	Contingent Valuation Method
DWAF	Department of Water Affairs and Forestry
GGP	Gross Geographic Product
HPM	Hedonic Pricing Method
IRR	Internal Rate of Return
KZN	KwaZulu-Natal Province
MPC	Marginal Private Costs
MSB	Marginal Social Benefits
MSC	Marginal Social Costs
NPV	Net Present Value
NWA	National Water Act (36 of 1998)
PPRI	Plant Protection Research Institute
PV	Present Value
RBM	Richards Bay Minerals
RDP	Reconstruction and Development Programme
SDI	Spatial Development Initiative
SEA	Strategic Environmental Assessment
SFRA	Streamflow Reduction Activity
TCM	Travel Cost Method
TFC	Total Fixed Costs
TVC	Total Variable Costs
WTA	Willingness to accept
WTP	Willingness to pay
WFW	Working for Water

EXECUTIVE SUMMARY

Alien invasive vegetation threatens the functioning of natural ecosystems as well as their services, which sustain human welfare, both directly and indirectly. The proliferation of this vegetation in South Africa has been attributed to the ignorance of the social implications affiliated to their existence. Investment decisions are predominantly based on the marginal private costs of an activity, since individuals have not been made accountable for costs imposed on society in the past. Consequently, their marginal private costs always fall well short of the marginal social costs. In order to promote sustainable development as well as curtail widespread invasion by alien plants in South Africa, it is essential to close the gap between these costs and support research aimed at ascertaining monetary values for non-market goods, such as biodiversity.

This study scrutinizes the economic viability of alien plant eradication in the Mhlatuze Catchment by comparing the costs and benefits associated with this eradication process. A series of formal in-depth interviews with major stakeholders residing in the upper reaches of the catchment were conducted in an attempt to evoke individuals' perceptions concerning alien vegetation together with the actual costs incurred in extirpating this vegetation. The contingent valuation method (CVM), which relies on surveys to elicit the maximum amount respondents would be willing to pay to obtain or retain some non-market good, was employed to glean monetary values for benefits such as biodiversity and augmented streamflow.

The findings suggest that there is a positive net effect associated with alien vegetation extirpation in the Mhlatuze Catchment, since the social benefits outweigh the costs. Given the temporal and financial constraints that prevailed, it was only possible to examine some of the benefits affiliated to this process, such as increased timber harvesting, streamflow, biodiversity and reduced fire hazard. Consequently, this analysis represents a minimum estimate of the benefits, further enhancing the argument in favour of extirpation. The results lend support to calls for greater policy emphasis on, as well as funds for, the eradication of alien invasive plants.

CHAPTER ONE

INTRODUCTION

Alien invasive vegetation threatens the functioning and existence of natural ecosystems in South Africa, since many of these plants have no predators or competitors, allowing them to dominate the ecosystem which they inhabit. This can result in the extinction of indigenous species and hence, the loss of genetic information which has irreversible implications for human welfare. This represents a global cost that is borne by society.

The rapid proliferation of alien vegetation, which is ascribed to the increase in afforestation and changes in land use, has had significant adverse impacts on water resources, biodiversity and the stability as well as integrity of these ecosystems. Thus, on the one hand timber species have a commercial value, whilst on the other, these species are invasive and have a damaging ability. This gives rise to a conflict of interests where the benefits accrue to a number of individuals, while society at large bears the external costs (de Wit and Crookes, 2000:3). In order to resolve this conflict it is necessary to firstly, establish the different ecosystem goods and services which will be obliterated by these invasive alien species and secondly, to analyse the costs as well as the benefits affiliated to this vegetation.

The Mhlatuze River Catchment, which is considered the most severely affected tertiary catchment in KwaZulu-Natal in terms of alien vegetation infestation, was selected for purposes of this research project. Many of the stakeholders residing in this catchment have shown apathy towards alien plant eradication, which requires investigation. Consequently, an economic analysis of the eradication and management of invasive alien vegetation in the upper reaches of this catchment is undertaken in this study.

The objective of this dissertation is thus to employ appropriate economic analysis in order to achieve a greater comprehension of the costs and benefits affiliated to alien plant eradication and to arrive at a possible explanation for the apathy towards clearing alien invasive vegetation which prevails in the Mhlatuze Catchment.

Although this analysis has been conducted in a small area, its findings can be extended to regional, national or even global situations. At the very least, such an analysis offers insight into the economic viability of alien plant eradication and ascertains whether or not this eradication is beneficial to both landowners and the broader society.

1.1 Outline of dissertation

Chapter two outlines the economic theory underlying the cost-benefit analysis (CBA) process as well as potential sources of inefficiency and market failure. This is essential in order to uncover the economic rationale for the differential attitudes towards eradicating alien vegetation.

Chapter three comprises the literature review and critically examines the CBA procedure, as well as assessing the importance of assigning monetary values to environmental goods and services and considering the main techniques whereby such values may be imputed.

Chapter four provides a background to the study area and defines the physical, economic and social characteristics associated with the Mhlatuze Catchment. Furthermore, the problems associated with alien plants and the benefits of removing these plants, are contextualised in this chapter. This is necessary firstly, to familiarise oneself with the area and secondly, to clarify the issues at stake. Based on these findings it was possible to adopt appropriate methods to assess the impacts of alien plant eradication.

Chapter five presents the research methods employed for purposes of this study as well as the limitations which were encountered. Much time was dedicated to this phase of the project, since it is evident that one's findings are highly dependent on the selection of methods.

Chapter six summarises the findings of the project and, where possible, appraises the costs incurred and benefits received by individuals in removing alien vegetation. In this chapter an evaluation of the economic efficiency of eradicating alien invasive vegetation is undertaken. This is done by comparing the costs to the benefits of extirpation.

Chapter seven analyses the findings presented in the previous chapter and contextualises these findings in terms of economic theory. Furthermore, the implications that these findings may have on future decision making are examined. This is the most important phase of the project. This is because recommendations concerning any future action that may be required to manage invasive alien vegetation follow from this discussion.

Chapter eight concludes the study with a succinct synopsis of the results derived and presents recommendations that should be implemented at various levels of authority.

CHAPTER TWO

THEORETICAL FRAMEWORK

2.1 Introduction

The term *cost-benefit analysis* (CBA) refers to the measurement of the economic costs and benefits associated with any change in resource allocation in the economy (Boadway and Bruce, 1984:292). The CBA, which has its foundation in welfare economics, will be employed to ascertain the welfare effects and evaluate the economic efficiency of eradicating alien vegetation in the upper reaches of the Mhlatuze River Catchment. It is evident that there is widespread apathy prevailing towards eradicating alien vegetation, and hence, in order to uncover the economic rationale for these attitudes, it is imperative to examine both the economic theory underlying project appraisals as well as any sources of inefficiency which lead to market failure.

2.2 CBA and emergence of environmental concerns

The CBA concept was first developed in the 1930s in the United States to assist government in ascertaining the welfare and economic efficiency effects of physical investment projects such as irrigation, hydroelectricity and water supply projects (Perkins, 1994:3). At the time, many of these projects were criticised, because environmental goods were not assessed in the same manner as other goods, due in large part to the lack of markets for such goods and to government's attitude towards these goods. Environmental issues were a low priority on the political agenda prior the 1970s, since the main objective of government at the time (both nationally and internationally) was to promote economic activity *per se*. Consequently, many environmental goods and services were assigned non-monetary or qualitative descriptions which were excluded from the analysis. This gave rise to the over exploitation, inadequate conservation as well as inefficient utilization of environmental goods (Panayotou, cited in Markandya and Barbier, 1992:330).

Neoclassical economics, which is based on the assumption that the economy has a natural tendency to operate at the full employment level, was the predominant paradigm in the mid-1900s and underpinned most government policies (Common, 1988:7). Given this neoclassical ideology, economists surmised that, provided the population was expanding and there was technological progress, total production and hence economic activity would increase over time. Temporary departures from such a trend were, however, to be expected.

Although economists, in general, accepted that levels of material well-being and economic activity might increase in the short-term with technological progress, some economists, such as Malthus (1798), Jevons (1865), Marshall (1890) and Pigou (1920) warned that this might not hold for all countries in the long-term, due to constraints imposed by the natural environment (Common, 1988:8). These economists emphasized that the natural environment is comprised of finite amounts of natural resources and hence, continually augmenting the flow of such resources into production could not be indefinitely sustained. Furthermore, economists suggested that escalating levels of production and consumption would augment the discharge of residuals (or waste products) into the environment and reduce its capacity to assimilate these residuals. This essentially culminates in environmental problems, such as pollution, which impairs the supply of natural resources and impedes future economic growth (Jain, 1997:151). Consequently, there was increased awareness after the mid-1900s that continuous unrestrained economic growth may severely or even catastrophically damage the life-support services of the natural environment and thereby drastically reduce the welfare of future generations (O'Riordan, 1995:58).

Increased awareness of these potential impacts as well as recognition that previous government policies had adversely affected the environment, gave rise to a revision of environmental priorities on the political agenda in many countries. In addition, techniques for assigning quantitative values to environmental goods were formulated and incorporated into project appraisal in the early 1990s. Consequently, with these recent advances in the development and application of CBA, project appraisals are now frequently employed by both the private and public sectors to assess projects with an environmental component.

2.3 Economic basis of Cost Benefit Analysis (CBA)

Economic theory, which underlies welfare economics, has been founded on the notion of a rational individual that is, a person who makes decisions on the basis of a comparison of benefits and costs (Brent, 1997:3). Thus, this theory underpins project appraisal, such as CBA and is rooted in utilitarian precepts aimed at the maximisation of social welfare (Joubert *et al.*, 1997:124). Social preference is interpreted as the aggregation of individual preferences and is measured according to the Pareto criterion.

The Pareto 'unanimity' criterion was one of the first yardsticks employed by economists to ascertain the welfare effects of a change in resource allocation. It states that a proposed project is socially beneficial if and only if it increases the welfare of at least one individual and leaves no single individual with reduced welfare (Pearce and Nash, 1981:2). It is apparent that this principle is extremely restrictive in terms of its application to real-life scenarios, since if projects could only be implemented if they were expected to result in an **actual** Pareto welfare improvement, very few, if any, would in practice be approved (Perkins, 1994:50). To overcome this problem, Hicks and Kaldor (1939) developed the concept of a **potential** Pareto improvement, or the compensation principle. This principle states that a given change in the allocation of resources will potentially improve welfare if those who benefit could in theory fully compensate those who lose, and still be better off themselves. Thus, a project that fulfills the compensation criterion may not necessarily result in an **actual** Pareto welfare improvement, but only in a **potential** improvement (Perkins, 1994:50), because it is clear that the compensation principle only requires the potential for compensation to exist.

The Hicks-Kaldor criterion is central to the theoretical justification of CBA in welfare economics and provides the rationale for selecting projects whose benefits outweigh their costs, even if those individuals who gain from a project are not the same as those who pay for it (Perkins, 1994:50). Thus, CBA is purely concerned with the economic efficiency of a project and whether or not this increases social welfare. Consequently, it is necessary to examine the requirements for economic efficiency.

2.4 Requirements for efficiency

The economic concept of efficiency, also termed Pareto-efficiency, is an 'ideal state' attained when all potential gains from trade in all sectors of a (perfect) economy are exhausted (Randall, 1987:153). A society is said to be economically efficient in its use of resources when the total net benefit from this use is maximised by that allocation and it is impossible to improve an individual's welfare without reducing the welfare of another (Tietenberg, 1992:21). Economic efficiency is measured without regard to whom the benefits and costs accrue and irrespective of whether society considers the prevailing distribution of income to be desirable (i.e. the equity effects associated with a particular project are ignored).

Economic efficiency is an important criterion which is used to judge the performance of markets and is useful in deciding between alternative projects. The accomplishment of economic efficiency is dependent on the fulfillment of certain conditions (to be discussed below) which are marginal conditions for efficient trade that will only be attained if an efficient property rights regime is in place (Randall, 1987:153). Consequently, it is imperative to examine both the conditions underlying Pareto-efficiency and the characteristics of an efficient property rights regime.

2.4.1 Conditions underlying Pareto-efficiency

A Pareto optimal or Pareto-efficient resource allocation is characterised by a series of conditions referred to as the Pareto optimality or efficiency conditions. The following conditions have been proposed by Randall, 1987:109: *efficient resource allocation, efficient product mix, efficiency in consumption* and *the coordination of production and consumption decisions*. Provided these conditions are adhered to, economies will operate efficiently, that is, resources will be allocated efficiently to the desired activities as indicated in the marketplace. In such a situation it will be possible to augment economic activity without inducing environmental problems.

1. *Efficient resource allocation*

A market economy will produce efficiently if factors of production like labour and materials, are allocated in such a way, that it is not possible to reallocate the factor inputs so as to increase production of one good without necessarily reducing the production of some other good (Boadway and Bruce, 1984:12). This occurs when the marginal rate of technical substitution of any pair of factor inputs is equal for all firms in the production of all commodities that use these factors and is equivalent to the ratio of prices of the factor inputs for all firms (Randall, 1987:109). Assuming two outputs (pastures and fruit) and two inputs (labour and water) this principle can be expressed in the following way:

$$(RTS_{W,L})_P = (RTS_{W,L})_F = \frac{P_W}{P_L}$$

where P = pastures

F = fruit

L = labour

W = water

2. *Efficient product mix*

An efficient product mix will occur when the rate of product transformation (i.e. the marginal rate at which one commodity must be sacrificed in order to increase output of the other commodity) of any two commodities is equal for every producing firm and is equal to the ratio of commodity prices. That is:

$$(RPT_{F,P})firm1=(RPT_{F,P})firm2 = \frac{P_F}{P_P}$$

3. *Efficiency in consumption*

Efficiency in consumption will occur when the rate of commodity substitution between any pair of commodities such as fruit and pastures, is equal for all consumers and is equal to the ratio of commodity prices. That is:

$$(RCS_{F,P})_1 = (RCS_{F,P})_2 = \frac{P_F}{P_P}$$

4. *Coordination of production and consumption factors*

A resource allocation will be Pareto-optimal provided there is efficiency in both production and consumption, and the two are coordinated, meaning that the production set exactly matches the consumption set. Coordination between these two activities is essential, since production is dependent on consumers' preferences (Randall, 1987:93). This coordination will result if the marginal rate of substitution between each pair of commodities is equal to the marginal rate of transformation (Boadway and Bruce, 1984:13). That is:

$$(\mathbf{RCS}_{\mathbf{P,F}})_1 = \ldots\ldots = (\mathbf{RPT}_{\mathbf{P,F}})_1 = \ldots\ldots = \frac{P_P}{P_F}$$

In the idealised world of perfect competition, the interaction of many profit-maximising producers and utility-maximising consumers gives rise to a Pareto-optimal situation. In such a world, prices reflect marginal economic costs and private and social optimums coincide (Munasinghe, 1993:1732). The existence of prices means that scarcity can be gauged through the market forces of demand and supply (Panayotou cited in Markandya and Barbier, 1992:329 and Randall, 1981:299). Only under these conditions will market prices provide a good measure of the economic value of goods and services and result in the efficient allocation of society's scarce resources (Perkins, 1994:95).

In the real world, however, distortions ascribed to monopoly practices, external economies and diseconomies or interventions in the market process through taxes, import duties and subsidies, culminate in market (or financial) prices for goods and services that do not fully reflect the marginal benefit of their consumption to society and which may diverge substantially from their true economic values or shadow prices (Munasinghe, 1993:1732). The failure of the market to efficiently price resources inevitably leads to their over-exploitation and/or inefficient utilisation. Hence, the overall efficiency conditions will be violated in the presence of such distortions and an argument can be developed for government intervention.

2.4.2 Essential attributes of an efficient property rights regime

The manner in which producers and consumers utilise environmental resources depends on the property rights regime governing these resources. Hence, it is imperative to define a property rights regime and examine the attributes which make such a regime efficient.

A property rights regime refers to a *social institution* that defines the usufructuary rights to utilise natural resources (Bromley, 1991:21). Essential characteristics of an efficient property rights regime as summarised by Tietenberg 1992:45, are as follows:

1) *Universality:* where all resources are privately owned and all entitlements completely specified. Consequently, owners of a resource have a powerful incentive to utilise that resource efficiently since an inefficient use represents a personal loss to the individual (Randall, 1987:155). Thus, it is anticipated that individuals who own land are more likely to engage in alien plant eradication than those that do not.
2) *Exclusivity:* where all benefits and costs which emanate as a result of owning and using the resources accrue to the owner, and only to the owner, either directly or indirectly by the sale to others. Thus, spillover benefits are paid for under these conditions. The distinction between private and social efficiency is relevant here.
3) *Transferability:* where all property rights are transferable from one owner to another in a voluntary exchange so that resources gravitate to the highest value uses.
4) *Enforceability:* where property rights are secure from involuntary seizure or encroachment by others.

In the idealised world where well-defined exclusive, secure, transferable and enforceable property rights over all resources exist (i.e. nonattenuated property rights) it is conceptually possible for a market economy to sustain efficient allocations (Tietenberg, 1992:47). However, in the presence of distortions such as public ownership, externalities and public goods, these attributes are unrealistic and as a result resources will be misallocated culminating in environmental degradation. This essentially implies that in the real world there are opportunities for mutual gains that are not being exploited. Consequently, it will be possible to reallocate resources and improve the welfare of at least one individual, without reducing the welfare of another (Boadway and Bruce, 1984:3). If such cases of inefficient depreciation of the environment are to be rectified, it is necessary to analyse the distortions which threaten efficiency and cause the market mechanism to fail.

2.5 Sources of inefficiency

Inefficiencies which stem from market imperfections lead to the market process emitting incorrect signals of relative scarcity and providing distorted incentives to consumers and producers. Such market failures essentially arise from three fundamental sources, namely externalities, monopolies and public goods, although these should not be considered as exhaustive or mutually exclusive (Boadway and Bruce, 1984:13). Only those sources of inefficiency that are relevant to this thesis will be discussed in further detail.

2.5.1 Presence of externalities

An externality exists where the action of one economic agent affects the utility or production possibilities of another in way that is not reflected in the marketplace (Just *et al.*, 1982:269). That is:

$$U_j = [X_{1j}, X_{2j}, \ldots\ldots\ldots\ldots X_{nj}, f(X_{mk})]; \quad j \neq k$$

where X_i ($i = 1,2 \ldots\ldots n, m$) refers to activities (i.e. beneficial or adverse), and j and k refer to individuals. This equation can be interpreted as the welfare of some individual, j, who is affected by those activities under his or her control and also by the effect, $f(X_{mk})$, of an activity, X_{mk}, that is under the control of somebody else, k (Randall, 1987:182).

For purposes of this dissertation only technological externalities will be considered. These externalities arise when one agent's activity level affects the welfare of another by causing a shift in the production function of the other agent. For example, the lack of alien plant eradication is an example of a negative externality, since this inactivity imposes costs on downstream users. These external costs are not borne by the producer of the externality, since the producer only considers his/her *private costs and benefits* (those actually incurred as a result of their actions) and not the costs or benefits that their actions have on society. Consequently, the exclusivity condition has been violated in this example and the output of downstream users will be lower than the socially optimal output level.

In the case of such a negative externality (or *external diseconomy*) it is expected that direct costs or marginal private costs (MPC) will consistently fall well short of the marginal social costs (MSC) borne by society (refer to figure 2.1). The presence of externalities therefore drives a wedge between private and social valuation of resources resulting in inefficient pricing and output levels (Mills and Graves, 1986:32). In order to correct for such a distortion and ensure the producer of an externality considers the real economic cost (i.e. the marginal social cost associated with an activity), government can impose a tax or charge on individuals who do not engage in alien plant eradication. The tax serves to internalise the external costs that upstream individuals impose on downstream users. Thus, the upstream individuals will be forced to consider not only their usual costs of production, but also the other forms of social cost that their activities (or lack of activities) entail (Baumol and Oates, 1988:22). It is worth noting that an effective tax is dependent on the information available, that is, how well-informed the government is and whether they can establish the marginal benefit and marginal cost schedules associated with eradicating alien invasive vegetation.

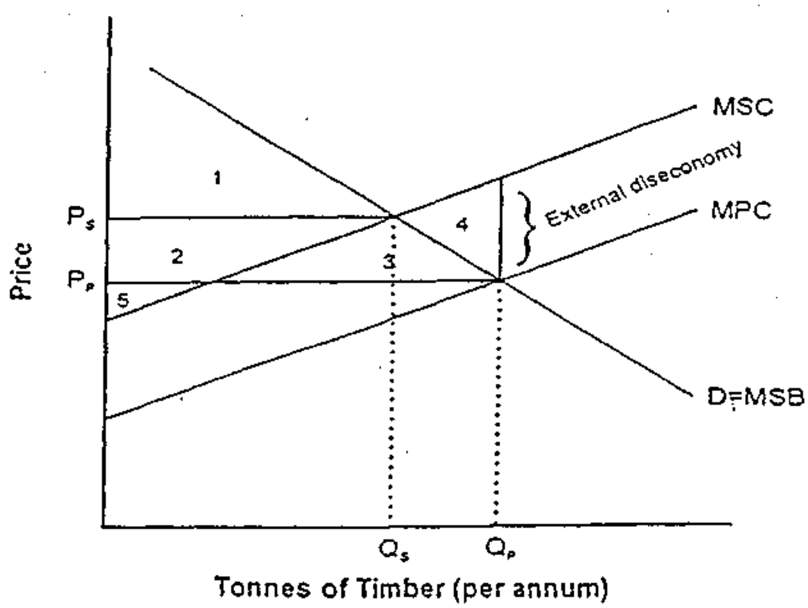

Figure 2.1: Private and social costs of invasive alien vegetation presence (adapted from Turner, 1995:323).

The above diagram depicts the output levels associated with those upstream individuals **generating** negative externalities. The social optimum output level occurs where the marginal social costs (MSC) intersects the marginal social benefits (MSB), which is at output level Q_s. In the absence of alien plant clearing, individuals (equating private costs and benefits) will produce output Q_p, which is more than the social optimum level. Therefore, instead of reducing their output and bearing the cost associated with removing alien plants, these individuals produce too much and sell this for a lower price than is socially optimal. In contrast, downstream users are forced to bear the external cost of this inaction, and produce less than the social optimum output level.

The cost of reducing the losses caused by external diseconomies is not, in the long run, always equal to the full value of the output lost. For example, it is possible that farmers can grow the same, or other, crops on land where higher quantities of water are available. Although the 'new' land may be less suitable than the old, the return to the capital and labour he employs may be much the same as before. Indeed in a highly competitive economy, he has to pay the same price for his capital and labour as before. Therefore, after some allowance has been made for the costs of movement, the loss falls on downstream owners. In the highly competitive economy, the rent of such land has to fall according to the reduction in total output suffered by the farmer in order to induce him to remain (Mishan, 1981:409). Once the output is such that, at a zero rent, the farmer does not cover his costs of production, he will relocate.

In summary, the private costs of downstream users are higher as a consequence of the externality resulting in lower output than the socially optimal output level. Therefore, downstream users need a subsidy to increase their output to the socially desirable level and compensate for increased private costs while upstream users need to be charged an alien plant tax to encourage them to reduce their output and remove this invasive vegetation.

2.5.2 Public goods

Many environmental effects fail to be recorded by market price movements, since environmental goods and services frequently display public good aspects (i.e. non-rivalry and non-exclusiveness in consumption). Non-rivalry refers to goods, such as clean air, which may be consumed by one individual without diminution of the amount effectively available to others, while non-exclusiveness refers to goods which are fully accessible to all (Randall, 1983:134). Subsequently, public goods present a particularly complex category of environmental problems.

A necessary requirement for efficiency in a competitive market economy, is that all goods must be purely 'rival', that is, the use of a unit of a good or factor by any individual precludes its use entirely by anyone else (Boadway and Bruce, 1984:118). However, in reality this requirement is often violated where goods are non-rival in consumption.

A discussion of public goods by Pearce and Nash (1981) suggests that their optimal provision requires the charging to *each consumer* of a price equal to the marginal benefit that the consumer derives from consuming the good. The marginal benefit that each consumer derives from consumption may be ascertained by eliciting a willingness to pay (WTP) for the good. However, if the good is non-excludable and is supplied in some amount x, then an individual can easily express no WTP for the good in the expectation that it will be supplied to others, including himself. This is known as the *free rider problem* in that while the individual values and utilises the resource, he is unwilling to contribute to its costs of production (Pearce and Nash, 1981:134).

Since some individuals may be willing to pay a large sum for the public good, whilst others are not, differential prices for the good may, in theory, be charged. The only requirement for charging differential prices is that the prices charged to each consumer should *amount* to the optimal market price for the public good. Although in theory this may be attainable, in practice, no such pricing mechanism exists. Rather, everyone pays the same price or because of non-excludability, no price is levied. Hence, even though exclusion of individuals from public goods such as increased biodiversity from the eradication of alien plants may be feasible by instituting a pricing scheme that excludes households who are unwilling to pay, it is economically inefficient as the marginal social cost of an extra user is zero (Boadway and Bruce, 1984:119).

In the presence of public goods, rates of commodity substitution for each individual will not equal the rate of product transformation. This can be problematic for project appraisal, because it may result in the acceptance of a project that should have been rejected or vice versa. Later chapters will show that some of the benefits of alien vegetation extirpation have 'public good' characteristics.

2.6 Conclusion

The manner in which producers and consumers engage in particular activities like alien plant clearing, and/or utilise environmental resources, is dependent on the property rights regime governing these resources. In order for a market economy to sustain efficient allocations, nonattenuated property rights over all resources must exist. However, many natural resources lie outside the domain of markets because they are unowned and unpriced. Consequently, there is an incentive for people to utilise these resources inefficiently and unsustainably, shifting their cost to others (Newson, 1992:324). Economic theory suggests that the lack of eradicating alien invasive vegetation is an externality problem that gives rise to individuals producing a higher output level than the social optimum and results in the inefficient allocation of resources. In order to correct for these distortions it is necessary for government to intervene. Either a tax should be imposed on individuals **not** currently engaged in alien plant eradication or alternatively, those that are eradicating alien plants should be subsidised in order to encourage individuals to produce at the social optimum level.

CHAPTER THREE
LITERATURE REVIEW

3.1 Introduction

CBA is a normative exercise which will be employed to establish the feasibility of alien plant eradication in the upper reaches of the Mhlatuze Catchment and will provide policy relevant conclusions, aiding, but not dictating decision-making. This chapter scrutinises the CBA procedure. It assesses the underlying importance of assigning monetary values to environmental goods and services as well as the techniques which may be employed for this purpose.

3.2 CBA Procedure

This section identifies the different phases comprising the CBA that will be adopted for purposes of this study. It is important to accentuate that the stages listed are not mutually exclusive, as there are different paths which can be followed. There are five basic elements which comprise a CBA, namely project definition and identification, enumeration of benefits and costs, aggregation of these impacts, sensitivity analysis and weighting, and the decision rule (i.e. whether to accept or reject a project). All of these will be discussed in detail below.

3.2.1 Project definition and identification

Among the basic tenets of CBA is the need to identify all costs incurred and benefits generated by a particular project. A project such as alien plant eradication gives rise to a reallocation of resources in the economy, because there is a rearrangement of demands and supplies in other markets. For example, in the case of alien plant eradication there will be an increased demand for herbicides required for clearing purposes (Boadway and Bruce, 1984:294). Both the direct and indirect impacts which flow from alien plant eradication must be incorporated into the analysis. This includes impacts that are intangible and unpriced, e.g. benefits like enhanced biodiversity which do not pass through markets. In the past, many environmental effects which failed to be recorded by market price movements, were excluded from analyses (e.g. preservation of biodiversity). Consequently, total impacts were undervalued in such analyses which would inevitably culminate in market inefficiencies. This highlights the importance of ensuring that all impacts associated with a project are identified and incorporated into the analysis even in instances where these cannot be quantified. Environmental goods and services are relevant both in carrying out the CBA of eradicating invasive alien plants as well as the resulting decision on project choice (Hanley and Spash, 1993:10). Thus, it is imperative to ensure that such effects are included and, where possible, quantified (refer to section 3.4 to review techniques which may be employed to value these goods).

3.2.2 Complete enumeration of impacts associated with the project

Traditional economic thought (i.e. conventional CBA) considered value as a 'utilitarian' concept – where items only have value because of the functions or services they provide for humans, that is **use values**. An important extension to utilitarian, or instrumental, use value which is adopted for purposes of this research project is the notion of an 'option' or **non-use value**. This recognises that individuals who do not presently use a resource may still value the option of using it in the future (O'Riordan, 1995:52). Two subdivisions exist here. Firstly, the ability to pass assets on to future generations represents a 'bequest' value. Secondly, 'existence' values refer to the value that an individual places upon the preservation of some asset which will never be used by him/herself or by future generations.

The concept of Total Economic Value (TEV) captures both use and non-use values and is employed in the evaluation of assets for this research project. In moving from utilitarian to TEV concepts of value, one is accommodating a considerable extension of people's attitudes towards the evaluation of assets. For example, utilitarian value theory is concerned only with individual gains from using a particular resource, whilst TEV recognises this as well as the notion that individuals are members of society and may have altruistic motivations (public preferences).

In essence, CBA entails measuring all project costs and benefits in such a way that they reflect the true cost to the economy of using inputs required and the true benefit to the country of the output produced (Perkins, 1994:9). In order to compare these effects it is necessary to value them in terms of a common numéraire, which for purposes of this study will be present values (this is discussed later in section 3.2.3). For those goods and services which are marketable, e.g. timber, prices can be readily derived. However, when they take forms which are not easily measured in the marketplace (e.g. bequest or existence values), the analyst must approximate these. This entails the calculation of shadow prices using one of a variety of tools (to be discussed later in section 3.4). The term 'shadow price' refers to a price that is imputed as opposed to being taken directly from market transactions (Pearce and Nash, 1981:105).

3.2.3 Aggregation of impacts over time

This stage entails the aggregation of cost and benefit streams for each time period in the project's life. It is impossible to compare benefits and costs of a project when they occur in different time periods, since income available from a project today is not as valuable as income that will only be available at some period in the future (Boadway and Bruce, 1984:294). Hence, it is necessary to measure all benefits and costs that occur in different periods over the project's lifespan in terms of some numéraire. For purposes of this study, the numéraire is assumed to be present consumption (i.e. a time period of zero). The conversion of future consumption values to present consumption values is achieved by a process known as discounting.

The discounting technique (and, indeed the size of the discount rate) plays a key role in the achievement of dynamic efficiency and its use is thus relevant to both the project analysis and outcome (Lumby and Saville, 1995:1). The use of this technique has been one of the major areas of controversy surrounding the application of CBA to environmental management, since its use has large implications for those projects with long-term effects. Consequently, some economists have advocated the use of a very low, or even a zero discount rate for those projects where benefits and/or cost streams accrue in the distant future, in order to eliminate the bias of placing the welfare of the current generation above that of future generations. However, such suggestions are ill conceived and would not result in an efficient, or even equitable, use of resources, since people would rather receive money today (and invest it) than the same amount of money sometime in the future. Hence, eliminating discounting would result in a net decrease, not an increase in social welfare (Dixon *et al.*, 1994:107). The following rationale for discounting the future has been proposed by Goodin, 1988:57:

- 'Pure time preference' points to people's psychological propensity to attach less importance to future payoffs, even if there is no rational reason whatsoever to do so.
- The uncertainty and risk which characterise future payments.
- Diminishing marginal utility. In a growing economy, where people will generally be better off in the future, diminishing marginal utility implies that they would derive more satisfaction from any given unit of a good now (when they have less) than later (when they have more).
- The opportunity costs. The argument supporting this is that if funds are devoted to a public project, they could earn *x per cent* as a rate of return of investment in the private sector. Hence, by consuming R100 today, we sacrifice the option of investing it and thus enjoying more than R100 tomorrow.

Following the conversion of impacts into a common numéraire, it is possible to aggregate these benefits and costs and in this way obtain an aggregate measure that indicates the welfare effects of the proposed project (Boadway and Bruce, 1984:294).

3.2.4 Sensitivity analysis and weighting

A sensitivity analysis is a crucial part of any properly conducted CBA and should be undertaken prior to deciding whether to adopt a project, such as alien plant eradication. A sensitivity analysis entails the examination of effects of key variables on the project's overall profitability and indicates factors on which the project decision is crucially dependent (Common, 1988:285).

CBA is purely concerned with the economic efficiency of a project and implicitly assumes that everyone has the same marginal utility of income. Efficiency is measured without regard to whom the benefits and costs accrue, or whether society considers the prevailing distribution of income to be desirable (refer to section 2.4 for further details). The reason for not incorporating distributional effects of a project into CBA is that this would usually involve some form of weighting of the costs and benefits accruing to specific social groups. This is extremely problematic, since it is highly subjective: "all weighting converts political, social and moral choices into pseudo-technical ones and in effect allows the analyst to impose their own judgement on all" (Rees, 1990:331). Furthermore, there is a lack of conclusive evidence proving that individuals have different marginal utilities of income, in other words, that the poor receive a greater increase in their utility or welfare from one extra rand of income than the rich do (Perkins, 1994:51). This lack of 'conclusive' evidence suggests that the theory that marginal utility of money falls as income increases is false. Since income is merely another means of holding wealth, then marginal utility from consuming goods also would not diminish. This is in direct contrast to economic theory.

Since this study aims to objectively present the findings, value judgements concerning the weighting of costs and benefits or losers versus gainers will not be the preserve of the researcher but rather the politician (Mishan, 1981:25). Consequently, the final decision concerning eradicating alien plants will depend on the 'political economy' which prevails as well as the aims and objectives of government. For example, if employment is a top priority government will weigh the importance of this more heavily than other factors like streamflow.

3.2.5 Decision rule (whether to accept or reject the project)

There are typically three methods which can be employed to compare costs and benefits emanating from a project, namely the net present value (NPV), internal rate of return (IRR) and the benefit-cost ratio (BCR). Each of these methods will be discussed.

3.2.5.1 Net Present Value (NPV)

The NPV of a project is simply the present value of its net benefit flow (i.e. all benefits minus all costs). This is important in evaluating projects as any resource use option will affect the resource endowment available in the future, thereby affecting the welfare of future generations (Dixon *et al.*, 1988:79). Due to the fact that benefits and costs occur at different times they need to be discounted back to the beginning of the base year to derive their present value, which facilitates their comparison (Clawson and Knetsch, 1971:258). The NPV formula is as follows:

$$\textbf{NPV}=\sum_{t=0}^{n}\left[\frac{(B_t-C_t)}{(1+r)^t}\right]$$ (Perkins, 1994:57)

Where $\mathbf{B_t}$ are project benefits in period t

$\mathbf{C_t}$ are project costs in period t

r is the appropriate economic discount rate

n is the number of years for which the project will operate.

The decision rule in relation to a project's estimated NPV is approve any project for which NPV exceeds zero, since if the benefits of a particular project outweigh the costs, then that project (and resource allocation) will serve to improve human welfare over multiple generations (Prest and Turvey, 1965:683). Such a project is regarded as sustainable in the long run.

The **major advantage** of the NPV selection criterion is that it is easy to apply. The **main disadvantage** of this criterion is that its use relies on the prior selection of an appropriate discount rate, which has been very controversial (refer to section 3.2.3) (Hanley and Spash, 1993:17).

NPV is the most widely used assessment criterion for establishing whether a project should be approved and is the decision rule used in this study (despite the disadvantages associated with this technique).

3.2.5.2 Internal Rate of Return (IRR)

The IRR is the discount rate that, if used to discount a project's costs and benefits, will make the project's NPV equal to zero (Perkins, 1994:60). The IRR measures the rate of net benefits generated by the project, but not their size. Consequently, this decision rule can be used to establish whether a particular project is economically desirable, but cannot be used to rank projects. The IRR is equivalent to the discount rate (r) that satisfies the following relationship (Dixon *et al.*, 1988:31):

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

The **major advantage** of the IRR is that it takes account of the time profile of a project and can be calculated without reference to a predetermined discount rate (Perkins, 1994:62). Furthermore, it is readily understood as a measure of project worth by non-economists.

There are, however, numerous disadvantages associated with the IRR criterion, which include:

- It is necessary to make an outlay before it is possible to calculate a return;
- No unique IRR can be defined for projects where there is more than one change in the sign of the cash flow (Brealey and Myers, 1991:82); and
- Problems arise when short-term interest rates differ from long-term rates and hence there is more than one opportunity cost of capital.

The NPV rule is considered a more convenient and reliable criterion than the IRR.

3.2.5.3 Benefit-Cost Ratio (BCR)

The BCR is simply the ratio of the sum of the project's discounted benefits to the sum of its discounted investment and operating costs (Perkins, 1994:75). The formula is as follows:

$$BCR = \frac{\sum \frac{Bt}{(1+r)^t}}{\sum \frac{Ct}{(1+r)^t}}$$

A project should be accepted if its BCR is greater than or equal to 1, since this implies that the project generates gains from an economic perspective and its discounted benefits exceed its discounted costs. It follows that the project with the highest BCR should be selected.

The **major advantage** of BCR is that it is readily understood by non-economists and it is easy to observe the impact of a percentage rise in costs or fall in benefits on the project's viability (Perkins, 1994:76). The BCR criterion has the following **disadvantages**:

- Ranking of alternative projects may result in an erroneous investment choice, since the BCR ratio discriminates against those projects with relatively high operating costs and gross returns, even though these may have a greater wealth-generating capacity than alternative projects with higher BCR (Carpenter, 1999: 45).
- The requirement to specify and adhere to conventions regarding the designation of expenditures as costs and benefits.

The BCR will not be employed in the analysis of the eradication programme because the NPV method is considered a more reliable indicator of the economic desirability of a project.

3.3 Criticisms of CBA

Although the CBA procedure is conceptually simple, there are a number of well-documented problems associated with it and its application to environmental issues. These are:

- The analyst is often faced with the difficulty of valuing goods which are not traded in markets and for which no obvious price exists, for example, the valuation of non-market goods, like wildlife and landscape.
- Ecosystems are extremely complex and hence, the accurate prediction of the effects on the environment is difficult if not impossible.
- There is much controversy surrounding discounting and the discount rate that should be employed, especially in the case of projects with long-term effects.
- CBA is usually focussed on those costs and benefits which occur on-site and as a consequence, costs that occur off-site due to the presence of externalities are often ignored. Thus, it is essential to incorporate both on and off-site costs and benefits in a CBA in order to assess the total contribution to social welfare.
- CBA does not have any particular merits concerning equity issues (Dockel *et al.*, 1990:9). Distributional effects are frequently ignored and consequently, projects are often approved on the basis of whether or not they are efficient. Furthermore, value judgements predominate in the decision-making process.

However, despite these theoretical limitations associated with the CBA technique, it can still be regarded as an essential tool, which aids decision-making. CBA provides a means to increase the rationality in decision-making and is meant to be a guide to decision-makers, but not the final determinant of choice (Clawson and Knetsch, 1971:255). Therefore CBA is an useful technique which will be employed despite the problems alluded to.

3.4 Techniques for valuing environmental goods and services

If decisions concerning the eradication of alien invasive vegetation are to be taken on the basis of the CBA technique, then it is essential to identify all benefits and costs associated with alien plant eradication and where possible, place an economic value on these. While some of the benefits and costs are easy to quantify, like consumptive use values, others such as bequest values are more difficult to incorporate into an analysis. Assigning economic values to the latter requires the application of certain techniques (Spash and Hanley, 1995:192). Where monetary values cannot be defined for the impacts of alien plants these must still be included in the analysis, qualitatively. Failure to include these represents an abandonment of the principles of CBA, which can adversely affect the outcome of the analysis.

3.4.1 Importance of assigning monetary values to all goods and services

Assigning monetary values (or shadow prices) to environmental goods and services may strike many as illicit or even immoral. It is, however, essential for several reasons:

- Individuals express their preferences in terms of monetary values (Pearce and Turner, 1990:121).
- Money is a common numéraire and accepted means of exchange. For example, the GDP is a composite of many different items which only makes sense when expressed in monetary terms. The same applies to costs and benefits.
- Environmental goods and services tend to be overlooked when they are not quantified and thus, assigning monetary values to these goods forces developers to consider them, prior to making decisions on a particular project.
- Attaching monetary values to environmental goods emphasises that they not free, but have values in the same sense as marketed goods and services (Pearce *et al.*, 1989:80).
- To support an argument with a monetary expression of one's concern or preference for a particular environmental good makes the case for preservation stronger.

- It is easier to justify budget outlays needed for the establishment and maintenance of environmental goods if monetary values are assigned to these goods and services (Dixon and Sherman, 1993:33).

The nature of goods determines whether monetary values can be readily established or not. For example, the consumptive use benefits associated with clearing alien plants, like the harvesting of timber, are easily captured from real markets, whilst non-use benefits such as improved aesthetics are not, because such values are not traded in the market place. When such circumstances are encountered it is necessary for the CBA analyst, where possible, to employ techniques to capture these environmental benefits in monetary terms (Common, 1988:270). This essentially entails the adoption of a 'shadow-pricing' approach. A shadow-price is "an estimate of the value that a good or service would have if a market could be established for it" (Stauth and Baskind, 1992:37).

Over the past few decades, a number of techniques using this approach have been developed. Two basic approaches to these techniques can be distinguished, namely *demand curve techniques* which estimate the value of a commodity via a marginal social benefit (MSB) or demand curve (i.e. Marshallian or Hicksian demand curve) and *non-demand curve techniques* (refer to figure 3.1). It is worth noting that the extent to which one can actually capture environmental effects in monetary terms differs according to their nature and relationship with existing markets (Bojö *et al.*, 1996:60).

3.4.2 Non-demand curve approaches

Non-demand curve approaches are useful in providing rough evaluations for environmental goods and services that might otherwise be treated as free (O'Riordan, 1995:50). For example, reduced soil erosion, a benefit associated with alien plant clearing in the long-term, can be ascertained by examining the cost of alternative structures necessary to provide the same protection as indigenous vegetation, such as gabions erected to stabilise banks and prevent soil erosion.

The non-demand curve approach does not seek to measure direct revealed preferences for the resource in question, but rather attempts to establish a 'dose-response' relationship between a good (e.g. indigenous vegetation) and some non-monetary effect such as reduced soil erosion (Pearce and Turner, 1990:142). Only once this relationship has been determined does this method apply willingness to pay (WTP) measures taken from the direct valuation approaches. For purposes of this study, non-demand curve approaches will not be utilised and hence, will not be discussed further.

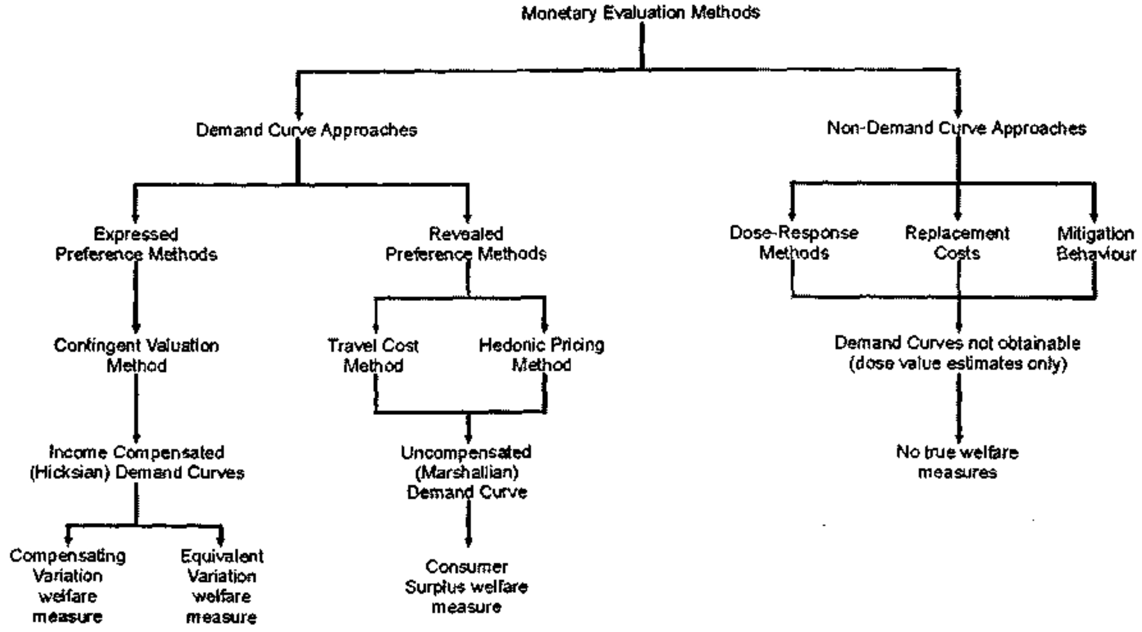

Figure 3.1: Methods for the monetary evaluation of the environment (Turner, 1995:123).

3.4.3 Demand curve approaches

The demand curve approach centres on the estimation of a demand curve for a particular environmental good. Figure 3.1 differentiates between two basic types of demand curve evaluation methods, namely expressed and revealed preference methods. In the former case, demand is measured by examining individuals' stated preferences for the good in question, whilst in the latter case demand is ascertained by examining the price paid for a closely associated good that is traded in the market place (Dixon and Sherman, 1993:35). Whilst only the expressed preference method will be used in this study, revealed preference methods could be used to support or build on aspects of the current study. Consequently, both types of evaluation methods will be critically examined below.

3.4.3.1 Travel Cost Method (TCM)

The travel cost method (TCM) is an inferential technique which entails identifying some marketed good, the demand for which may provide an indication of the value of a particular non-market good (Carpenter, 1999:38). A marketed good may be used to infer the value of a non-market good when both goods are complementary in consumption (Randall, 1981:300). For example, the value of a recreational area may be inferred by measuring the travel, time and subsistence costs which individuals have incurred in visiting the area. The economic principle associated with this, is that people spend time and money travelling to recreational sites, and these expenditures incurred to use the site can be treated, with proper interpretation, as a value for the site. By treating increasing travel cost as a surrogate for variable admission prices, a demand curve can be derived. This demand curve essentially reflects consumers' value of the recreational area (i.e. the benefit derived from visiting it). Therefore, the TCM is a survey technique which entails the administration of a questionnaire to a sample of visitors at a site, in order to ascertain their place of residency and frequency of visit to this and other sites.

Strengths associated with this technique include its use of actual visitor behaviour, that is the collection of demographic and attitudinal information of visitors. Information pertaining to the individual's trip such as purpose, length and associated costs is elicited from individuals by means of a questionnaire.

The **limitations** associated with the TCM include its ability to capture only the 'use value' of recreation sites because questionnaires can only be completed by individuals who actually visit the site. Hence, non-visitors are excluded from this type of analysis and this can bias the findings. Thus, where non-use values are relevant and significant, the TCM will underestimate the total economic value of the good in question. A further weakness of the TCM, is its assumption that all travel costs are undertaken for the sole purpose of visiting one particular area and that the journey itself provides no utility to the consumer (Carpenter, 1999:39). Although the TCM will not be used in this study, it could be used to support the valuation of non-market goods arising from alien eradication (for instance increased biodiversity) in subsequent research.

3.4.3.2 Hedonic Pricing Method (HPM)

The Hedonic Pricing Method (HPM) is a revealed preference method which attempts to impute a price for an environmental good by examining the effect which its presence has on a relevant market-priced good (Turner, 1995:233), for example, the valuation of environmental goods such as landscape amenity as reflected in local property prices. The price paid for a property directly reflects the benefits or characteristics of that land (O'Riordan, 1995:56). Thus, by controlling the structural (e.g. space size), locational (e.g. access to workplace) and other characteristics of land, it is possible to isolate the effect which environmental characteristics, such as improved air quality, have upon land price and thereby ascertain the implicit price of this characteristic. The objective of HPM is to derive a demand curve that relates the environmental service, like improved air quality, to individuals' WTP for this improvement.

The **strengths** of this technique include its use of actual market prices (e.g. property prices) and its ability to isolate the effect which environmental characteristics have upon such prices.

Limitations of the HPM include its assumption of perfect information concerning property prices and environmental characteristics which define a particular portion of land as well as the assumption that buyers and sellers are aware of these environmental characteristics. Since perfect information was not readily available, it was not possible to utilise this method in this analysis. However, if such data were to become available in the future, this method could be used to establish how the eradicating of alien plants affects property prices.

3.4.3.3 Contingent Valuation Method (CVM)

The contingent valuation method (CVM) is an expressed preference method which attempts to estimate values for non-market goods and services by eliciting individuals' preferences for these goods, either through the use of a questionnaire or by experimental techniques in which subjects respond to various stimuli in 'laboratory' conditions (Pearce *et al.*, 1989:71).

This method is particularly concerned with option and non-use values. As a result CVM has a distinct advantage over other methods, since it can be used to evaluate resources which people never visit but value the continued existence of (Turner, 1995:124). This was one of the limitations of the TCM (refer to section 3.4.3.1). It is anticipated that the benefits associated with alien plant eradication will comprise both use and non-use values and it was thus essential to employ the CVM in this research project.

Individuals' preferences for a particular good, e.g. increased biodiversity, can be established by examining their behaviour when presented with choices between goods (Pearce and Turner, 1990:125). It is assumed that a positive preference for a good will show up in the form of a WTP for it. WTP, which is directly dependent on the benefits received, is measured by the area under the demand curve (Brent, 1997:135). Once consumers' individual WTP have been ascertained, these can be aggregated to secure a total WTP.

3.4.3.3.1 Economic basis of the CVM

The values elicited from individuals can be used to determine how changes in the provision of environmental goods and services impact upon individuals' utility levels, that is their welfare gain or loss. Traditionally, the welfare gain or loss from changes in provision has been approximated by changes in consumer surplus (Turner, 1995:136). Consumer surplus is defined as the 'excess' benefit that individuals obtain and equates the difference between what they do and what they are prepared to pay. The consumer surplus is depicted as the area that lies beneath the ordinary (Marshallian) demand curve but above the price line. The Marshallian demand curve records the 'full price effect' which occurs when the provision of a good changes and has typically been used to show the effect of a price change on the quantity consumed of a normal good. The Marshallian demand curve, which holds money income constant, is useful in determining how consumption of a normal market good increases when its price falls. However, it is inappropriate for determining the consumption effects of non-market or environmental goods, since the individual often faces a quantity rather than a price constraint with these goods. Furthermore, these goods often have much higher income elasticities than those associated with market goods (Turner, 1995:136). As a result, the large real income effect arising from a change in quantity provision may undermine the consumer surplus measure of welfare change. It is necessary to compensate for this real income effect by holding real income constant and thus moving from the use of the ordinary Marshallian demand curve to the compensated (Hicksian) demand curve. The Hicksian demand curve holds the individual's utility constant and can be used to evaluate the monetary income adjustment necessary to maintain a constant level of utility before and after the change in the provision of a good.

3.4.3.3.2 Welfare change measures

There are two basic concepts which can be employed in the CVM to ascertain the welfare effects of a change in the provision of an environmental good, namely WTP for increased provision or willingness to accept (WTA) compensation for a loss or reduction of some environmental good or service (Braden and Kolstad, 1991:123). The neo-classical utility theory of economics suggests that these measures should be similar in magnitude for most goods which are close substitutes and for which the real income effect is small. However, in practice CVM studies have recorded very wide divergences in values obtained by using these two approaches (refer to Brown and Gregory, 1999, for greater insight and explanation of this disparity).

The WTP or WTA concepts are measured by examining the welfare effects associated with a change in provision. Two concepts of welfare change measures under the Hicksian or compensated demand function exist, namely, **compensating variation** (surplus) and **equivalent variation** (surplus) which can either be positive (welfare gain) or negative (welfare loss). These are accurate measures of welfare effects as a result of a change in the provision of some good.

The compensating and equivalent **variation** measure is used when the individual is free to purchase varying quantities of a good, whilst the **surplus** measure is used when the individual is constrained to purchase only fixed quantities (Carson and Mitchell,1989:25). It is worth noting that for any specific question involving welfare change, only one of these measures will be appropriate.

Only the compensating variation method is to be discussed further given its relevance to the study and since the vast majority of policy decisions allow the consumer free adjustments. The compensating variation (CV) measure is the money income adjustment (welfare change) necessary to keep an individual at their initial level of utility (I_0) throughout the change in provision (refer to figure 3.2). For a **proposed welfare gain**, arising for instance from the increased provision of an environmental good, the CV measure indicates the maximum amount the individual is WTP to secure his welfare gain.

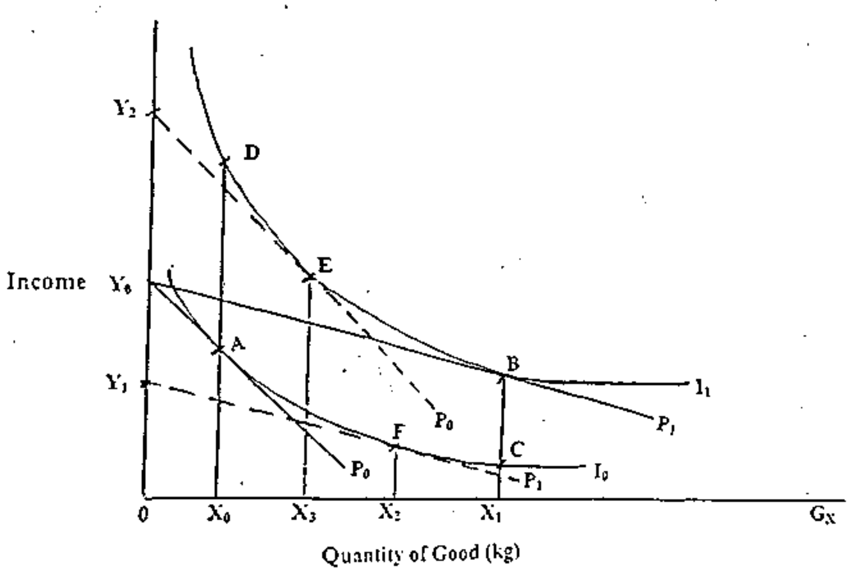

Figure 3.2: Compensated welfare change measures for an unpriced quantity-constrained good (adapted from Just *et al.*, 1982:88).

The above figure shows the consumer's **ordinal** preference for some normal good. The consumer has an income of Y_0 and the price of good x is given by the slope of the budget line Y_0P_0. The price falls from P_0 to P_1 and the consumer moves from A to B. The compensating variation is Y_0Y_1 (refer to figure 3.2). This is the maximum the consumer would pay at price P_1 to buy any quantity he likes so that his welfare is unchanged at the initial utility level, that is I_0 level. At income Y_1 and price P_1 the consumer would purchase X_2 units.

Generally speaking, for any exogenous change that affects the consumer's welfare (like a price or income change or the introduction or removal of a new good on the market) the CV is that amount which, if paid or received by the consumer, will maintain his original welfare level. If the change is positive, the CV represents the maximum he would be prepared to pay to secure that change, and if it is harmful, the CV is the minimum he must receive to endure the harmful effects.

For purposes of this study it was deemed useful to elicit how much individuals are WTP for an increase in biodiversity as a consequence of eradicating alien plants. It is anticipated that the individuals' WTP for increased biodiversity will depend on their preference for the good in question, whether or not they belong to a conservancy, as well as whether they own a guest lodge. This can be summarised in a mathematical form as follows: **WTP (B_f) = f (C, P, G) Ceteris Paribus**

where B_f = increased biodiversity

C = member of conservancy

P = preference for good (dependent on farming activity engaged in)

G = guest lodge owner

The CVM approach, in eliciting explicit statements of how much individuals are WTP to ensure a welfare gain is, in theory, directly estimating the true Hicksian welfare measures of these changes (Turner, 1995:140).

For a **proposed welfare loss**, the compensating variation measure indicates how much an individual is WTA in compensation to endure a welfare loss arising from the removal of some good or service like biodiversity. This measure will not be employed for this study.

3.4.3.3.3 Strengths of CVM

A major attraction of the CVM is that it can be applied to situations where markets for environmental goods do not exist, are not well-developed, or where there are no alternative markets (Dixon *et al.*, 1994:70). For example, it can be employed to capture passive use values like existence value, stewardship value and bequest value.

Furthermore, the CVM does not infer values from an existing market, but rather facilitates the construction of a market in which the researcher can observe an economic choice directly related to the provision of the environmental good of interest (Carson, 1998:17). This characteristic makes CVM the only economically consistent approach available for making holistic judgements about the benefits of providing environmental amenities with substantial passive use values.

The success of the CVM depends on the fulfillment of the following conditions (Carson, 1998:17):

- Non-marketed goods must be well defined.
- The scenario must provide a plausible means of provision and the payment vehicle should ideally have the ability to coerce payment from individuals if the good is provided. This is to ensure respondents take the survey seriously and do not have an incentive to over/understate WTP.
- There must be a plausible mechanism for making the trade-off between the consumption of private goods and the non-marketed good of interest.

3.4.3.3.4 Limitations of CVM

The root of the difficulty with the CVM is that it makes use of a survey instrument to directly question respondents concerning hypothetical values rather than relying on overt market behaviour, however indirect. Hence, this method relies on intentions, ideals or behaviour expressed in hypothetical circumstances. Individuals' asserted preferences are typically costless to express, or nearly so, which suggests that they may not be considered as carefully as are real consumption choices (Braden and Kolstad, 1991:12). Consequently, individuals' stated preferences may bear no systematic relationship to their true preferences for the good in question.

The limitations or biases associated with the CVM are dependent on the approach adopted (i.e. bidding game, take-it-or-leave-it experiments, trade-off games, the costless choice or the Delphi technique). The CVM is subject to the following biases:

- **Strategic bias** may arise when respondents either understate or overstate their expressed preference for a good.
- **Information bias** can arise either as a result of providing too little information about choices offered or from misleading statements made by the interviewer (Dixon *et al.*, 1994:80).
- **Part-whole bias** (also referred to as the embedding effect) may occur when stated WTP for an environmental good is systematically biased upwards because participants in such surveys do not properly observe their personal budget constraints, or alternatively respondents do not regard the amount stated by them as reducing their budget left for the purchase of private goods (Ahlheim, 1998:205).
- Respondents may conceal their true preference for a good in the hope that someone else will bear the cost (commonly referred to as the 'free rider' problem).
- Individuals refuse to make a trade-off between environmental goods and money and hence, under such circumstances, the CVM fails as a good measure of welfare change.

This candid discussion of the limitations associated with the CVM in the evaluation of environmental goods and services suggests that its implementation must be exercised with extreme caution. It does not, however, suggest that these valuation techniques are ineffectual, as in most cases they can be extremely useful in providing estimates of the value of environmental impacts resulting from a project. Thus, the careful employment of such a technique can generate more accurate and balanced appraisals of proposed projects.

3.5 Conclusion

Conventional CBA evaluates the desirability of any project – and hence allocates resources – on the basis of four main factors, namely, the benefits generated by the project; the costs imposed by the project; the period of time over which these costs and benefits occur; and the discount rate applied to these cost and benefit flows (Lumby and Saville, 1995:1).

CBA is an essential tool for establishing the economic feasibility and efficiency of a project and in this way enhances the decision-making process. The success of the CBA is largely dependent on the approach adopted and the impacts associated with the project. For those projects with a large environmental component such as is evident with alien plant eradication, it is essential to ensure that **all** impacts are identified and where possible quantified. Where the quantification of such impacts using monetary evaluation approaches is not possible then it is essential to incorporate these impacts qualitatively.

CHAPTER FOUR

BACKGROUND TO STUDY AREA

4.1 Introduction

The study area was confined to the upper reaches of the Mhlatuze River Catchment and was selected for the following reasons:

- This catchment is the worst affected tertiary catchment in KwaZulu-Natal in terms of infestation by alien vegetation.
- This catchment was the first pilot focus area within the Department of Water Affairs and Forestry's (DWAF's) Strategic Environmental Assessment (SEA) for Stream Flow Reduction Activities (SFRA) and hence, a large amount of data had previously been collected and collated.
- The close proximity of the catchment to Pietermaritzburg meant that the area was easily accessible.
- A few of the farmers in the upper reaches of this catchment had previously experienced difficulties in irrigating crops and this was ascribed to invasion by alien vegetation.
- Most of the landowners in the upper reaches of this catchment have embarked on a rigorous eradication of invasive alien vegetation on their properties which made it possible to elicit and appraise the costs and benefits associated with this process.

Before an economic analysis of the eradication and management of invasive alien vegetation can be undertaken, it is necessary to firstly, define the study area and secondly, carefully examine the impacts associated with invasive alien plants as well as alien plant eradication programmes which have been initiated in the catchment. In effect this means defining the physical, economic and social characteristics of the catchment. This will assist in clarifying the issues at stake and is beneficial because it can be used to establish the potential effects of the eradication process.

An understanding of these aspects and issues pertaining to the catchment is important for defining and assessing the social costs and benefits connected with alien plant eradication. Consequently, the findings of this chapter will feed into the analysis to be undertaken.

4.2 Physical Characteristics of the Mhlatuze Catchment

The Mhlatuze River Catchment, which has a surface area of approximately 4,209 km^2, is situated in the northern coastal region of KwaZulu-Natal (refer to figure 4.1). This catchment is characterized by a high annual rainfall, ranging from 800mm/annum in the upper and middle parts of the catchment to 1400mm/annum near the coast (Versveld *et al*, 2000:9). The Mhlatuze River Catchment is thus a high rainfall region in comparison with other areas in South Africa.

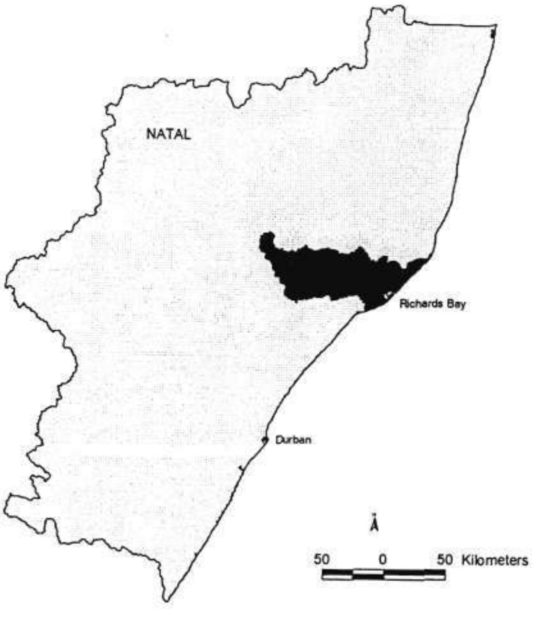

Figure 4.1: Mhlatuze Catchment in KwaZulu-Natal (Dallimore, 2000).

4.2.1 Land-use

The Mhlatuze Catchment is divided into three distinct zones, namely:

- An **upland region,** which incorporates those areas situated above the Goedertrouw Dam (refer to figure 4.2). This area comprises largely undeveloped tribal land and extensive tracts of forestry plantations as well as dry-land sugar cane in the vicinity of Melmoth. The study area selected as the focus for this research project is confined to those high lying areas surrounding the Melmoth region.
- A **central belt**, which has extensive undeveloped tribal lands, juxtaposed with very intensive irrigated agriculture producing chiefly sugar cane and citrus.
- The high rainfall **coastal belt** which has been heavily afforested to the north, but also includes agriculture, and, most importantly, heavy industry (Versveld *et al*, 2000:iv).

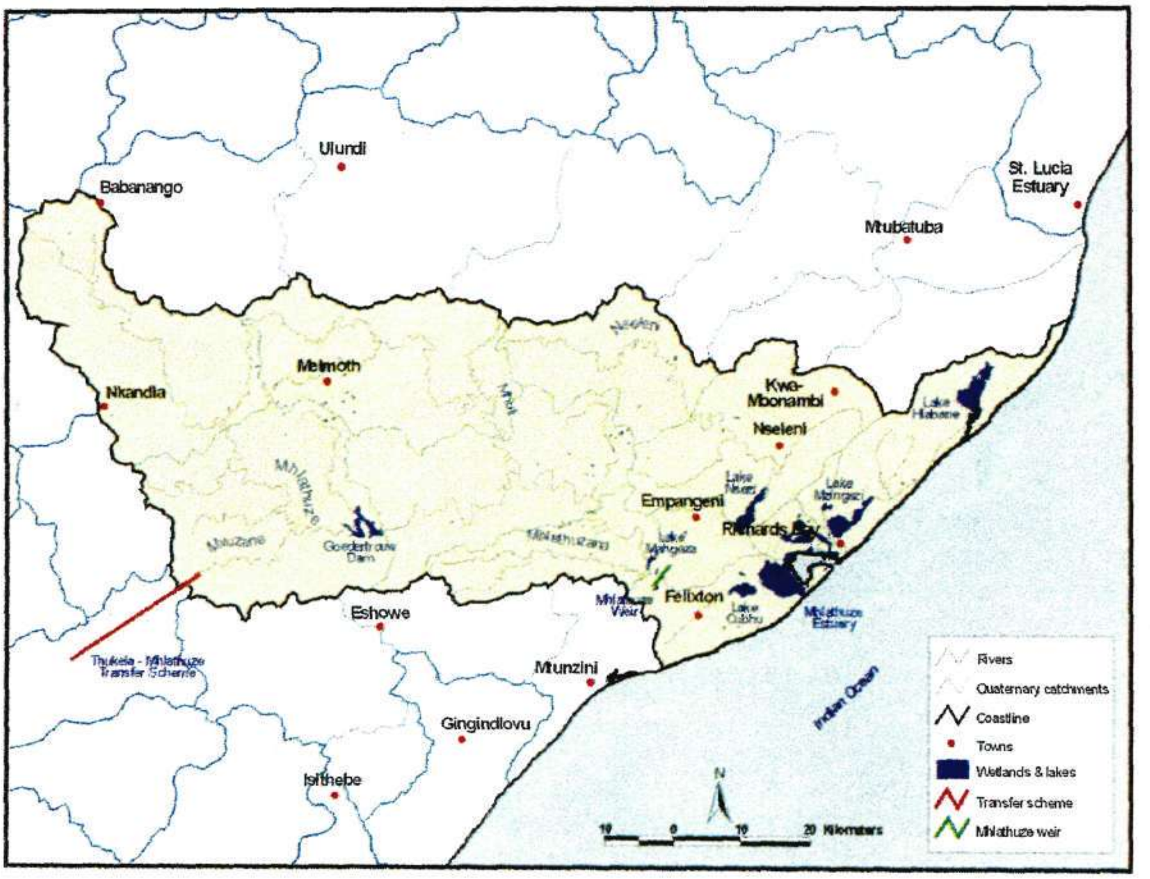

Figure 4.2: Water features in the Mhlatuze Catchment (Versveld *et al*, 2000:29).

4.2.2 Extent of afforestation

The lack of a natural source of fast growing timber trees has led to the establishment of plantations of alien or introduced species. This has been one of the main factors leading to increased alien vegetation invasion and has been particularly significant in this catchment.

Timber plantations comprise 554km^2 or thirteen *per cent* of this catchment. Timber plantations are the largest land-use sector in the catchment (refer to figure 4.3) and can be divided into two distinct geographical regions, namely:

- High lying areas around Melmoth and Babanango (above the Goedertrouw dam) predominantly contain wattle which is the *Acacia* species. The majority of timber plantations in the study region also comprise this species.
- Coastal areas (around Kwambonambi) predominantly contain gum or the *Eucalyptus* species with a few stands of pine (*Pinus* species) (Versveld *et al*, 2000:31).

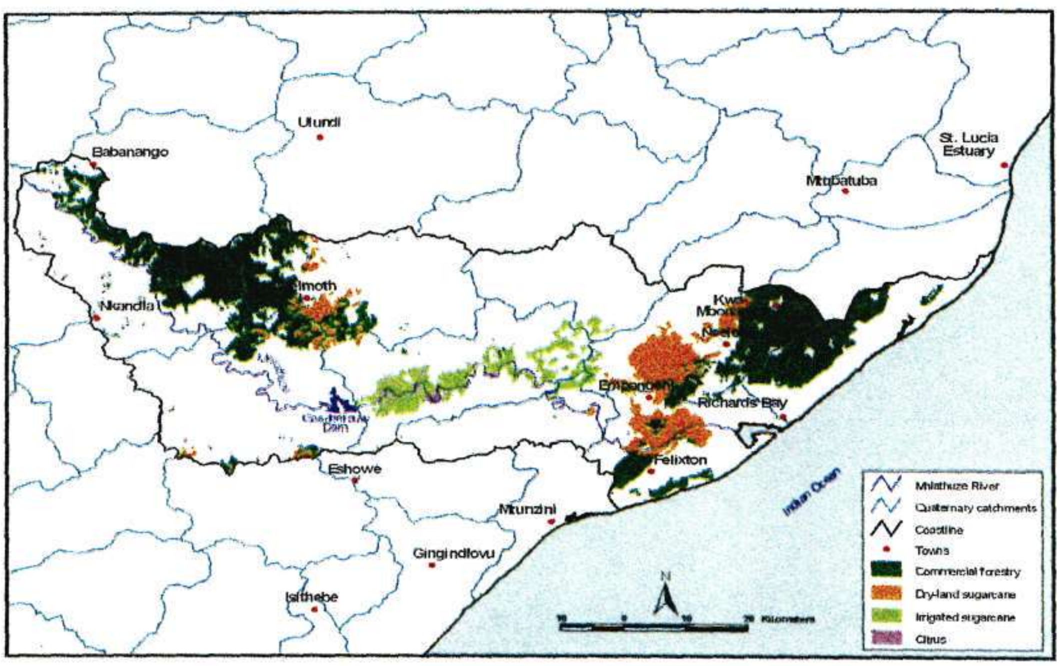

Figure 4.3: Commercial agriculture in the Mhlatuze (Versveld *et al*, 2000:32).

The large majority of these timber plantations are owned by commercial forestry sectors such as Mondi Forests (who own almost half the total plantations in the catchment), Sappi, Safcol and Central Timber Co-operative (CTC).

4.2.2.1 Afforestation legislation in South Africa

Landowners must acquire permits to plant timber and these must be registered with the DWAF. Consequently, the afforestation of alien plant species, for example *Acacia*, *Eucalyptus* and *Pinus* species, is strictly controlled in South Africa. Planting of commercial timber plantations is presently forbidden within 30m[1] of wetlands and water courses because:

- Water is the main dispersal agent of alien vegetation seeds.
- More water is available for uptake by trees in riparian zones.
- Riparian areas are important for water generation and are centres of biodiversity (DWAF, 2000a:10). There is currently a moratorium on further afforestation in the Mhlatuze Catchment as it is evident that the current available water in the catchment is under 'stress' (refer to section 4.4.1 for more details).

In terms of the **National Water Act (Act 36 of 1998)** (NWA) timber plantations have been declared a streamflow reduction activity (SFRA) and hence, owners of these plantations will be required to apply for 'water use licenses'. The licenses are to be issued for limited periods of time up to a maximum of forty years and are subject to review at least every five years (NWA, 1998).

4.2.3 Agricultural activities

Agricultural production, which includes both commercial and subsistence agriculture, is the second most dominant land-use sector in the catchment. This sector consists almost

[1] The delineation of both wetlands and riparian zones is in the process of being redefined and this figure is subject to change.

exclusively of sugar cane (±387km^2 of which 243 km^2 is dry-land and 144 km^2 irrigated) and citrus (16km^2) (Versveld *et al*, 2000:30).

4.2.3.1 Sugar Cane

Sugar cane, predominant in both the catchment and study region (refer to figure 4.3), is by far the most important agricultural crop in terms of employment and water use (Versveld *et al*, 2000:96). Dry-land sugar cane is principally grown in the upland regions and is thus an important use of land in the study area, whilst irrigated sugar cane dominates the central and western half of the catchment. The Mhlathuze catchment area has been identified as one of the highest yielding sugar cane regions within the South African sugar industry, producing on average approximately twelve *per cent* of the total cane of South Africa (Dallimore, 2000:38).

4.2.3.2 Citrus

Citrus is a relatively new industry which has been established in the Mhlatuze Catchment, which explains its limited distribution within the area (refer to figure 4.3). Seventy *per cent* of the total citrus area or 11.2 km^2 contains grapefruit with the balance being Valencia oranges.

4.2.4 Industrial development in the catchment

All industrial development in the Mhlatuze Catchment is concentrated in the coastal regions within the Empangeni/ Richards Bay complex (Versveld *et al*, 2000:iv). This complex is one of the most important industrial areas in South Africa, and is based on the export of coal from the immediate vicinity as well as heavy industrial development, notably aluminium smelting, pulp and paper, and fertilisers. For a historical overview of industrial development in the catchment refer to Dallimore (2000).

4.2.4.1 Initiatives introduced to increase economic growth

Although investment in the coastal area has recently increased, this has largely been confined to heavy industrial projects with little downstream manufacturing activity. In an attempt to alter this pattern of investment, the Richards Bay Spatial Development

Initiative (SDI), one of the eight SDI's in the country, aimed at encouraging private sector investment in regions that demonstrate significant economic potential, was launched in 1998 (Versveld *et al*, 2000:19). The SDI, which is concerned with national as well as local development, aims to encourage the expansion of export-oriented industries that will introduce a base of secondary manufacturing into the economy.

4.3 Main water sources

The main water supply systems in the Mhlatuze Catchment are the Goedertrouw dam, natural lakes and the Thukela transfer scheme. This scheme is used to pump water from the Thukela river to the Goedertrouw dam when there is insufficient water to meet the demands (refer to figure 4.2).

4.4 Water usage

Total water usage by the key sectors in the Mhlatuze Catchment has been summarised in table 4.1. From this table it is evident that the total volume of water reliably available for allocation each year from the catchment (the systems yield) is 270 million m^3. Of this, 186 million m^3/annum is obtained directly from the Goedertrouw dam, whilst 50 and 34 million m^3/annum are obtained from lakes and the Thukela-Mhlatuze, respectively (Versveld *et al*, 2000:29).

Table 4.1: Water balance of Mhlatuze Catchment (DWAF, 2000b).

Water availability	Available	Requirement	Balance
Systems yield	**270 million m^3**		
Current requirements			
Irrigation		176.5 million m^3	
Domestic Urban and light industrial Rural and stock watering		 32.4 million m^3 3.1 million m^3	
Industrial		74.4 million m^3	
Total		**286.4 million m^3**	
Balance			**-16.4 million m^3**

Total current water requirements, excluding water required for the ecological reserve, amounts to 286.4 million m^3/annum. This demand exceeds the available supply by

16.4 million m^3/annum. If one includes the water requirements of the ecological reserve as stipulated in the NWA to ensure ecological sustainability, an additional release of 16 million m^3/annum is required (Versveld *et al*, 2000:34). This was established from a preliminary determination of the water quantity component of the ecological reserve undertaken for the Mhlatuze River below the Goedertrouw dam.

Total water use of the catchment and hence, impact on systems yield, amounts to 302.4 million m^3/annum, exceeding the systems yield by **32.4 million m^3** (refer to table 4.2). It is worth noting that this water use analysis excludes the water consumption by alien invasive vegetation, due to the uncertainty surrounding its water uptake.

__Table 4.2:__ Water use in the Mhlatuze Catchment (Versveld *et al*, 2000:vi).

Water use	**Impact on natural runoff million m^3**	**Impact on systems yield million m^3**
Dry-land forestry	47	12.7
Dry-land sugarcane	±12	±3
Irrigation		176.5
Urban domestic and light industrial		32.4
Heavy industry		74.4
Rural domestic and stock watering		3.1
Ecological Reserve		16
Total		**302.4 million m^3**

In summary, the Mhlatuze Catchment is 'water stressed' as more water has been allocated to users than is theoretically available (Versveld *et al*, 2000:v).

4.4.1 Water use and tariffs of various sectors

The largest amount of water in the catchment is allocated to the irrigation reliant agriculture, which is currently allocated sixty *per cent* of the total, followed by the domestic and industrial sectors that are allocated fourteen and twenty-six *per cent* of the total, respectively (refer to table 4.3). The agricultural irrigation sector pays 2.08 cents/m^3 for water, whilst domestic and industrial sectors pay 42.34 cents/m^3 (van der Merwe *pers comm.*). These tariffs are based on August 2001 prices as well as the current water tariffs imposed by the DWAF. Thus, the highest water users pay the lowest tariff and this is only five *per cent* of the industrial and domestic water tariff collected by DWAF.

The low water price which the irrigation sector faces is ascribed to the highly subsidised government water scheme. This is a contentious issue, and one which warrants further research and policy attention (although it is beyond the scope of the present study), since the opportunity cost of this water is clearly considerably higher than the price charged to agricultural users. The differential between prices charged to the various sectors also reflects the assurance of water supply to these different sectors (van der Merwe *pers comm.*). For example, large industries such as Richards Bay Minerals (RBM) and Mondi have international commitments concerning the supply of their products. Consequently, these industries require a high assurance of water supply, especially during drought years or periods of water shortage, substantiating the costly water tariff borne by this sector (Perkins *pers comm.*).

Table 4.3: Current allocation of water and differential water tariffs sustained by sectors located in the Mhlatuze Catchment (van der Merwe *pers comm.*).

Sectors of water use	Current allocation of Available water (%)	Current water price[1] (cents/m^3)
Irrigation sector	60	2.08
Domestic sector	14	42.34
Industrial sector	26	42.34

1- price includes infrastructure and catchment management charge.

4.4.2 Commercial forestry sector

Timber plantations in the Mhlatuze Catchment are estimated to reduce natural runoff and streamflow by 47 million m^3/annum (refer to table 4.2). However, the impact on the systems yield (the amount of water which can be reliably captured and extracted from the system for direct use) is only 12.7 million m^3/annum, which was calculated using

DWAF's Water Balance Model. In terms of the systems yield, the water utilised by the entire forestry sector represents only seven *per cent* of that used by irrigated agriculture.

4.4.3 Agricultural sector

Irrigated agriculture, especially sugar cane, is clearly the largest water user in the Mhlatuze Catchment and has the greatest impact on systems yield, estimated to be 176.5 million m^3/annum (refer to table 4.2). It is apparent from this table that dry-land sugar cane uses considerably less water than other irrigated crops or commercial forestry. Dry-land sugarcane in the Mhlatuze Catchment has a total impact of approximately 12 million m^3/annum on natural runoff and an impact of only 3 million m^3/annum on the systems yield (Versveld *et al*, 2000:33). Consequently, in terms of the impact on the systems yield, dry-land sugar cane represents less than two *per cent* of the total water use of irrigated agriculture. The assurance of water supply to this sector is low justifying the modest water tariff of 2.08 cents/m^3 that is charged by DWAF.

4.4.4 Industrial sector

The industrial sector comprises light and heavy industry (refer to table 4.2). Heavy industry, which includes mining, has the second largest impact on systems yield after irrigation (74.4 million m^3/annum. The major existing water users are *mining* (32.9 million m^3/annum), *paper and pulp* (29.2 million m^3/annum), *fertilisers* (5.6 million m^3/annum) and *aluminium smelting* (1.9 million m^3/annum) based on 1999 figures (Versveld *et al*, 2000:104). The water tariffs charged by DWAF have been discussed previously.

4.4.5 Rural population

Tribal areas occupy more than fifty *per cent* of the Mhlatuze Catchment and contain some ninety *per cent* of the area's total population (Versveld *et al*, 2000:vii). The rural population are currently only allocated 3.1 million m^3 of water per annum for domestic consumption and stock watering purposes (refer to table 4.2). This represents only one *per cent* of the total Mhlatuze Catchment's systems yield.

It is anticipated that this amount will increase in the future, given the central guiding principles of South Africa's NWA which stress equity of access to water and sustainability of use (NWA, 1998). The NWA considers water for basic human needs (BHN) a right which must be set aside as a reserve before water is allocated for alternative purposes such as irrigation. The BHN reserve "provides for the essential needs of individuals served by the water resource in question and includes water for drinking, food preparation and personal hygiene purposes" (NWA, 1998). The BHN has provisionally been set at twenty-five litres per person per day (DWAF, 2000b:10). This would essentially augment the total water requirements of the Mhlatuze Catchment to 5.1 million m^3/annum, which will place additional constraints on existing water resources.

4.5 Economic characteristics

A large proportion of the data included in this section was obtained from the 1996 census which was the latest available for the KwaZulu-Natal province at the time. Consequently, it is acknowledged that some of the data will have become outdated and may not accurately depict the current scenario. It is requested that this be borne in mind whilst perusing this section.

4.5.1 Production and output

The Mhlatuze Catchment is the third most important sub-region in KwaZulu-Natal in terms of production and output (following Durban and Pietermaritzburg) and has achieved very high economic growth rates in the past. This economic growth is attributed to the following:

- the development of a deep water bulk port in Richards Bay;
- the abundance of natural resources, including timber plantations as well as significant mineral deposits; and
- significant government investment like the construction of a railway line from Vryheid to Empangani (Dallimore, 2000:19).

On average the catchment contributes eight *per cent* to the provincial GGP and six *per cent* to the total formal employment (Dallimore, 2000:19). The major contributor to economic growth has been the manufacturing sector which contributes on average fifty-five *per cent* to the regional GGP. This sector has also shown the highest annual average growth rate in GGP and is followed by the agricultural and transport sectors (refer to figure 4.4). The economic growth within the catchment area has not been constant but rather has followed boom-bust cycles closely related to single large-scale investment projects and international trends.

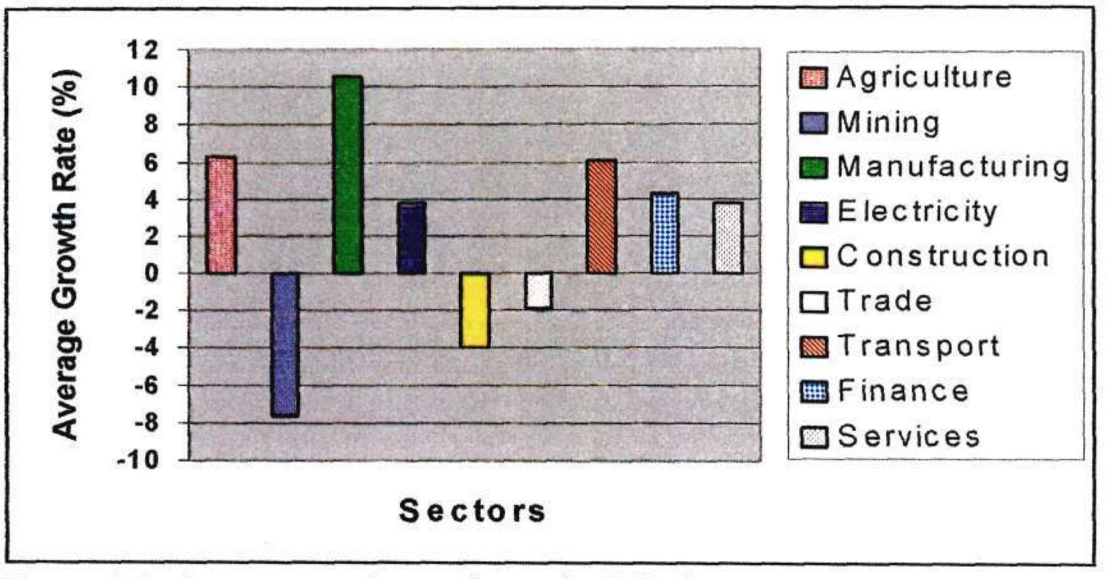

Figure 4.4: Average annual growth rate in GGP by Economic Sector (1980-1991) (Richards Bay SDI, 2000).

4.5.2 Employment

Whilst the Mhlatuze Catchment can be termed an 'engine of growth' within the South African economy, the same cannot be said concerning its ability to generate employment. It is apparent from table 4.4 that this catchment is characterised by exceptionally high levels of unemployment. The unemployment in this area is approximately forty-three *per cent* which exceeds the provincial average by four *per cent*. This very high level of unemployment may be attributed to the large number of unskilled individuals who inhabit the catchment. The economically active population is defined as "all persons over the age of 15 years who furnish their labour for the production of goods and services, whether employed or not; this includes workers formally or informally employed, the self-employed, employers, and the unemployed wishing to work (Barker, 1999:xviii).

Table 4.4: Employment figures of those economically active (StatsSA, 1999)

	Mhlathuze Catchment	Kwazulu-Natal
Employed	57.20%	60.90%
Unemployed	42.80%	39.10%
Total	**100.00%**	**100.00%**

The economic sectors which employ the greatest proportion of individuals within the catchment, include the social services, manufacturing, agriculture, trade and the private household sector. It is important to emphasise that the main sectors contributing to economic growth often employ a small percentage of the total workforce. For example, the manufacturing sector contributes fifty-five *per cent* to the regional GGP, yet only employs thirteen *per cent* of the workforce, whilst the agricultural sector contributes an average of six *per cent* to GGP, yet employs approximately twelve *per cent* of the workforce (refer to table 4.5).

Table 4.5: Employment by economic sector (StatsSA, 1999).

Economic sector	Mhlathuze Catchment
Agriculture *	12.60%
Mining	3.90%
Manufacturing	13.00%
Utilities	1.30%
Construction	7.90%
Trade	12.30%
Transport	8.50%
Business Services	6.00%
Social Services	22.20%
Private household	12.20%
Unspecified	0.10%
Total	**100.00%**

*Local experts are of the opinion that employment within the agriculture sector is under-estimated at 12.6% (due to certain areas not visited during the census) and a more realistic employment rate could in fact be close to 25%.

4.5.3 Access to basic services

The large majority of the rural population in the Mhlatuze Catchment reside in less arable areas where facilities are poor or nonexistent. This has been attributed to the social engineering of apartheid legislation, for example, a low proportion of rural dwellers have access to services such as electricity, sanitation and refuse removal, whilst a high percentage of urban dwellers already have or are in the process of obtaining such services (Versveld *et al*, 2000:63). Consequently, many rural individuals have struggled to support themselves, let alone their families, resulting in extreme poverty.

The various levels of household access to water services in the Mhlatuze Catchment is denoted in table 4.6 and this is compared with the provincial average (Dallimore, 2000:15). It is worth noting that this data is now five years old and, given the aims of the Reconstruction and Development Programme (RDP) as well as the government's commitment to provide water for BHN and basic infrastructure, it is anticipated that some improvements would have occurred in the interim.

Table 4.6: Household access to water (StatsSA, 1999).

	Mhlathuze Catchment	**Kwazulu-Natal**
Piped water in dwelling	26.10%	39.20%
Piped water on site	2.80%	8.70%
Public tap	8.00%	18.30%
Water carrier/tanker	1.10%	1.20%
Borehole/rainwater tank	11.30%	6.70%
Dam/river/stream	49.10%	24.30%
Unspecified/other	1.60%	1.60%
Total	**100.00%**	**100.00%**

From the table above, it is evident that there is a large contrast between the catchment and KZN as a whole in terms of access to basic services. For example, just over one-quarter of households in the catchment have piped water in their dwellings, compared with just under forty *per cent* of individuals residing in KZN. Furthermore, just under fifty *per cent* of these households rely on dams, rivers or streams for water. These are sources which are generally considered unsafe. The comparative figure for non-piped water supply for the province as a whole is about twenty-four *per cent*.

4.6 Social characteristics

The Mhlatuze Catchment is characterised by two extreme zones of development. The coastal area is highly developed, with modern housing, shopping centres and extensive industrial activity, whilst the upper regions of the catchment are undeveloped and very rural. Individuals residing in these rural areas are largely engaged in a subsistence lifestyle and depend on this type of farming for an income and for survival (Versveld *et al*, 2000:20). The juxtaposition of a highly developed coastal zone, perceived as an area of relative wealth, and impoverished rural settlements in the upland regions, inevitably has significant economic and social consequences, which could culminate in conflict and tension concerning the management of natural resources. This tension is essentially a "microcosm of the contrast between political struggles over the environment that occur in developed and developing countries" (Preston-Whyte, 1996:183). Hence, first world systems tend to encourage the conservation and preservation of natural resources, while third world reality and needs result in the environment being perceived as a source of food and livelihood.

4.7 Impacts associated with alien invasive vegetation

The invasion of natural ecosystems by alien plants is a serious environmental problem that threatens the sustainable use of benefits derived from such ecosystems (van Wilgen *et al.*, forthcoming:2). Although alien invasive vegetation may have benefits, for example it may provide food for human consumption (e.g. guavas) or may have aesthetic beauty, substantial costs are associated with this vegetation. Adverse impacts include:

- Streamflow reduction;
- Loss of biodiversity (as well as ecosystem resilience);
- Increased costs of fire protection and damage in wildfires;

- Loss of potentially productive land;
- Loss of grazing potential and livestock production;
- Erosion following fires in heavily invaded areas; and
- Siltation of dams (DWAF, 2000b:16).

Only those impacts associated with alien vegetation which are the most relevant to and important for purposes of this dissertation will be explored in detail below.

4.7.1 Streamflow reduction

Extensive research has been conducted in South Africa to document the effects of alien vegetation on streamflow. For example, a twenty-year experiment was undertaken in two small catchments in the KwaZulu-Natal Drakensberg to investigate the impacts of pine trees on surface water resources. This study revealed that there was an eighty-two *per cent* reduction in streamflow subsequent to the planting of pines.

Previous studies suggest that the extent of streamflow reduction is dependent on a number of factors, namely:

- **Location** of alien vegetation, that is, whether the vegetation is situated inside or outside of riparian zones. Water uptake is greater in the riparian zones due to the high availability of water in these zones (Carpenter, 1999:3). Studies have established that in some cases water use in riparian zones is almost double that of the same trees growing away from rivers.
- **Size** or biomass of the alien vegetation. An increase in biomass is accompanied by augmented plant transpiration rates giving rise to a greater reduction in streamflow. Invasions of open grasslands and riparian zones are likely to have a greater impact than invasions of already dense forest or shrubland.
- **Species** and **size** of indigenous vegetation which replaces the alien vegetation in the long term. It should be noted that not all alien plant infestations use more water than the indigenous vegetation that they replace but, as a general rule, trees tend to utilise more water than grasses or shrubs.

- **Species** of alien plants. Water use varies according to species and consequently, the magnitude of reduced stream flow is dependent on the type of alien plant and the size of the area invaded. Different alien plant species have been shown to have different water use characteristics (e.g. *Eucalyptus* and *Pinus* species) (Le Maitre *et al.*, 1997:3).

It is important when analysing the effects of alien plants on streamflow to be conscious of the fact that not all alien plants utilise more water than their indigenous counterparts. Rather this is dependent on the biomass of plants and their transpiration rates. Indigenous vegetation tends to have smaller leaf areas than alien plants and thus, the interception of rainfall is lower. As a result of this alien invasive vegetation has a greater adverse affect on water resources. Most indigenous vegetation becomes dormant in the dry periods, as opposed to invasive alien plants which transpire all year round. The conclusion is, therefore, that indigenous species are more conservative water users (Carpenter, 1999: 4).

4.7.2 Increased fire management costs and soil erosion problems

Studies have established that fire management costs increase substantially with the invasion of alien vegetation. This is attributed to the augmented above ground biomass associated with alien invasive trees and shrubs which in turn increases the fuel loads and fire intensity (van Wilgen *et al.*, 1997:409). The increased fire hazard posed by the alien vegetation is largely dependent on the type and size of alien vegetation. For example, fuel loads of grass and shrubs range from 0.3-4 tonnes per hectare, while those of trees like pines and gums range from 10-25 tonnes per hectare. The augmented fuel load associated with alien invasive trees is a potential threat to land use activities such as timber plantations and can give rise to substantial damage costs (Carpenter, 1999:19).

Numerous alien invasive species, e.g. black wattle and pine trees, have shallow rooting systems and are unable to withstand high volumes of flood waters. Thus, during times of heavy deluge massive flooding results along with accelerated river bank erosion. A study undertaken in the Hartbeespoort Dam catchment highlights how dense stands of invading alien vegetation on the banks of the Crocodile River have decreased the capacity of this river to channel high volumes of flood water, resulting in massive flooding, soil erosion and decreased bank stability (DWAF, 1995:3).

4.7.3 Biological diversity

Biological diversity is a term used to describe the number, variety and variability of living organisms with respect to genes, species and ecosystems (Brown *et al.*, 1993:8). It is critical for maintaining the **resilience** of ecosystems allowing ecosystems to respond to changes induced by economic activity. The resilience of ecosystems refers to the capacity of an ecosystem to maintain its characteristic patterns and rates of processes such as primary productivity in response to environmental conditions. Therefore, the more diverse a system, the greater its ability to withstand shocks and stresses (Khan, 1995:360).

Alien invasive plants are considered one of the greatest threats to biodiversity and are largely responsible for the extraordinarily high number of endangered and threatened species that exist (Hosking and du Preez, 1999:445). This is ascribed to a number of factors, namely, many of these alien species have no natural predators and competitors and as a result are able to grow faster than most indigenous species. Furthermore, many of them are more efficient users of available resources like water and sunlight (McNeely, 1990: 32).

4.8 Working For Water Programme

Alien plant invasion threatens the existence of natural resources and adversely impacts on the surface water resources of a catchment. The Working for Water (WFW) Programme, which is a government funded initiative that aims to sustainably control invading alien plant species (under the auspices of the DWAF) has been operating in the Mhlatuze Catchment, more specifically the Mfuli catchment, since 1997.

The objectives of the WFW Programme include the following:

- To enhance water security;
- To improve the ecological integrity of natural systems;
- To restore the productive potential of the land;
- To invest in the most marginalised sectors of South Africa and enhance their quality of life through job creation;
- To train people in a range of skills in order to empower these individuals to acquire other employment as the programme develops;
- To develop economic benefits from wood, land and water; and
- To establish secondary industries which can lead to those in the programme finding long-term employment (DWAF, 2000a:2).

One of the most significant benefits associated with alien plant eradication is the provision of employment and the empowerment of labourers through training. It has been estimated that 23 662 jobs were created by the WFW Programme during 1998 alone, the duration of which is expected to last for a minimum of 20 years (DWAF, 1999:5). Consequently, it is evident that the WFW Programme promotes social upliftment, alleviates poverty in the rural areas and eases escalating unemployment rates in South Africa (DWAF, 1997:3).

It is envisaged that the WFW Programme can serve as a platform to train people in a range of skills from machine operation and driver's licences, to teamwork, supervision, management and entrepreneurial skills. This will assist people in seeking alternative employment once the eradication process has been completed (DWAF, 1997:3). Skills training is critically important, especially as it will be difficult to employ the same people as the programme develops. For example, as clearing progresses downstream, it may be necessary to substitute workers from an upstream community with those from a downstream community around which the eradication will resume.

4.9 Legislation pertaining to alien vegetation

Alien invasive vegetation control in South Africa is currently regulated by the **Conservation of Agricultural Resources Act (Act 43 of 1983)**. In terms of this Act, invasive species occurring on private land must either be eradicated or effectively controlled. However, although it is evident that the responsibility for eradicating alien vegetation lies with the owner of private property, in the past this responsibility has not necessarily been acted upon by landowners. The WFW Programme has compounded this inaction of landowners by effectively subsidising those who have mismanaged their land (DWAF, 2000a:10). Consequently, this Programme has in the past, absolved owners of any responsibility for clearing alien vegetation and given them little or no incentive to undertake the necessary tasks when required to do so in the future (Umgeni Water, 2000:13).

The **Conservation of Agricultural Resources Act** is in the process of being updated and new regulations pertaining to alien vegetation are due to be promulgated within the next year or so. It is anticipated that the new regulations will create a mechanism for preventing the sale, transfer, rezoning, subdivision or change in land-use practice of infested land. Furthermore, it is expected that certain powers will be delegated to the Working for Water officials (DWAF, 2000a:10).

Other legislation which pertains to the management of invading alien plants includes the **Convention on Biological Diversity (1992)** and the **Forest Act (Act 122 of 1984)** which has been superseded by the **National Water Act (Act 36 of 1998)** (NWA). As a signatory to the biodiversity convention, South Africa is obliged to "prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species" (DWAF, 2000a:5). In terms of the NWA the planting of alien trees, e.g. commercial forestry plantations, is to be strictly controlled, whilst the planting of riparian zones and/or wetlands is forbidden.

4.10 Conclusion

It is evident from the findings presented in this chapter that the Mhlatuze Catchment is dominated by the agricultural, forestry and industrial sectors. All these sectors are important either in terms of their contribution to the local economy or their employment of local people. The success and future growth of these sectors is largely dependent on the availability of water resources. It has been established that the Mhlatuze Catchment is 'water stressed', since there is insufficient water to meet current, let alone future demands. This scenario will deteriorate in the future, due to population and economic growth, the launching of the Richard's Bay SDI and given that the rural population has not been allocated any significant volumes of water at present. Thus, if future growth in the catchment is to be encouraged along with the social upliftment of the rural poor, it is essential to examine means of augmenting the existing water supply.

It is recognised that although many species of alien invasive vegetation have benefits, e.g. provide food and have aesthetic beauty, the invasion of natural ecosystems by these plants is a serious environmental problem. The following adverse effects are associated with alien plants: streamflow reduction, biodiversity loss, increased fire management costs, and loss of potentially productive land. As a consequence, it is essential to control the proliferation of these invasive alien species.

CHAPTER FIVE
METHODOLOGY

5.1 Introduction

A multidisciplinary approach was adopted to document the findings of this research project because of the wide range of biological, economic and social implications associated with the eradication of invasive alien vegetation. The scope of this research project was confined to the high-lying areas of the Mhlatuze Catchment in the immediate vicinity of Melmoth, totalling 48 633 hectares. Qualitative and quantitative techniques were employed to assess the impacts associated with eradication as well as to establish the economic viability of this activity in the study area. From the literature review conducted it is apparent that the impacts of alien plant eradication are diverse and that numerous individuals will be affected by such a process. Consequently, a comprehensive assessment of these impacts is imperative for the success of the Cost-Benefit Analysis (CBA). A thorough examination of the main methods selected for this research project is presented in this chapter.

5.2 Source of data collected

All the data derived for this research project directly or indirectly pertain to the impacts arising from the eradication of alien plants. Data were gleaned from an array of sources which included books, journals, reports and government as well as policy documents. Furthermore, the research area was visited on a number of occasions and formal in-depth interviews were conducted with experts, major stakeholders and WFW employees. The purpose of these interviews was to identify the most significant impacts and acquire deeper insight into the eradication process. The use of interviews as a research tool was an essential component of this project, since it dealt with people's perceptions, attitudes and beliefs regarding alien plant clearing. All the data generated from this process were used to compile the results section of the report that contextualises the costs and benefits affiliated to alien plant eradication.

5.3 Research design and interviews conducted

A longitudinal research design, where data is collected at several intervals by means of questionnaire surveys, was adopted for this study (Bless and Higson-Smith, 1995:67). Since the bulk of the data was collected by means of questionnaires careful attention was paid to both the design and structure of the questionnaire. The questionnaire design was based on criteria proposed by Parfitt (1997).

A total of thirteen stakeholders located in the study area and five experts were interviewed. These interviews were largely non-structured and this encouraged the respondents to relate their own experiences, discussing issues which **they** felt were relevant and/or significant. As a consequence of the small number of individuals interviewed, it was possible to employ an in-depth interviewing strategy, which enabled the researcher to obtain insight into the impacts of alien vegetation on the environment and effects of this on society.

Since some of the data to be collected were categorised as sensitive (e.g. information pertaining to income and wages of employees), there was a high probability that the taping of interviews might give rise to non-responses and information loss. As a result note-taking was solely relied upon in the interviews. All the interviews were personally conducted ensuring that maximum insight into the responses given by the individuals could be attained.

5.3.1 Key informant interviews

As defined by Kumar (1987:7), "key informants interviews involve interviewing a select group of individuals who are likely to provide the needed information, ideas, and insights on a particular subject". In-depth interviews were conducted with five experts who were purposefully selected according to the organisation they represent and their position (refer to Appendix I page 138 for a list of these targeted individuals and the purpose of the interviews). The interviews were undertaken over a period of nine months, from December 2000 to August 2001, with the majority of them taking place in December. Each individual interview lasted approximately two hours.

Due to the wide array of positions held and organisations represented by these experts, unique questionnaires were compiled for each interview. These questionnaires were tailored to the specialised field of each expert. The questionnaires predominantly comprised open-ended questions, because this encouraged individuals to express their answers in a way they felt most appropriate, as well as raise issues that the interviewer may not have anticipated. As a rule of thumb, general questions were included at the outset of the interview to instill confidence in the respondents, with more specific questions following later, hence narrowing the scope and focus of the interview (Flowerdew and Martin, 1997:86).

These experts were asked about what they considered to be the most significant impacts associated with alien plant eradication and on their area of expertise (refer to Appendix I page 138). Based on the responses obtained from these experts, on the stakeholder responses and on the literature survey conducted, those impacts with the highest relative importance were identified and included in the analysis. The impact parameters selected for this survey include: harvesting of alien vegetation, streamflow amount, biodiversity and fire control.

5.3.2 Interviews with WFW employees

The WFW employees residing and working in the study area were interviewed in order to ascertain their present social status, to evaluate the social effects of alien plant eradication, and to establish the benefits, if any, received from the WFW Programme. The benefits associated with this programme which were idenfitied, included: employment creation and the reduction of poverty and crime.

A highly-structured, standardised questionnaire encompassing closed-ended questions, that confine the choice of response by forcing the interviewee to respond in terms of the present categories or alternatives, was employed (refer to Appendix II page 139 for the questionnaire structure). The questionnaire structure presented in this Appendix facilitates an easy comparison of the data collected and enables relationships between answers to different questions to be established (Bless and Higson-Smith, 1995:109).

In-depth interviews with thirty randomly selected WFW employees were conducted on-site on two separate occasions during December 2000. The number of interviews conducted daily ranged from ten to twenty, according to the spatial location of the alien plant eradication tasks assigned by co-ordinators of the programme. When the tasks assigned were situated near main roads which were easily accessible, numerous interviews were undertaken; however, when accessibility to areas was poor a much lower number of interviews were conducted. Each of the interviews took approximately 45 minutes.

Since the large majority of respondents only conversed in *isiZulu*, it was necessary to employ an interpreter to translate both the questions contained in the questionnaires and responses elicited. Previous studies have shown that translation poses serious problems in that it prevents open discussion between the interviewee and the respondent. However, such problems do not negate the collection of data where translators are required. For purposes of this study, the project manager who resides in the immediate vicinity and has extensive knowledge of the alien vegetation eradication process as well as considerable interviewing and fieldwork experience, was employed to translate. These are critical components which contribute to accuracy and are required for the success of any research project.

Each one of the WFW employees was co-operative and made a concerted effort to answer all the questions posed to the best of his/her ability. One particular problem that was encountered in these interviews was the inability of many labourers to comprehend terms such as biodiversity. As a consequence the data collected for some sections of the questionnaire were very limited and could not be utilised in the study. Where possible the data collected from these interviews were analysed to ascertain the trends and/or relationships which prevailed.

5.3.3 Interviews with stakeholders

A substantial component of this research project entailed conducting interviews with major stakeholders. These included private farmers and large companies such as Mondi and Sappi. This was done in order to capture salient information pertaining to the impacts flowing from alien plant eradication. All thirteen stakeholders residing in the study region, who were selected from an extensive list supplied by the Melmoth Farmers Association, were interviewed (refer to Appendix III page 144). A series of interviews was conducted with these stakeholders.

5.3.3.1 First series of interviews conducted

A non-scheduled, unstructured interview was conducted with each and every stakeholder in the study area in order to elicit individuals' concerns regarding alien plant eradication. Given this approach, principally open-ended questions were used for the interviews. Closed-ended questions were only used where the ranking of various impacts associated with the eradication of alien vegetation was required. The ranking of these impacts was an essential component of this research project, since it was simply not possible to consider all the economic impacts flowing from eradication. A sound understanding of the issues pertaining to alien invasive plant eradication was established from this first series of interviews. The interviews were conducted during the first week of December 2000, and each interview lasted approximately two hours.

Based on these interviews, a hypothetical model was constructed in an attempt to discern what additional data would be required to fulfil the objectives of the study. This model was then used as the basis for compiling a second questionnaire which was to be administered to the same stakeholders later.

5.3.3.2 Questionnaires administered

One of the main objectives of the questionnaire compiled was to identify the actual costs sustained by stakeholders and to define the benefits obtained from alien plant eradication. In most instances, alien invasive vegetation located on the stakeholders' land was scattered over a large area and consequently, it was extremely difficult for individuals to establish the costs associated with removal. As a result, it was necessary for stakeholders to convert all the medium and/or light alien vegetation infestations on their land, into dense hectares (i.e. hectares with a canopy cover of one hundred *per cent*). This was done in order to facilitate a more accurate estimation of the 'direct costs' of eradication. Stakeholders were asked to consider all timber located **outside** of formal plantations as alien invasive vegetation and to include the removal costs of such timber in their assessment of the costs associated with alien plant eradication. The total condensed area of invasive alien vegetation in the study area amounts to 3 767 hectares.

The design of the questionnaire was such that it could be disseminated and filled in by stakeholders in private. This approach was necessary in order to grant respondents time to reflect on and obtain factual information pertaining to the actual costs and benefits associated with eradicating alien invasive vegetation. Furthermore, such an approach enabled respondents to complete the questions at their own pace. Stakeholders had more time to consider their responses and were not influenced by the presence, personality and intonation of an interviewer. As a result of this lack of direct personal contact, it was imperative to pilot the questionnaire to verify the research techniques employed and ensure the researcher's and respondent's frames of reference corresponded (Blaxter *et al.*, 1996:121).

Piloting the questionnaire helped in anticipating and consequently avoiding potential problems. In addition, sources of bias, for example, questions interpreted differently by respondents, were identified and changed accordingly. A potential problem averted as a consequence of this piloting was recognition that the income brackets defined initially were too small. As a result, both the size and number of income brackets included were increased. All the difficulties encountered with the pilot questionnaire were altered accordingly and questionnaires were then either e-mailed or faxed to the targeted individuals during mid-July 2001. Such a distribution was possible as it was established that all respondents had access to at least one of these means of communication.

The responses obtained from these questionnaires were thoroughly analysed and were used to compile a final questionnaire.

5.3.3.3 Final series of interviews conducted

At the outset it is essential to emphasise that the purpose of compiling a final questionnaire for the interviews with each stakeholder in the study area, was to:

- Clarify any issues which were unclear from responses already obtained.
- Follow-up on unanswered questions.

- Address any concerns which stakeholders might have.
- Elicit monetary values for non-market goods, such as biodiversity, that do not pass directly through markets.

Standardised questionnaires comprising predominantly open-ended questions were complied for purposes of these interviews (refer to Appendix IV page 145). The questions were presented to each respondent in an identical manner to minimise the role and influence of the interviewer, as well as to ensure a more objective comparison of the results. Furthermore, the WTP questions were phrased so as to present a realistic scenario to the various stakeholders and the appropriate payment vehicle was overtly defined as a conservation trust fund (Bateman *et al.*, 1995:169). Interviews were conducted during August 2001 and lasted approximately one hour each.

5.4 Appraisal of costs and benefits

The costs and benefits associated with alien plant eradication were elicited from stakeholders and then calculated for the study area based on the assumption that eradication is undertaken annually and that the project lifespan is ten years. Where possible the values of impact parameters connected with the eradication process were quantified. The various methods employed to value these impact parameters are presented below.

5.4.1 Total costs

The costs associated with eradication such as the costs of labour, herbicide and transport, were elicited directly from the interviews conducted with stakeholders. The stated costs were per dense hectare of alien invasive vegetation. It was, therefore, necessary to average the costs obtained from different respondents and then multiply these by the 3 767 densely invaded hectares.

5.4.2 Benefits of alien vegetation eradication

Benefits flowing from alien plant eradication are utilisation of alien vegetation, reduced fire management costs, increased streamflow and increased biodiversity. Each of these will be discussed below.

5.4.2.1 Utilisation of alien vegetation

Benefits from utilisation of alien vegetation depend on the value of timber used for paper and pulp purposes. The value of this benefit was calculated by multiplying the areas of different alien vegetation which are utilizable (e.g. *Eucalyptus*, *Acacia* and *Pinus* species) with the monetary value that each stakeholder receives for each of these species at the paper and pulp mill. The monetary values obtained for various species would finally be summed to obtain a total value.

5.4.2.2 Reduction in fire management costs

Fire management costs increase substantially with infestation of alien vegetation. Thus, clearing of this vegetation will reduce fire costs. The reduction in burning costs which arise from alien plant eradication was ascertained by establishing from stakeholders how much costs would decline per hectare if alien vegetation were eradicated. This stated amount elicited from each stakeholder was then averaged and multiplied by the number of invaded hectares in the study area.

5.4.2.3 Increased streamflow

To calculate the increased streamflow benefit arising from eradication it is necessary to calculate the amount by which streamflow is reduced by alien vegetation. This is possible using the following formula, which was derived from earlier research (Le Maitre *et al.*, 2000:398):

$$\textbf{Streamflow reduction (mm)} = \textbf{0.0238 x biomass (g/m}^2\textbf{)}$$

This equation converts estimates of biomass into estimates of streamflow reduction in millimetre rainfall equivalents. The equation was based on data from mature plantations with a closed canopy. Consequently, canopy cover in areas with less than one hundred *per cent* had to be adjusted to equate to a canopy cover of one hundred *per cent.*

The biomass differs according to the composition of the vegetation structure (i.e. tall trees, medium trees and shrubs) and thus, different equations exist for these various vegetation structures (refer to table 5.1).

Table 5.1: Biomass equations for different vegetation structures (Le Maitre *et al.*, 2000:398).

Equation number	Vegetation structure	Biomass (g/m^2)
1	Tall alien shrubs	$b=5\,240 \log_{10}(a)-415$
2	Medium alien trees	$b=9610 \log_{10}(a)-636$
3	Tall alien trees	$b=20\,000 \log_{10}(a)-7060$

Once the streamflow reduction due to the alien plants had been established, it was possible to calculate how much water would be available in the future. This available water was then divided amongst the various sectors according to current allocations. These amounts were then multiplied by the current water tariffs which the different sectors face and aggregated to give the value of total streamflow reduction.

5.4.2.4 Increased biodiversity

The contingent valuation method (CVM) was used to appraise the increased biodiversity associated with alien plant eradication. This entailed eliciting the amount respondents would be willing to pay (WTP) for an increase in biodiversity (for more information pertaining to this method, refer to section 3.4.3.3 page 30).

For purposes of ascertaining these WTP values for biodiversity, the payment vehicle was defined as a conservation trust fund, which had the advantage of realism as well as of immediate applicability. All respondents were assured that any contributions made to this conservation trust fund would be managed efficiently and payments made would be used to enhance biodiversity levels in the area. Furthermore, individuals were informed of the benefits which would accrue from an increase in biodiversity. This was done in order to assist them in assigning a value to it. It was intended that individual WTP amounts would then be summed to obtain the total value of increased biodiversity.

Much attention was devoted to whether or not individuals stated a positive WTP for biodiversity and whether this was related to variables such as disposable income. Based on economic theory it was expected that a positive correlation would be found between WTP for increased biodiversity and the individuals' disposable income.

5.5 Comparison of costs and benefits

The comparison of costs and benefits arising from the eradication of alien plants is a critical phase of the CBA. However, because the cost and benefit flows occur in different time periods, it was necessary to convert all flows into common units for purposes of comparison. The present value (PV) technique was employed in this research study to convert all impacts into present consumption values (i.e. base year was set at 2001). Where information was only available for other years, figures were adjusted accordingly to reflect 2001 values. This adjustment was obtained by discounting the stream of costs incurred and benefits derived in the project's lifetime (i.e. ten years).

5.5.1 Selection of a discount rate

The CBA technique evaluates projects by discounting future cost and benefit flows into present value terms, because of time preference (refer to section 3.2.3). The derivation of a discount rate is a fundamental step in CBA and its use is relevant to the project analysis and outcome. The discount rate for this study was based on the average real interest rate on long-term bonds in South Africa over the last ten years. This rate was chosen in order to obtain an accurate reflection of the rate of return on investments which are low-risk and longer-term (and thus comparable to the current project).

The discount rate for this project was calculated in the following manner (see Appendix V for further details):

- Nominal interest rates on ten-to fifteen- year bonds and rates of increase in consumer prices were obtained from SARB data, for 1990-2000.
- The increase in consumer prices was subtracted from the interest rate for the ten years to obtain an estimate of the real interest rate.
- The average real interest rate for the ten-year period was found to be five *per cent*.

The discount rate employed for purposes of this research project was thus set at five *per cent* for the next ten years. Using this discount rate, the NPV of alien plant eradication was calculated.

5.6 Sensitivity analysis performed

A sensitivity analysis of the final NPV outcome to the discount rate employed as well as to those assumptions made with relatively low confidence estimates was performed. The sensitivity of NPV to both a reduction and an increase in the discount rate was examined. Two values, one standard deviation on either side of the project discount rate, were selected for this analysis, that is, a zero and ten *per cent* rate respectively. The assumptions with low confidence estimates for this project (ascertained by ranking them) include: the anticipated increase in streamflow subsequent to eradication, and water prices that various sectors will face in the future. The effect of changes in these components on the final NPV outcome were investigated. Based on these findings it was possible to establish to which components, if any, the NPV is sensitive.

5.7 Study limitations

The constraints of these methods employed include:

- The NPV outcome is dependent on the choice of the discount rate and the time period over which cost and benefit flows occur. Consequently, the outcome may vary considerably from that obtained if an alternative discount rate is employed.

- Equal welfare weights were used in this study and distributional effects were ignored. This may give rise to accepting projects which make the rich richer and the poor poorer.
- The actual costs and benefits are obtained directly from farmers and other stakeholders which may be prone to errors or inaccurate.
- Translation of questions was necessary when interviewing the WFW employees and is a potential problem, especially where translation is not one hundred *per cent* accurate.
- The WFW project manager was employed to translate questions contained within the questionnaire and responses elicited from WFW employees. Consequently, the question of neutrality and objectivity must be raised in terms of his involvement in the fieldwork.

However, despite these findings, the techniques identified are still useful and can play a critical role in future decision making.

5.8 Conclusion

The approach and methods used in this research project have been outlined and explained above. It is evident that both a qualitative and quantitative approach was adopted and that the questionnaire survey was an indispensable tool utilised to extract primary data relating to individuals' attitudes and perceptions concerning alien plant eradication. Consequently, in an attempt to enhance the quality of research data collected for this project, a substantial proportion of time was dedicated to the questionnaire design. Most of the costs and benefits flowing from the eradication of alien plants were quantified and, where this was not possible, a qualitative analysis of the impacts was undertaken. Based on the findings, that is the comparison of actual costs and benefits associated with alien vegetation eradication, the economic viability of this process was evaluated and suitable recommendations formulated.

CHAPTER SIX

RESULTS

6.1 Introduction

This chapter scrutinises the economic viability of alien plant eradication in the upper reaches of the Mhlatuze Catchment by comparing the costs and benefits associated with this process. It is necessary to ascertain what constitutes invasive alien vegetation eradication in order to ensure appropriate decisions are taken in the future. The study area comprises a total area of 48 633 hectares, of which approximately eight *per cent* or 3 767 hectares, is densely infested with invasive alien vegetation. Due to temporal and financial constraints it was not cost-effective to examine all the benefits flowing from the eradication process, so these were ranked according to their level of importance. The ranking was based on expert opinion and on the literature review. The following benefits were incorporated in this study: increased streamflow and biodiversity, reduced fire management costs, and the harvesting of suitable alien invasive vegetation. Where it was not possible to quantify impacts these were assessed qualitatively.

6.2 Extent of alien plant eradication

At the outset it is essential to accentuate that all farmers and other major stakeholders who form part of the commercial forestry sector and who reside in the study area are engaged in a programme to eradicate alien invasive vegetation. However, the level of eradication undertaken differs amongst these stakeholders, with some merely engaging in sporadic clearing. Furthermore, it was established from interviews conducted that eradication has been less rigorous on commercial forestry land (refer to table 6.1). For example, this sector owns 35 541 hectares or seventy-three *per cent* of the total study area, but this includes 3 249 hectares of invasive alien vegetation, which represents eighty-six *per cent* of the total invaded area.

It was apparent from the interviews that all the commercial forestry companies located in the study area (Mondi, Sappi and CTC) have, or are in the process of embarking on, an alien weed control programme. For example, Sappi are engaged in a five year plan to combat alien plants (Buchler *pers comm.*).

It is worth noting that some stakeholders have guest houses and some do not. It is anticipated that the extent of alien plant eradication is partly dependent on this, which should be kept in mind when analysing the extent of alien plant clearing in the study area.

Table 6.1: Extent of alien plant eradication in the study area.

	Total area owned (ha)	Area comprising alien vegetation (ha)
Commercial forestry land	35541 (73%)	3249 (86%)
Private farmland	13092 (27%)	518 (14%)
TOTAL	**48633**	**3767**

6.3 Cost flow of alien vegetation eradication

Alien plant eradication costs are contingent upon the control method adopted (mechanical, chemical or biological control). It was evident that at least one biological control agent has been released in the immediate vicinity of the study area to combat the proliferation of the Port Jackson Willow (*Acacia saligna*) and has proved to be very successful (Olkers *pers comm.*). Biological control is expected to play a critical role in the control of alien invasive vegetation in the future and where successful will reduce costs considerably. However, although these bio-control agents are self-sustaining which means that follow-up operations are not required, this is a very lengthy procedure and it takes on average between two and four years to formulate an appropriate agent. Consequently, such control cannot be depended upon (Olkers *pers comm.*).

Individuals in the study area adopted both mechanical as well as chemical control methods. The costs associated with these methods include capital, operating and maintenance costs as well as the costs of follow-up operations. Rehabilitation costs are excluded from this analysis since it was evident from questionnaire responses that no individuals had been engaged in such a process. Rather indigenous vegetation was left to establish itself naturally subsequent to clearing away the alien plants.

Total costs can be divided into total variable costs (TVC) and total fixed costs (TFC). For purposes of this project, TVC, which vary with output (levels of eradication), include wages and salaries, herbicides, transport, running expenses, and the cost of protective clothing. These costs are dependent on the degree of infestation (the density of alien plant cover), the alien invasive plant species, the age of the species and ease of access to the area (Hosking and du Preez, 1999:445). From interviews conducted, it was established that no fixed costs existed, as machinery and other equipment was hired.

The total costs anticipated over the ten-year lifespan of the alien plant eradication project were elicited from stakeholders and averaged. From the interviews it was estimated that on average sixty-five *per cent* of the total costs pertained to labour, whilst twenty-five and ten *per cent* were correlated to herbicide and other costs like hired equipment and transport. The average costs of the various phases of alien plant eradication (refer to table 6.2) are based on this categorisation and on the following assumptions:

- The average weighted daily wage rate for labourers (ascertained from stakeholders) was fixed at R25.00 per person. In the initial phases of eradication this average would be disproportionately larger since more skilled labourers are required (Schramm *pers comm.*).
- All stakeholders adopted the same control methods (refer to table 6.3).
- **Garlon** was the only herbicide considered in this analysis, since it was established from interviews conducted that over eighty-five *per cent* of the total farmers and other stakeholders residing in the study area utilised this particular herbicide. This is a very strong assumption to make, given that many stakeholders utilise a selection of herbicides. The cost of **Garlon** is R142.00 per litre (PPRI, 2000:20).
- For the study area, it was anticipated that four follow-up operations would be required and this was based on the period of time needed to ensure alien plant density declines to less than ten *per cent* cover (Goodall *pers comm.*).
- Each stage of eradication is initiated annually in order of sequence (refer to table 6.2). In those cases where this is not applied, the costs presented in this study will be inaccurate because alien vegetation along with total eradication costs will increase rapidly if regular, annual, eradication is not undertaken.

Table 6.2: Total costs associated with eradicating alien invasive vegetation for different phases.

Stages of eradication	Labour cost (Rands/hectare)	Herbicide cost (Rands/hectare)	Other costs (Rands/hectare)	Total cost (Rands/hectare)
Initial eradication	R 1,300	R 500	R 200	R 2,000
First follow-up	R 494	R 190	R 76	R 760
Second follow-up	R 280	R 107	R 43	R 430
Third follow-up	R 156	R 60	R 24	R 240
Fourth follow-up	R 123	R 48	R 19	R 190
Maintenance	R 104	R 40	R 16	R 160

The above table highlights that if regular eradication is embarked upon, the total costs associated with clearing decline with each successive year (refer to table 6.2). For example, it is apparent from this table that the total costs of R2000/ha sustained in the initial stages of eradication are high in comparison to those of the maintenance phase at R160/ha. This is not surprising since the density and spread of alien vegetation is systematically reduced with regular eradication, thus making it easier to manage as well as to maintain.

Table 6.3: Control methods adopted for alien plant eradication based on stakeholder response.

Species	Initial clearing treatment	First follow-up treatment
Bugweed (*Solanum mauritianum*)	Felling with slashers Cut-stump treatment	Foliar spray
Wattle (over 2metres)	Fell with chain saws	Spray wattle
Wattle (0-2m)	Fell with slashers and treat stump immediately	Foliar spray
Bramble (*Rubus cuneifolius*)	Foliar spray	Foliar spray
Eucalyptus grandis (trees)	Cut-stump treatment treat at once	Foliar spray
Lantana	Slash with slashers and cut stump treatment	Foliar spray
Triffid weed	Slash with slashers and cut stump treatment	Foliar spray

6.3.1 Initial eradication phase

In the initial eradication phase, the total costs are high due to the dense invasion of alien vegetation that prevails (refer to plate 6.1 for the before and after scenarios concerning alien plant eradication).

In the initial eradication phase, wages and salaries account for R1 300/ha, which is equivalent to approximately 52 labour days at R25.00 per labour day per hectare. This represents a clearing rate of roughly 0.019ha/labour day. It is evident that this first stage of eradication is very labour intensive. The labourers' duties include the felling of trees, the carrying and stacking of wood outside the cleared areas, and the application of herbicides to vegetation stumps.

The total herbicide cost associated with this phase is R500/ha, which essentially amounts to 3.5 litres of concentrated Garlon per hectare. Transport and equipment costs, which include costs of protective clothing, running expenses, petrol/oil as well as spare parts, comprise the balance of the total costs and work out to R200/ha.

Plate 6.1: Before and after initial eradication on 'Kataza Farm', Mondi, in the Mhlatuze Catchment.

6.3.2 First follow-up phase

Assuming that the initial eradication phase has been properly implemented, the total overall costs associated with alien plant eradication diminish from R2000/ha to R760/ha. This is a reduction of sixty-two *per cent* or R1240/ha in the first follow-up phase (refer to table 6.2). This decline in costs is a consequence of the lower vegetation density because only the re-growth and seedlings which appear after the initial control require removal (Goodall *pers comm.*).

The labour cost amounts to R494/ha, which corresponds roughly to 20 labour days at R25.00 per day per hectare. Thus, 32 fewer labourers per hectare are required for clearing purposes in this phase, because the average clearing rate per labourer increases from 0.019ha/labour day in the initial phase to 0.05ha/labour day in the first follow-up phase. This represents a more or less three times as rapid rate of removal compared with the initial eradication phase. Herbicide costs account for R190/ha of the total cost in this stage of eradication, which is equivalent to approximately 1.4 litres of concentrated Garlon per hectare. Transport and equipment costs of R76/ha comprise the remainder of the total cost.

6.3.3 Second follow-up phase

Total costs decline from R760/ha to R430/ha provided previous eradication stages have been appropriately executed. This represents a forty-three *per cent* reduction, that is, R330/ha in the second follow-up phase (refer to table 6.2). The labour cost is R280/ha, which is synonymous to approximately 11 labour days at R25.00/day per hectare. The mean clearing rate per labourer escalates to around 0.09ha/ labour day in the second follow-up phase, which is almost twice as rapid as that recorded in the first follow-up phase. The herbicide cost amounts to R107/ha, which is equivalent to 0.75 litres of concentrated Garlon per hectare. Transport and equipment costs total R43/ha.

6.3.4 Third follow-up phase

Total costs diminish from R430/ha to R240/ha in this phase assuming that the preceding eradication phases have been performed appropriately. This is a forty-four *per cent* or R190/ha decrease in costs in the third follow-up phase. The labour cost amounts to R156/ha, which is tantamount to 6 labour days per hectare. The standard clearing rate increases from 0.09ha/labour day in the second follow-up phase to 0.16ha/ labour unit in the third follow-up phase. This is almost twice as quick as that recorded in the second follow-up phase. The aggregate herbicide cost is R60/ha or 0.4 litres of concentrated Garlon per hectare. Transport and equipment costs account for R24/ha of the total cost.

6.3.5 Fourth follow-up phase

Provided the previous phases have been implemented effectively total costs decline from R240/ha to R190/ha. This is a reduction in costs of twenty-one *per cent* or R50/ha in the fourth follow-up phase (refer to table 6.2). Labour costs are equivalent to R123/ha, which corresponds roughly to 5 labour days at R25.00/day per hectare. The average clearing rate amounts to 0.2ha/ labour day in this phase and only marginally exceeds the third follow-up clearing rate of 0.16ha/labour day. The herbicide cost is R48/ha or 0.3 litres of concentrated Garlon per hectare; whilst the transport and equipment cost amounts to R19/ha.

6.3.6 Maintenance phase

The difference in costs between the fourth follow-up and the maintenance phase is negligible. Total costs diminish by sixteen *per cent* or R30/ha, from R190/ha to R160/ha. In this phase, low-density invasions of five *per cent* cover, comprising mainly weed seedlings in treated areas, but also young infestations in new areas, are eradicated and controlled. The costs sustained in this phase are the costs which will indefinitely be borne by stakeholders, and this represents the benchmark which all stakeholders should strive to achieve (Goodall *pers comm.*).

6.3.7 Total costs of eradicating invasive alien plants from study area

Using both the total area of 3 767ha invaded by alien plants in the study area and the costs referred to above, it is instructive to depict the change in total costs associated with alien plant eradication over the ten year lifespan of the project (refer to figure 6.1). **It must be noted that the total costs will only follow this given trend if each and every eradication phase is properly and effectively implemented.**

It is essential to emphasise that all of the major stakeholders and a few of the farmers have not had to bear the full costs associated with clearing alien plants since 1997 because of the assistance provided by the WFW Programme operating in the area. This programme targets heavily infested areas where landowners have made little or no effort to eradicate alien vegetation. Consequently, those individuals who were engaged in alien plant eradication prior to 1997 are generally excluded from the benefits of this WFW Programme and instead have had to bear the full clearing costs. As a result of this, such individuals feel resentful towards the WFW Programme.

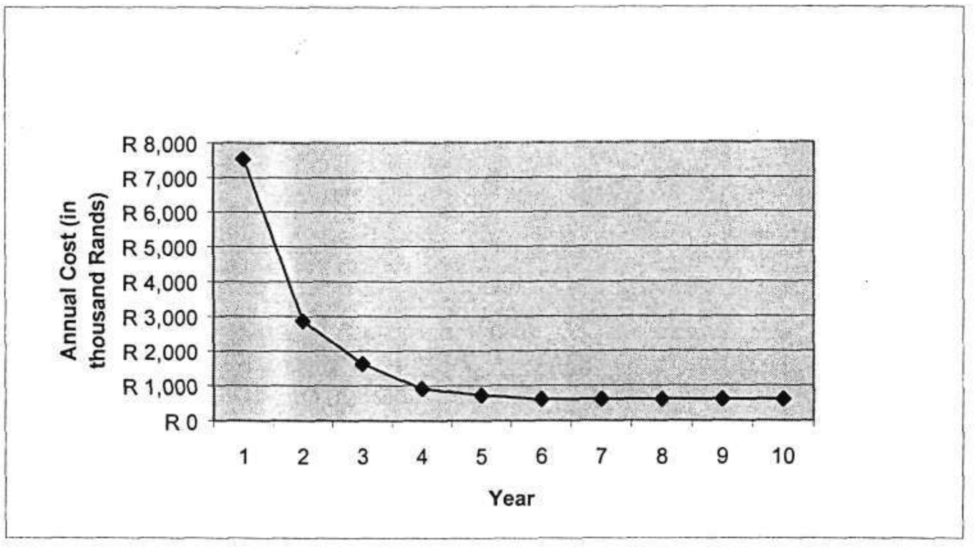

Figure 6.1: Total costs associated with eradication in the study area.

It is necessary to point out that some of these commercial forestry companies have made monetary contributions to the WFW Programme in the past. For instance in 1997, Sappi donated R7 million to the WFW Programme. In addition, they have supplied bio-control agents to this programme as well as provided technical assistance, for instance in developing management guidelines and planning (Lotter *pers comm.*). Thus, although these commercial forestry companies have received the greatest assistance in terms of the control of alien invasive plants, some of them have also contributed money and given technical assistance to the WFW Programme.

6.4 Benefit flow of alien vegetation eradication

A distinction is made between private and social benefits associated with alien plant eradication, since it has been established that numerous individuals frequently consider only the private impacts connected to an activity when allocating resources. This ignorance of social impacts has given rise to the misallocation of resources in the past and thus, this distinction is a very significant and important one to make.

6.4.1 Private benefits

The private benefits of alien invasive vegetation eradication are those accruing directly to individuals, for example, income derived from the harvesting of alien vegetation and reduced fire management costs. Monetary values for direct benefits are generally easy to derive from markets. For example, the price of commercial timber species is readily ascertained through market processes.

6.4.1.1 Utilisation of alien vegetation

The harvesting of alien vegetation is a **consumptive use value** that is dependent on the species eradicated, the relative age of this vegetation and the extent of its infestation. From interviews conducted, it was apparent that the only alien invasive vegetation harvested were commercial timber species (*Eucalyptus*, *Pinus* and *Acacia* mixed species). Consequently, the use of other alien species such as bramble (*Rubus cuneifolius*), which essentially could be utilised as forage for cattle and goats (Goodall *pers comm.*), were excluded from this analysis.

From the literature review and expert opinion, it was established that *Acacia* species were the most predominant commercial forestry species in the study area, occupying 1921ha or fifty-one *per cent* of the invaded area. *Eucalyptus* and *Pinus* species comprised just under two *per cent* or 68ha and one *per cent* or 26ha of the invaded area respectively (Wood *pers comm.*). The monetary value of commercial timber is species specific (refer to table 6.4 for the average price per tonne of the different timber species).

From interviews conducted with stakeholders it was ascertained that on average between 25 and 30 tonnes of timber per hectare of densely invaded alien vegetation, could be extracted from the initial eradication phase. However, it was cautioned that this was dependent on the location and condition or state of the timber. For example, it would not be financially viable to extract small woodlots in inaccessible areas (Leitch *pers comm.*) or to harvest timber that cannot be processed because it does not fulfil specification requirements (Buchler *pers comm.*). Consequently, a more realistic average extraction rate in the initial phase of eradication is 20 tonnes of timber per densely invaded hectare. This extraction rate is employed for this analysis.

Under those circumstances where extraction is not financially viable due to inaccessibility or to poor timber quality, locals from the surrounding communities are permitted to harvest the timber for their personal use. The benefit of this timber to local communities is not incorporated in this study as it is extremely difficult to quantify, but this spillover is clearly positive.

Table 6.4: Total value (August 2001 values) of commercial forestry species located in invaded areas of study area.

Commercial Forestry species	Size of area[1] (in hectares)	Tonnes of timber to be extracted[2] per hectare	Average price per tonne[3] (in Rands)	Total value (in Rands)
Eucalyptus spp.	68	20	R200	R 272,000
Pinus spp.	26	20	R130	R 67,600
Acacia mixed spp.	1921	20	R290	R 11,141,800
TOTAL	2015	-	-	R 11,481,400

1-area occupied by harvestable commercial forestry species within the densely invaded area of the study region (i.e. 3767 hectares).
2- this is with reference to the **initial eradication phase** only.
3- average price for specified commercial timber, which was derived from stakeholders in the study area (August 2001).

The value of harvesting alien vegetation in the initial phase of eradication amounts to R11 481 400 (refer to table 6.4). This is based on the assumption that the entire invaded area is cleared in the first year. This is a very strong assumption, since initial eradication of the total invaded area may well be implemented in stages (i.e. over a couple of years) given the extent of the area.

6.4.1.2 Reduced fire management costs

A widely held belief amongst farmers and other stakeholders in the study area is that alien plant species increase fire management costs due to the threat they pose to land activities, such as formal timber plantations. The cause of these augmented costs include:

- Increased above ground biomass and decreased accessibility (Chandler *pers comm.*). Fire management costs increase substantially with above ground biomass, because an increase in biomass is associated with an increase in fuel loads and consequently, fire intensity (Thomas *pers comm.*).
- High fuel loads of alien woody species (Paterson *pers comm.*).

- Greater labour days and a higher level of supervision are required when burning in the presence of alien vegetation. This arises because of the augmented heat intensity associated with this alien vegetation and the consequent danger of burning (Schramm *pers comm.*).
- The burning technique adopted. Burning in small blocks is necessary in the presence of alien vegetation in order to prevent the rapid spread of fire (Smith *pers comm.*).

Sixty-nine *per cent* of the stakeholders interviewed asserted that fire is a potential threat to their farming activities in the case of commercial plantations and/or sugar cane production. As a result, firebreaks are burnt annually to reduce the risk of fire to these land uses. Consequently, the reduction of fire management costs associated with alien plant eradication was considered a fundamental private benefit, the economic value of which was included in the CBA undertaken in this study.

6.4.1.2.1 Costs associated with burning

From questionnaires administered, it was apparent that the average cost of burning open grassland per hectare is R46/ha per annum. The presence of alien invasive vegetation increases the average cost to R74/ha per annum, which is an increment of sixty *per cent* or R28/ha. Consequently, *ceteris paribus*, alien plant eradication would reduce fire hazard or management costs by the same proportion, that is R28/ha per annum. The annual reductions in fire management costs associated with alien plant eradication over the ten-year project period are given in table 6.5 and depicted in figure 6.2. Figure 6.2 clearly illustrates that the benefit of reduced fire management costs falls over time and is not evenly distributed. The fire management costs are based on the following assumptions:

- The expected rate of recovery over time (dependent on the establishment of indigenous vegetation) will give rise to reductions in fire management costs of: 100% in the initial year, 95%, 90%, 85%, 70%, 60%, 50% and 45% in each successive year thereafter subsequent to alien plant eradication. Therefore, the maximum reduction in fire management costs occurs in year one, followed by small increments in costs up to the point where costs reach 55% of their pre-eradication levels (i.e. a sustainable saving of 45% of the base year).

- Costs are based on the current scenario in the study region (i.e. total area invaded by alien vegetation which amounts to 3 767 hectares).

Table 6.5: Reduced fire management costs associated with the different stages of alien plant eradication for the ten-year project.

Project life-time	Rate of recovery (%)	Total reduction in fire management costs per annum (in Rands)
1	100	R 105,476
2	95	R 100,202
3	90	R 94,928
4	85	R 89,655
5	70	R 73,833
6	60	R 63,286
7	50	R 52,738
8	45	R 47,464
9	45	R 47,464
10	45	R 47,464

The increment in fire management costs associated with alien invasive plants comes to R28/ha per annum for the ten-year period (i.e. from R46/ha to R74/ha). In the first year, costs will decline by one hundred *per cent* or R 105 476 because all alien plants are eradicated. However, as indigenous vegetation establishes itself, annual fire management costs slowly begin to escalate, so that in the long run the reduction in fire management costs is less than was initially evident. This explains why the line in figure 6.2 begins to flatten after seven successive years of alien plant clearing.

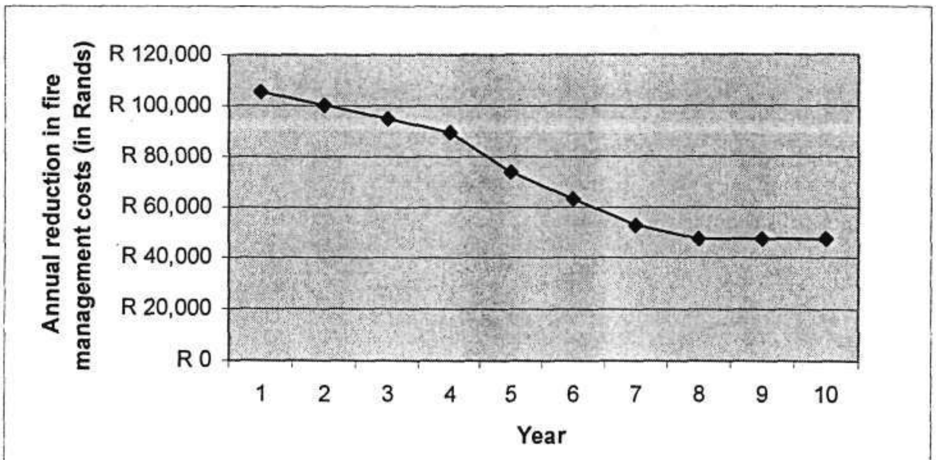

Figure 6.2: Annual reduction in fire management costs associated with the different stages of alien plant eradication for the ten-year project.

It is worth noting that in the very long run, depending on the area and type of indigenous vegetation which re-establishes, the fire management costs might decrease further because dense indigenous vegetation has a high moisture content. However, this will only occur, if at all, after approximately 20-30 years when indigenous vegetation has reached maturity. This potential benefit is therefore beyond the scope of this project.

6.4.1.2.2 Indigenous vegetation as a buffer

All the stakeholders interviewed declared that 20 metre zones of indigenous vegetation act as good firebreaks. Furthermore, the majority of these respondents regarded indigenous vegetation firebreaks as being superior to grassland firebreaks of the same width, for one of the following reasons:

- Indigenous vegetation, which is both tall and has a well-established canopy, restricts the movement of airborne combustible material (McMurray *pers comm.*).
- Dense indigenous vegetation has a high moisture content and this reduces the quantity of combustible fibre substantially, thus diminishing the fire hazard (Smith *pers comm.*). This explains why the fire management costs referred to in section 6.4.1.2.1 may fall further in the very long run.
- No burning is required with dense zones of indigenous vegetation (Schramm *pers comm.*).
- Indigenous vegetation is an effective firebreak which lasts all the year round. In contrast, burnt grassland firebreaks are only effective for 3-4 months after burning (Leitch *pers comm.*).

6.4.1.2.3 Fire insurance premiums

It was evident from the questionnaires administered that the size of insurance premiums is not dependent on, or influenced by, the presence of invasive alien vegetation on one's property. Consequently, the following changes to existing insurance premiums were proposed by some respondents:

- Premiums should be reduced under those circumstances where alien plants have been eradicated, since the spread of fire is much easier to control. Furthermore, this reduction would function as an incentive for all individuals to remove alien plants from their lands (Leitch *pers comm.*).

- Premiums should be reduced where eradication of alien vegetation has been initiated, as these areas are more accessible and manageable when cleared and the fire hazard is consequently, substantially reduced (Aitken *pers comm.*).
- Premiums should be augmented where individuals have not attempted to eradicate alien invasive plants from their land. This will essentially reduce their profits (or total revenue) and hence will act as an incentive for individuals to initiate the process of eradication (Chandler *pers comm.)*.

6.4.2 Social benefits

The social benefits connected to alien plant eradication are those which accrue to society as a whole and include increased streamflow, increased biodiversity as well as employment benefits. It is important to incorporate social impacts into this analysis to prevent the misallocation of resources stemming from irrational decisions based on incorrect pricing information.

6.4.2.1 Increased streamflow

The negative impact of alien invasive vegetation on streamflow is well documented (refer to section 4.7.1 page 52) and is further substantiated by a series of photographs taken in different years at the same site on 'Diepkloof' farm, located in the study region (refer to plates 6.2 and 6.3). These plates suggest that streamflow has been considerably reduced over the past thirty years. This is ascribed to the increased invasion of alien plants, especially in riparian zones (McMurray *pers comm.*). This perception is supported by responses obtained from WFW employees. Ninety-four *per cent* of the WFW employees indicated that alien plants reduce streamflow and therefore, water available for use. The reduced streamflow has adversely affected some irrigators in the upper reaches of the catchment. For example, in September 1999 some farmers were unable to irrigate their pastures (McMurray *pers comm.*).

Plate 6.2 Mpopoma falls on 'Diepkloof' farm (McMurray, 1972).

Plate 6.3 Mpopoma falls on 'Diepkloof' farm (McMurray, 1999).

In order to calculate the current water uptake of invasive alien vegetation in the study area and the anticipated increase in streamflow that will accrue from clearing this vegetation, it was necessary to ascertain the following:

- The total dense hectares of alien invasive plants in the study region. This has previously been established at 3 767 hectares.
- The location of alien vegetation (i.e. whether contained inside or outside riparian zones). From interviews conducted with farmers and other stakeholders, it was established that approximately eighty *per cent* of all alien vegetation in the study area occupies riparian zones.
- The average area and age class of each alien vegetation structure (i.e. tall alien trees, medium alien trees as well as tall alien shrubs) situated within and outside riparian zones in the study area (refer to Appendix VI).

From Appendix VI it is evident that medium trees (area under class 2) dominate the invaded area by occupying over seventy *per cent* of the total invaded area. Tall alien trees (class 3) have the highest average age class at 15 years. It has previously been established that streamflow reduction is positively related to biomass and therefore to the age of the alien vegetation. Consequently, it follows that the higher the average age class of the alien vegetation the more serious the effect on streamflow.

Using the data contained in Appendix VI, the streamflow reduction associated with these alien plants was calculated for riparian and non-riparian zones (refer to Appendix VII to review the calculated streamflow reduction for each vegetation type). Figure 6.3 summarises the findings recorded in Appendix VII, which are based on the following assumptions:

- Increased biomass is accompanied by increased streamflow reduction (Le Maitre *pers comm.*). Consequently, if the area of alien vegetation were to expand, streamflow reduction would increase substantially.
- Streamflow reduction figures are based on the current scenario that is, total area presently invaded by alien vegetation which is 3767ha.

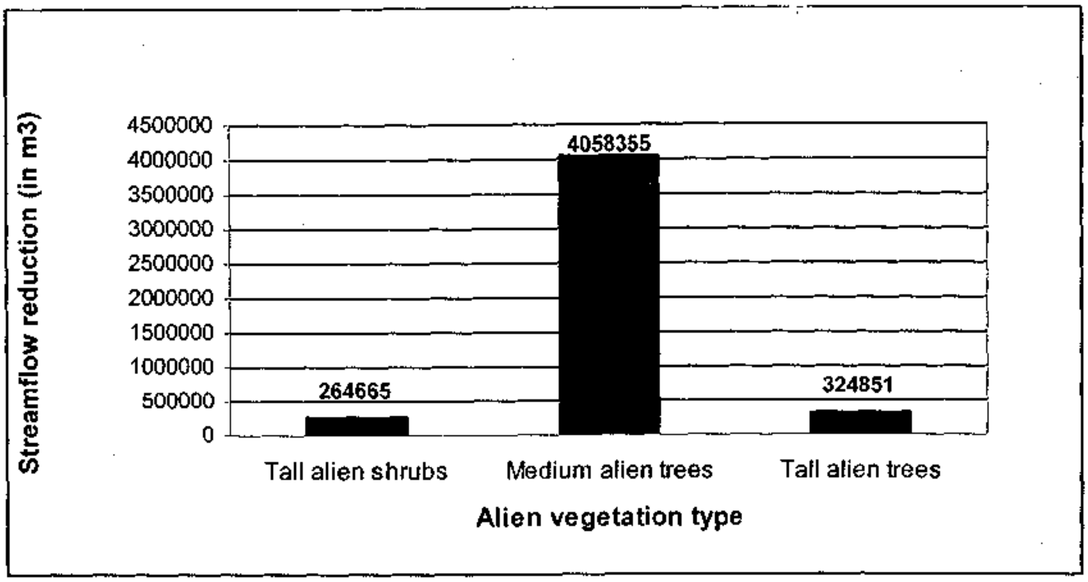

Figure 6.3: Total streamflow reduction (in m^3) associated with each alien vegetation type in study area.

Existing alien invasive vegetation contained in the study area reduces streamflow by a total of 4 647 871m^3 or approximately 4.6 million m^3 per annum. Consequently, the eradication of this vegetation is expected to increase streamflow by the equivalent magnitude. The annual increase in streamflow associated with alien plant eradication is dependent on the rate of recovery over time and type of indigenous vegetation that is re-established. Based on expert opinion the following assumptions were made prior to establishing the amount of water which would become available for utilisation:

- Shrub type natural vegetation will replace alien vegetation in the long-term, given the natural landscape of the catchment (Wood *pers comm.*). As this type of vegetation is established, it will reduce streamflow somewhat (but by far less than the alien vegetation).
- The anticipated increase in streamflow in the study area is thus: 100% in the initial year, 95%, 90%, 85%, 70%, 60%, 50% and 45% for each successive year. Thus, after eight years a 'constant' state is attained when the increase in streamflow stabilises at a level 45% above that prevailing in 2001.

6.4.2.1.1 Actual water availability for utilisation

Not all of the anticipated 4.6 million m^3 increase in streamflow will be available for downstream use, since it has been established (in section 4.4.2 page 45) that only a portion of this can be reliably captured and extracted using existing infrastructure

(Wood *pers comm.*). Hydrology experts such as David Le Maitre and James Wood predict that a minimum of fifty *per cent* of the increase in streamflow (about 2.3 million m^3 per annum) will be available for downstream use. Hence, in order to provide a more prudent appraisal of the analysis, this conservative estimate was employed.

6.4.2.1.2 Monetary value of increased streamflow

The following simplifying assumptions were made in calculating the monetary value associated with increased streamflow per annum for the ten-year project:

- The additional water supply would be used in proportion to the sectoral breakdown of current allocation (refer to table 4.3 page 45). This is a reasonable assumption, because it is presently unclear to whom the additional water might be allocated.
- The water prices that different sectors are required to pay represent August 2001 prices and are based on the current water tariffs imposed by the DWAF (refer to table 6.6). As pointed out in section 4.4.1, the tariff charged to agricultural users is heavily subsidised, so this assumption results in a conservative estimate of the true value of the additional streamflow. The possible impact on NPV of increasing the price charged to this sector is returned to in section 7.7.1.
- Constant technologies and institutional frameworks are assumed.
- Any potential water efficiency gains resulting from more water-saving economic activities have been excluded from this analysis.

Table 6.6: Anticipated allocation of water amongst sectors and final value of increased streamflow accruing from alien plant eradication.

Sectors of water use	Future allocation of Available water (m^3)	Current water price (cents/m^3)	Value of increased streamflow (Rands)
Irrigation sector	1394361	2.08	R 29,003
Domestic sector	325351	42.34	R 137,754
Industrial sector	604223	42.34	R 255,828
TOTAL	**2323935**	-	**R 422,585**

The irrigation sector in the catchment is currently allocated sixty *per cent* of the total available water (or 1 394 361 m^3), whilst the domestic and industrial sectors are allocated fourteen (or 325 351 m^3) and twenty-six *per cent* (or 604 223 m^3) of the total, respectively. Using the estimates contained in table 6.6 and the minimum increase in water availability (i.e. 2.3 million m^3), the monetary value associated with increased streamflow per annum was calculated for each sector of water use (refer to table 6.6 and figure 6.4). The total monetary value of increased streamflow to all the sectors would amount to R422 585 per annum if all the alien vegetation were removed from the study area.

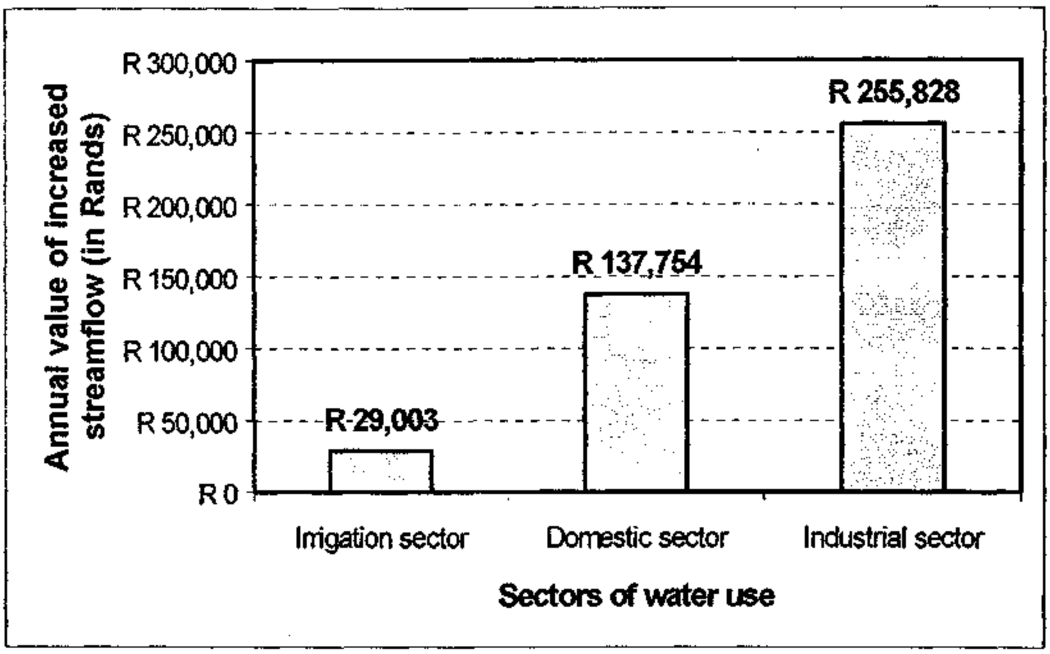

Figure 6.4: Value of increased streamflow per annum accruing from various sectors, when **all** alien vegetation is cleared from the study area.

In order to assess the monetary value of increased water availability over the ten-year life span of the alien plant eradication project, it was necessary to apply the rate of recovery over time which had previously been established (page 86). In the initial phase of eradication (i.e. year one) assuming that the entire area invaded by alien plants is cleared, streamflow will increase by one hundred *per cent* which amounts to R422 585 (refer to table 6.7). This value will decline in subsequent years with the establishment of indigenous vegetation. Figure 6.5 clearly illustrates how the benefit of increased streamflow declines over time due to the natural vegetation which establishes itself.

Table 6.7: The anticipated increase in streamflow over the project life-span.

Project life-time	Rate of recovery (%)	Total increase in streamflow (in Rands)
1	100	R 422,585
2	95	R 401,455
3	90	R 380,326
4	85	R 359,196
5	70	R 295,809
6	60	R 253,550
7	50	R 211,292
8	45	R 190,163
9	45	R 190,163
10	45	R 190,163

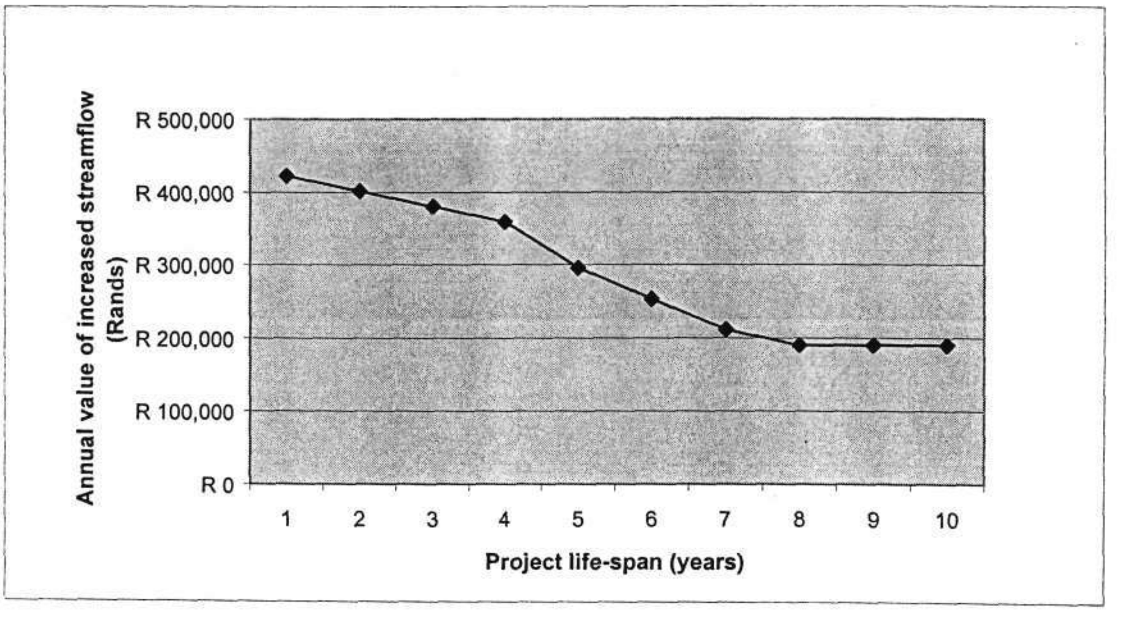

Figure 6.5: The value of the anticipated increase in streamflow over the project life span.

6.4.2.2 Increased biodiversity

In comparison with other areas situated within the Kwazulu-Natal region, the Mhlatuze Catchment (particularly the upper reaches) has high biodiversity at the landscape as well as species level; and moderate biodiversity at the ecosystem/community level (Goodman *pers comm.*) (refer to Appendix VIII). Furthermore, given the climatic conditions, it is anticipated that medicinal plants with great economic importance (e.g. *Scilla natalensis*, *Eucomis autumnalis*, *Boweia* *volubilis, Alepidea amatymbica, Ocotea bullata* and *Curtisia dentata*) are distributed in this catchment (McKean *pers comm.*).

6.4.2.2.1 Importance of biodiversity

Eighty-five *per cent* of the responses elicited from stakeholders in the study area asserted that biodiversity was important and was a benefit associated with alien plant eradication. This suggests that stakeholders consider the benefits of biodiversity a high priority good. This was substantiated by the fact that all these stakeholders are members of the Melmoth conservancy, established in 1988. Conservancy members are required to pay an annual fee, which is dependent on the size and use of the land. According to major stakeholders, this is the longest operating as well as the most successful conservancy in the region (Paterson *pers comm.*). The main functions of this conservancy are to:

- preserve fauna and flora;
- increase security measures; and
- control theft of both sugar cane and timber in the area (Chandler *pers comm.*).

From responses elicited it was established that fauna and flora have increased in the area since the conservancy's inception and stakeholders have derived a positive satisfaction from this. In order to evaluate the importance of increased biodiversity to the stakeholders in the study area (i.e. non-use values) stakeholders were questioned directly about their WTP for an increase in biodiversity. The response, however, was poor with all respondents stating zero WTP. This suggests that increased biodiversity has a low priority in the preferences of stakeholders. This is in direct conflict to the earlier responses elicited from stakeholders concerning the importance of biodiversity.

The 'maximum extra WTP' towards the conservancy was investigated in an attempt to resolve the apparent contradiction by showing that a WTP for more biodiversity does exist. Ninety-two *per cent* of respondents disclosed that they would retain their conservancy membership in the event of an increase in the payment by R1.00 per hectare per annum. In some instances, this entailed paying an additional R10 000 per annum. This indicates that the conservancy and hence, biodiversity is important to the majority of stakeholders in the study area. Although there are too few observations to ascertain with certainty whether or not there is a direct relationship existing between extra WTP for the conservancy and ownership of a guest lodge, the results collected suggest that there is a positive correlation between these two variables. For example, eighty *per cent* of guest lodge owners asserted that they would retain their conservancy membership in the event of an increase in the annual payment by R3.00 per hectare per annum, whilst only twenty-five *per cent* of non-guest lodge owners indicated the equivalent (refer to figure 6.6).

It is surmised that the higher extra WTP of guest lodge owners is a direct consequence of the demands of visitors. For example, increased biodiversity will attract more tourists and/or encourage visitors to stay longer. The monetary values provided in this section cannot be extrapolated to other geographical areas and are only quoted to illustrate the importance of increased biodiversity to stakeholders residing in the study region.

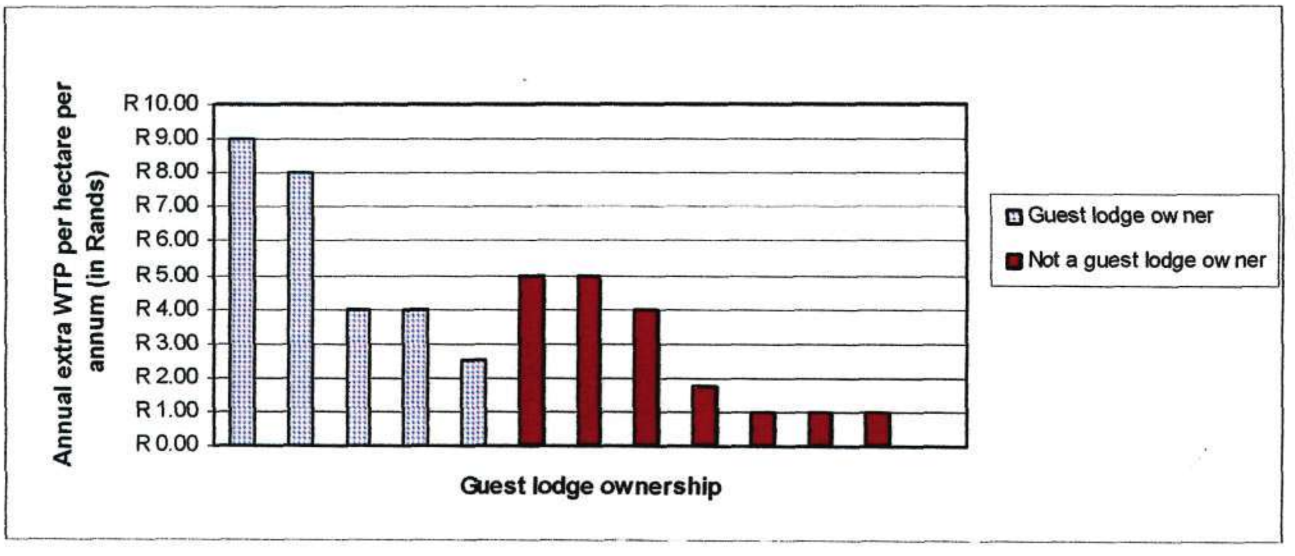

Figure 6.6: Correlation between guest lodge ownership and extra WTP for the conservancy.

Although it is evident that biodiversity is an important benefit flowing from the eradication of alien invasive vegetation, it is difficult to measure and/or quantify this non-use value. This is due to the complexity of critical ecosystem services which encompass biodiversity, and the non-market nature associated with many of the benefits (Goodman *pers comm.*). For example, although it can be assumed that alien plant eradication will augment biodiversity at the ecosystem/community level, the extent of this is uncertain. In addition, benefits of greater biodiversity at the species level are very complex and difficult to ascertain, because these benefits are largely dependent on the species composition (or richness) which existed prior to alien plant eradication, as well as on the extent of alien vegetation infestation. Consequently, given the inherent uncertainties regarding the increase in biodiversity, it was more prudent to consider that all biodiversity is valuable as a resource and to conclude that eradication of these alien invasive plants is socially desirable.

6.4.2.3 Employment benefits

From interviews conducted with a team of WFW employees who resided in the upper reaches of the Mhlatuze Catchment, it was evident that the region is characterised by high levels of unemployment, crime and poverty. Furthermore, these WFW employees have been forced to become self-sufficient, which was substantiated by the fact that eighty-one *per cent* of these respondents were engaged in a subsistence lifestyle.

Attempts to quantify the social benefits of employment creation are beyond the scope of this study, however, this issue is worth examining in more detail in a qualitative way, because of the significant positive social impact it has.

6.4.2.3.1 Additional benefits received

All the WFW employees (thirty in total) were found to have received some form of training from the Programme, which was an additional economic benefit to their wages. The skills that employees obtained from the Programme are provided in figure 6.7. From a brief analysis of the training acquired, it is evident that the skills obtained were very specific to the task at hand, for example, the identification of alien plant species. Very few, if any, employees were taught general skills which they could apply to other disciplines subsequent to the Programme, for instance, first aid skills and/or obtaining their driver's licence.

In addition, it is essential to accentuate that none of the WFW employees were permitted to remove any of the alien vegetation eradicated from the land. Instead the utilisable alien vegetation was either stacked and transported to the mill by the proprietor or sold to the local people as firewood. This has caused a lot of controversy and conflict amongst the WFW employees.

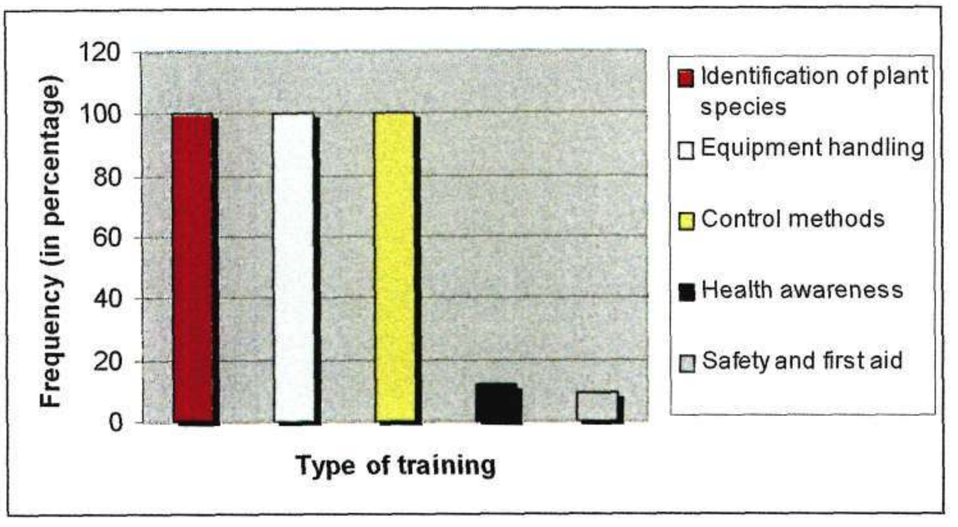

Figure 6.7: Training WFW employees received from the Programme.

6.4.2.3.2 Characteristics of WFW employees

The importance of increased employment created by the WFW Programme was contextualised by analysing the characteristics of those employees interviewed. Firstly, it was apparent that the majority of those employed in alien plant eradication were female workers. Secondly, seventy-seven *per cent* of these employees were the sole breadwinners, in other words, the only individuals in the household earning an income. In addition, fifty-seven *per cent* of the WFW employees were responsible for supporting more than five people. Finally, two-thirds of those employed by the programme were previously unemployed.

6.4.2.3.3 Potential problems with alien plant eradication programmes

Although it has been acknowledged that the eradication of alien invasive plants does create employment, and hence reduces poverty as well as crime, stakeholders from the catchment have cautioned and criticised the implementation of eradication programmes such as the WFW Programme in the study area for the following reasons:

- Many of the current WFW employees were previously employed by farmers, but abandoned their employment due to higher wages offered by this Programme along with shorter working hours (Smith *pers comm.*).

- Labourers are assigned daily tasks which are often inadequate for a day's work and consequently, labourers complete these tasks and leave early. As a result of this, conflict and tension have developed between WFW employees and farm employees (Schnetler *pers comm.*).

6.5 Cost-benefit analysis

The costs and benefits outlined in the preceding sections were analysed to ascertain the economic viability as well as the desirability of alien plant eradication in the upper reaches of the Mhlatuze Catchment. Appendix IX lists the annual costs and benefits associated with the ten-year alien plant eradication project.

6.5.1 Net Present Value (NPV)

The cost and benefit flows occur at different stages of alien plant eradication as well as in different years, and thus, in order to compare these flows it was essential to convert them into common units, such as present values, determined by a process known as discounting. The discount rate selected for purposes of this project was five *per cent* (refer to section 5.5.1 for the derivation of this discount rate). Using this discount rate, the eradication of alien vegetation in the study area will realise a Net Present Value (NPV) of R4 047 703 over ten years (refer to table 6.5).

In order to test the sensitivity of the NPV result obtained to the discount rate, rates of zero and ten *per cent* were employed for purposes of this analysis. This is one standard deviation on either side of the discount rate selected (i.e. five *per cent*). From Table 6.5 it is apparent that the NPV is very sensitive to the choice of discount rate. When the discount rate is reduced to zero *per cent*, which means that future cost and benefit flows are not actually discounted, then the NPV amounts to –R1 551 529 over ten years. Under these circumstances alien plant eradication would be undesirable and rejected. However, a five *per cent* increment in the discount rate from zero to five *per cent*, is accompanied by a R 5 599 232 increase in the NPV. In contrast, when the discount rate is increased from five to ten *per cent*, NPV increases to R4 250 973 showing a much smaller increase of only R203 270. The cause of these changes can be investigated by examining the cost and benefit flows associated with alien plant eradication over the ten-year period.

Table 6.8: Cost and benefit flows associated with alien plant eradication in the study area.

Year	Total benefits (in Rands)	Final cost (in Rands)	Net Benefit/ Cost	NPV Discount rate 0%	NPV Discount rate 5%	NPV Discount rate 10%
0	R 12,009,460	R 7,534,000	R 4,475,460			
1	R 501,657	R 2,862,920	R -2,361,263			
2	R 475,254	R 1,619,810	R -1,144,556			
3	R 448,851	R 904,080	R -455,229			
4	R 369,642	R 715,730	R -346,088			
5	R 316,836	R 602,720	R -285,884			
6	R 264,030	R 602,720	R -338,690			
7	R 237,627	R 602,720	R -365,093			
8	R 237,627	R 602,720	R -365,093			
9	R 237,627	R 602,720	R -365,093			
TOTAL	-	-	-	R -1,551,529	R 4,047,703	R 4,250,973

The total benefits of alien plant eradication listed in the second column of Table 6.8 include the private and social benefits discussed above. The largest benefit is realised in the base year as a consequence of alien plant harvesting subsequent to eradication as well as increased streamflow and fire management savings. The final costs associated with removing alien plants are given in column three and include labour, herbicide and other costs like transport. The largest cost is realised in the base year. Although the total costs associated with the eradication of alien plants decrease with time, these are still substantial over the ten-year lifespan of the project when compared with the benefits. The net benefit/cost column is simply the total benefits less the costs.

For all years except the current year (in which the eradication effort is assumed to be initiated), the costs of eradication outweigh the benefits. In other words, sizeable net costs (i.e. negative net benefits) are recorded for years 1 to 9. The higher the discount rate employed, the lower the importance of more distant cost and benefit flows today. Thus, large negative net benefits which stretch into the future will be substantially reduced when a high discount rate is employed and in some instances may even become negligible, making the alien plant eradication process more desirable.

On the other hand, the largest of the quantified benefits of eradication are realised in the base year, and are not subject to discounting (because the immediate benefits from timber sales, the initial streamflow increase and reduced fire management costs are experienced as soon as clearing is undertaken). The use of a higher discount rate therefore does not affect the benefits to the same extent as the costs associated with alien plant clearing.

Examination of the results derived in Appendix IX highlight that the NPV outcome is dominated by the revenue obtained from harvesting alien vegetation, and eradication costs. It is surmised that the final outcome will be sensitive to substantial changes in these components. The other impacts play a relatively minor role.

6.6 Conclusion

The cost-benefit analysis (CBA) undertaken indicates that alien plant eradication in the study area is economically viable as well as socially desirable when a discount rate of five *per cent* is employed. Further enhancing the argument in favour of extirpation, is recognition that the CBA undertaken for purposes of this study only examined some of the benefits associated with this project and hence represents a minimum estimate of the benefits. If other benefits like increased biodiversity, employment benefits, reduced soil erosion and increased productive potential of the land were to be quantified and incorporated into this analysis, the net benefit of alien plant clearing would increase along with the NPV, making eradication more desirable.

CHAPTER SEVEN
DISCUSSION

7.1 Introduction

Although it has been demonstrated that alien plant eradication is an economically viable activity with a NPV of R4 047 703 over ten years at a discount rate of five *per cent*, the findings presented in the results chapter need to be evaluated as well as discussed. This will facilitate insight into the issues at stake and assist policy-makers in discerning appropriate management strategies that may be adopted to combat the rapid proliferation of alien plants. Further discussion will also improve the management of alien vegetation in the future. The structure of this chapter will emulate that of the previous one.

7.2 Alien plant eradication in the study area

It has previously been established from interviews conducted that all private farmers and other major stakeholders in the study area are engaged in some form of alien plant control, suggesting that these individuals are concerned and thus have made a concerted effort at eradication. The aggregate efforts of these individuals may be responsible for the low alien plant infestation in the upper reaches of the catchment (i.e. only eight *per cent* of the research area is infested compared with thirty-nine *per cent* of the entire Mhlatuze Catchment) (Versveld *et al.*, 1998:Appendix 5 page 10).

Analysis of the results highlights that alien plant clearing has been more rigorous on private farmland. For example, it is evident that in total the commercial forestry sector owns seventy-three *per cent* of the entire research area (refer to table 6.1) and yet eighty-six *per cent* of the total invaded area is contained on this land. It is surmised that this skewed distribution of alien vegetation is a consequence of the personal interest private individuals have in their own land. In contrast, individuals employed by large organisations, such as the commercial forestry sector, do not possess a similar interest or personal stake. However, it is important to stress that this is not due to the lack of interest in alien vegetation by these large companies because it has been established that all of the commercial forestry companies located in the study area have or are in the process of embarking on an alien weed control programme. Thus, it is anticipated that the current scenario will improve in the future.

7.3 Cost flow of alien vegetation eradication

The extent of the costs is dependent on the type of control method employed (mechanical, chemical or biological control) as well as on the stage and on the frequency of alien plant eradication. It is necessary to emphasise that if regular clearing is not undertaken, costs will increase substantially. Where mechanical and chemical control methods are adopted, the full costs affiliated to alien plant eradication are borne by the individuals engaged in such an activity, except under those circumstances where the WFW Programme has been initiated on the individual's land.

The WFW Programme, initiated in the study area in 1997, has largely been confined to commercial forestry owned land where higher levels of alien vegetation infestation prevail. Consequently, these commercial forestry sectors have been 'exempt' from carrying the full costs associated with such a process, while the majority of the private farmers have had to bear these costs in full. It has been established, however, that some of the commercial forestry companies like Sappi, have assisted the WFW Programme financially and this has been complemented by the provision of appropriate management frameworks and their implementation. From responses elicited it is unclear whether private farmers in the study region are conscious of this, which may be the primary cause for the tension which exists between the various stakeholders. Verifying the high feelings of stakeholders, apparent from their responses to the questions, are the personal communications of Smith, Leitch and McMurray (2001). These stakeholders have criticised the WFW Programme for the following reasons:

- The current WFW programme is inequitable because the distribution of benefits is heavily skewed in favour of large commercial forestry operators who in the past have generally not engaged in removing alien plants.

- WFW Programme 'takes' responsibility for eradicating alien plants on private individuals' land, which is in direct contrast to many of the owners' beliefs that alien plant eradication is the personal landowners' responsibility.
- The WFW Programme initiative abolishes all incentives for individuals to engage in alien plant clearing on their own land.

Turning to biological control measures, these entail the use of an association between natural enemies such as insects and fungi and a target plant, which restricts the growth or reproduction of the plant where it is considered undesirable (Denny, 1997:27). These control measures are largely government funded initiatives, although some companies, like Sappi, are actively engaged in developing and testing bio-control agents and hence, bear the cost of these. Bio-control, when successful, is a cost-effective way of controlling invasive alien plant species, since it severely reduces the invasive potential of these plants. Subsequently, total eradication costs borne by individuals are substantially diminished in the presence of biological control agents, as lower levels of labour and herbicides are required for clearing purposes (Versveld *et al.*, 1998: 118). However, these control measures are not a quick-fix solution. This is because firstly, researchers are only able to study a few bio-control agents at a time, secondly, success is not guaranteed and finally, these agents are not formulated for **all** invasive alien plants (Denny, 1997:77). Thus, even in instances where biological control measures have been employed, individuals are still required to engage in some alien plant clearing on their properties.

From research conducted it was established that at least one bio-control agent has been released in the immediate vicinity. For example, *Sulchobruchus subsuturalis* (seed beetle) was formulated by the Plant Protection Research Institute (PPRI) to combat the spread of the Port Jackson Willow (*Acacia saligna*) in the Mhlatuze Catchment. Although this beetle's release has proved to be very successful in reducing the proliferation of this *Acacia* species, the effect of it on the total costs of alien plant clearing is difficult to assess at present and was thus excluded from this analysis.

7.3.1 Control methods adopted

Interviews conducted with stakeholders in the study area indicate that both mechanical and chemical control methods are employed to eradicate alien invasive plants. These mechanical and chemical control methods were compared with the recommended guidelines established by the PPRI. This comparison highlighted that although the majority of stakeholders are utilising appropriate methods and herbicides, the quantities utilised differ from those prescribed by the PPRI. For example, from the findings presented in section 6.3.1 it is apparent that on average stakeholders utilise 3.5 litres of concentrated Garlon to eradicate one hectare of densely invaded alien plants in the initial eradication phase. The prescribed dosage is 3 litres on average (refer to Appendix X). The majority of stakeholders are profit-maximising individuals and it is highly unlikely that they would use more herbicides than is required. Consequently, either stakeholders' experience is such that the recommended dosage is ineffective (perhaps as a result of variations in climatic conditions), or current management practices are inefficient as a saving of approximately R71.00 (R142.00/2) per dense hectare of alien invasive vegetation eradicated is possible.

7.3.2 Comparison of costs incurred

In order to assess the credibility of the total stated costs (refer to table 6.2.), these were compared with costs incurred in the Nagle Dam region. It was suggested that Nagle Dam had a similar level of alien plant infestation to the study area and for this reason was selected for comparative purposes (Wood *pers comm.*). Although clearing costs in the Nagle Dam area were differentiated into tree- and shrub-type aliens (refer to Appendix XI) it was still feasible to compare these to the costs incurred in the study region.

A comparison of the costs indicates that large discrepancies exist between the two regions. For example, in the Nagle Dam area, initial clearing costs per hectare incurred in removing tree-type aliens approximate R6 120 per hectare, whilst that incurred in clearing shrub-type aliens is R5 100 (refer to Appendix XI). Thus, on average the costs of eradication in the Nagle Dam region amount to R5 610 per hectare of densely invaded land. This is more than twice the stated costs borne by stakeholders in the study area which are R2000 per densely invaded hectare.

From a brief analysis of these clearing costs, it is apparent that this large discrepancy is related to the differences in the daily wage rate of labourers, the team composition as well as administration costs. In the Nagle Dam project, labour wage rates were substantially higher than those paid by stakeholders in the study area (R35.00 per person per day as opposed to R25.00, refer to Appendix XI). Furthermore, the team composition used in each region differed. For example, in the Nagle Dam region a full-time supervisor was employed to oversee and monitor the eradication progress, whereas in the Mhlatuze study area this was undertaken by the landowner where required. The final discrepancy in the costs was due to the inclusion of fixed costs, such as administration costs, in the Nagle Dam project. The individuals interviewed in the study area clearly did not account for these costs and consequently, these were excluded from the alien plant eradication analysis. It can be concluded that the lower costs reported by the stakeholders are credible since the daily wage rate of labourers was R10.00 lower per day, the alien plant clearing team used in the study region was smaller and the administration costs were excluded by the stakeholders.

7.4 Benefit flow of alien vegetation eradication

The positive impacts associated with alien plant eradication were categorised into private and social benefits. Private benefits include monetary gains from alien vegetation harvested, reduced fire hazard as well as increased production of non-riparian land following alien plant extirpation. Private benefits accrue entirely to the proprietor, even in those instances where the WFW Programme operates on the land. In contrast, the social benefits which include increased streamflow, biodiversity and employment, are distributed amongst society.

7.4.1 Utilisation of alien vegetation and land

From the research conducted, it was ascertained that the direct use value of commercial alien vegetation contained within the invaded area of the study region amounts to R11 481 400 in total. If all the alien vegetation is eradicated in the first year then the entire benefit will flow to private individuals in the same year. It is worth noting that so long as the eradication of alien plants is carried out effectively, this benefit will only accrue in the initial year. The largest proportion of this potential income will accrue from the harvesting and sale of *Acacia* or wattle *species*, which occupy fifty-one *per cent* of the total invaded area. The dominance of this species is attributed to the large wattle plantations in the study area, which is a consequence of the high average price per tonne it fetches in relation to the other commercial timber species (refer to table 6.4).

Those invaded areas situated **outside** riparian zones could essentially be utilised for alternative purposes subsequent to the eradication of alien plants, like the planting of crops. Thus, by not engaging in alien plant clearing, especially in non-riparian zones, landowners suffer a potential profit loss which represents an opportunity cost. This potential benefit was excluded from the analysis due to the temporal constraints, but adds weight to the argument that the estimated NPV of alien plant eradication should be seen as a minimum estimate.

7.4.2 Reduced Fire Management Costs

Although the benefit of reduced fire management costs is considerably lower than the other benefits (refer to Appendix IX), it was identified by stakeholders in the study area as a high priority and hence was incorporated into the analysis. From the findings presented, it was apparent that the majority of stakeholders burnt firebreaks annually to reduce the risk of fire to their land activities (e.g. plantations). Firebreaks are also burnt because they are prescribed by insurance brokers. Consequently, numerous stakeholders in the study region are directly affected by fire management costs.

The reduction in fire management costs is essentially a private benefit in that it enhances the profit of those individuals engaged in alien plant eradication. However, under certain circumstances the reduction in fire management costs may also be a social benefit. For example, if the eradication of alien vegetation occurs on land adjacent to an area of conservation significance, then this adjoining land will be subject to reduced fire hazard and this is a beneficial externality enjoyed by all who visit the area.

It has been established in the literature review that the reduction in fire management costs will depend on the type of alien vegetation species that will be eradicated as well as the indigenous vegetation which will be established subsequent to alien plant removal (refer to section 4.7.2). For instance, if grassland species replace alien invasive trees, fire management costs will be substantially reduced due to the typical fuel loads associated with grasslands. Whilst fire intensity and hence fuel loads generally increase with biomass, a dense conglomeration of closed canopy mature indigenous vegetation is an exception to this rule due to the high moisture content contained within it. Consequently, a compact aggregate mass of closed canopy mature indigenous vegetation provides effective firebreaks. This was corroborated by responses elicited from stakeholders in the study area. Furthermore, indigenous vegetation has deep rooting systems and is thus able to withstand flash floods with little or no damage to the soil, unlike alien vegetation (refer to section 4.7.2). This is important, especially given that many rural communities lead a subsistence lifestyle and therefore are reliant on the soil for growing crops (refer to section 4.6).

7.4.3 Increased streamflow

From the literature review, it was established that the Mhlatuze Catchment is 'water stressed', since current water allocations exceed available water (refer to section 4.4). Furthermore, the NWA requires that the water allocations for ecological components are met in the future to ensure the maintenance of ecological functions. This essentially entails augmenting water allocation by an additional 16 million m^3/annum and in this way exerting even greater pressure on the available water resources (Versveld *et al.*, 2000:v). Consequently, it is apparent that increased water supply is a crucial factor which is urgently required to satisfy current demands for water and to promote future economic growth in the catchment.

7.4.3.1 Quantity and value of utilisable streamflow

The research undertaken suggests that existing alien vegetation diminishes streamflow by approximately 4.6 million m^3 per annum. Thus, it is anticipated that eradication of such vegetation will increase streamflow by the same amount. However, based on expert opinion it was established that only fifty *per cent* of this increased streamflow is likely to be available for downstream use, due to the limitations of existing infrastructure and an expected loss of water to the sea.

It was assumed that this additional water supply would be allocated to the various sectors in the same proportions as currently and that sectors would sustain identical water prices. Consequently, the monetary value of this increased streamflow of 2.3 million m^3 per annum was estimated to be R422 585 in the initial eradication phase.

It is worth noting that the increased streamflow accrues to individuals downstream from where alien plants have been eradicated and this includes rural communities, private farmers as well as industries. This increased streamflow is an example of a positive externality, in that it enhances society's welfare because downstream individuals are able to expand their production capacity. Increased streamflow is a social benefit which has often been, and continues to be, overlooked by private individuals engaging in alien plant clearing, since such a benefit does not directly enhance their private welfare or production activities. By not engaging in alien plant eradication, negative environmental externalities arise, which are sustained by society. For example, decreased water supply is accompanied by lower potential output, which is synonymous with profit loss. Thus, in the absence of alien plant removal, downstream users encounter an opportunity cost as production potential is restricted by available water supply.

In the past new dams have been constructed to meet escalating water demands, however increased costs, environmental concerns, and a shortage of further dam sites have forced a re-evaluation of such policies (van Wilgen *et al.*, 1997:404). According to a study conducted by Umgeni Water on the feasibility of implementing riparian corridor rehabilitation in the Nagle Dam area, alien plant eradication was identified as an "effective catchment management strategy that could improve water supply as an alternative or supplementary strategy to conventional augmentation schemes" (Haynes and Gillham, 2000:1). Furthermore, it was emphasised that alien plant eradication is the most economical means of augmenting the water supply in the area. However, this is very site specific and is dependent on the level and density of alien plant infestation.

7.5 Biodiversity effects

Many environmental effects, such as biodiversity, are not captured by markets due to the nature and characteristics of these public goods. For example, biodiversity displays public good aspects such as non-rivalry and non-exclusiveness in consumption which implies that exclusion of individuals from the enjoyment of benefits associated with such a good is either not possible (e.g. existence value) or inefficient. The non-rival aspect of biodiversity is particularly relevant to this study because it implies that goods may be consumed by one individual without diminution of the amount effectively available for others (Randall, 1983:134). In order to achieve efficiency in the consumption of these goods, it is essential to establish the demand for these goods by eliciting individual WTP for the good. The CVM was employed in an effort to derive the demand for biodiversity and obtain a value for it.

From responses elicited, it was established that all stakeholders in the study area regard biodiversity as a high priority and all of them are members of the local conservancy. One of the major functions of this conservancy is the preservation of biodiversity. Based on these findings, it was hypothesised that stakeholders would state a positive WTP for an increase in biodiversity, which would follow alien plant eradication. However, this hypothesis was disproved when all respondents asserted a zero WTP and in this way implied a lack of concern for increased biodiversity.

In order to assess the validity of the responses obtained, the individuals' maximum extra WTP towards the conservancy was investigated. Maximum WTP essentially indicates the importance of the conservancy and by implication, biodiversity, to the individual. It was evident from responses elicited that the majority of the individuals are prepared to contribute a higher payment towards the conservancy than currently, with some asserting increased contributions of up to R9,00 more per hectare per annum. Thus, in an attempt to value increased biodiversity subsequent to alien plant clearing, contradictory responses were obtained (refer to figure 6.6). These responses are inconsistent with economic theory, since they suggest that individuals are prepared to contribute a positive sum of money for unchanged functions of the conservancy, yet unwilling to contribute any payment for an increase in biodiversity.

There are several probable explanations for this atypical behaviour. Firstly, such a non-compensatory stance can be viewed as evidence of a lexicographic preference[1]. Individuals may express no WTP for increased biodiversity as a protest against the implication that it could be traded for other goods or money. Lexicographic preferences suggest that utility functions cannot be defined for an individual (Spash and Hanley, 1995:203). Secondly, individuals may have experienced problems in comprehending the concept of biodiversity and/or the benefits which would accrue from an increase in biodiversity, since such benefits are often intangible and hence, difficult to grasp. Thirdly, individuals may be uncertain as to whether alien plant eradication will result in increased biodiversity, since a change in the biodiversity level is often difficult to assess and/or demonstrate. Finally, biodiversity has 'public good' characteristics and thus individuals may easily express no WTP for the good and conceal their true preferences in expectation that others will sustain the cost. This is frequently referred to as the free rider problem which stems from the non-exclusive or joint supply nature of public goods. Although an individual values and benefits from a particular resource, he is unwilling to contribute anything because he knows he cannot be excluded from enjoying the good (Pearce and Nash, 1981:134).

7.5.1 Utilisation of biological resources

The upper reaches of the Mhlatuze Catchment are very rural and undeveloped, with a large proportion of the people engaged in a subsistence lifestyle. Consequently, the majority of these people depend on biological resources for food, medicine and fuel. From contemporary research conducted in South Africa, it was estimated that there are approximately six million indigenous medicine consumers in KwaZulu-Natal and twenty-seven million consumers in South Africa (Mander, 1998:2). Furthermore, Mander has established that households spend on average between four and eight *per cent* of their annual incomes on indigenous medicine services. This highlights the importance of medicinal plants in the health care industry of South Africa.

It is anticipated that medicinal plants with great economic importance are likely to be distributed in the study area (refer to Appendix XIII) (McKean *pers comm.*). It is

[1] Lexicographic preference occurs when individuals are unwilling to trade-off one good for another (Spash and Hanley, 1995:203).

apparent that all these medicinal plants have high commercial values and so an increase in these plant populations could have a substantial impact on the local economy. A complete assessment of the biodiversity benefits associated with alien plant eradication would need to incorporate the consumptive use value of increased biodiversity – one important element of which would be the harvesting of medicinal plants. It was unfeasible to calculate the expected economic benefit that alien plant removal would have on medicinal plant populations in the study area, due to the lack of data pertaining to the actual distribution and populations of these species. Thus, in order to accurately estimate a value for this benefit in the future, further research is required.

Given the uncertainties and complexities associated with valuing biodiversity, it was not possible to quantify this benefit in the analysis. However, based on available literature and responses elicited, it is surmised that the economic value of increased biodiversity attendant on alien plant eradication would be potentially significant.

7.6 Employment benefits

Although the employment of individuals is essentially a cost associated with alien plant eradication, when such employment enhances the welfare of society it may also be regarded as a social benefit. From the literature review as well as interviews conducted with WFW employees and other major stakeholders in the study area, it was established that this region is characterised by high levels of crime and poverty. These are likely to be reduced in the event of increased employment. Consequently, employment, in addition to representing a cost to stakeholders, will also be considered as a social benefit.

The magnitude of the employment benefit is contingent upon the number of labourers employed, which in turn is positively related to the form of alien plant control adopted. For example, the employment benefit derived from mechanical and chemical control methods is large, since these techniques are labour intensive (i.e. between 4-60 labour units are prescribed for the initial eradication of one hectare of densely invaded alien vegetation) (de Wit and Crookes, 2000:41). In contrast, bio-control methods do not compare favourably in terms of job creation, since it is anticipated that this control option will lead to a loss of jobs in the WFW Programme and other programmes aimed at eradicating alien plants. For purposes of this research project, however, only mechanical and chemical control methods are considered because the exact effects of bio-control agents in the area are difficult to assess.

7.6.1 Levels of unemployment and crime rates in the catchment

The Mhlatuze Catchment is characterised by high levels of unemployment of approximately forty-three *per cent* and this exceeds the provincial average by roughly four *per cent* (refer to section 4.5.2 for more details). These high unemployment levels have culminated in the escalation of crime and violence in the immediate vicinity. This further corroborates the paramount importance of job creation affiliated to alien plant removal in the catchment.

Previous studies, which have assessed the social impacts of the WFW Programme, reveal that in some areas crime rates have declined by up to twenty *per cent* (Asmal, 1996:5). Unfortunately, for purposes of this research the only crime statistics available were for the entire Ulundi region and so a similar evaluation could not be made. Nevertheless, analysis of the general crime statistics obtained suggest that whilst the number of some criminal offences has declined in certain categories, the overall crime rate has increased in the area, since WFW's inception in 1997 (refer to Appendix XII). Although accurate conclusions cannot be extrapolated from these results, it is surmised that the escalation in crime rates is a direct consequence of the high population growth rate as well as an increase in the number of individuals entering the job market. In order to accurately assess the social impacts of alien plant eradication programmes it is necessary to segregate these regional crime statistics into different towns.

7.6.2 Characteristics of WFW employees

Interviews conducted with WFW employees suggest that over fifty *per cent* of current employees are female. This is desirable, since it facilitates the development and empowerment of previously disadvantaged members of society such as females and previously unemployed persons, which is one of the main objectives of the Reconstruction and Development Programme (RDP).

Furthermore, it was established that approximately seventy-seven *per cent* of the WFW employees are the sole breadwinners. This highlights the extreme poverty of the households in general and the dependence of other family members on this source of income. Also it was apparent that two-thirds of the WFW employees in the study region were previously unemployed, which although high is significantly lower than levels recorded in other areas. For example, a case study undertaken in the Okhombe region disclosed that eighty-two *per cent* of their WFW employees were previously unemployed (de Wit and Crookes, 2000:107). From a social welfare perspective, it may be argued that it is more desirable to employ previously unemployed individuals than the previously employed, since the former are likely to have a greater need for skills development, and are less likely to have long-term financial commitments (an important consideration given the short-term nature of employment offered by the WFW Programme). Whether or not this argument is accepted, it can be concluded that employment is created through alien plant eradication and will certainly assist in poverty alleviation in the local economy.

7.6.3 Objectives of the WFW Programme

One of the main objectives of the WFW Programme is to train people in a range of different skills in order to empower these individuals to acquire future employment as the Programme develops (refer to section 4.8 for further clarification of these objectives). However, from research conducted, it was evident that the majority of training received by the WFW employees is very specific to alien plant eradication (e.g. alien plant identification). Thus, it will be exceptionally difficult to apply skills acquired to other areas of employment. Consequently, WFW employees are essentially not any better equipped to seek alternative employment once the Programme has been terminated, which is problematic given the short-term nature of this Programme.

Another objective of the WFW Programme is to empower labourers by developing viable secondary industries, for example, a charcoal production industry, which could be sustained subsequent to the cessation of the Programme. Such industries would provide long-term economic benefits to the local communities. However, this objective has not been attained in the study area. This is largely attributed to the fact that the majority of alien plant eradication undertaken by the WFW Programme has been confined to private land, where individuals are forbidden to remove and/or utilise any vegetation for charcoal production or any other purpose.

7.6.4 Problems associated with alien plant eradication programmes

It is apparent from the stakeholder responses that there are serious problems associated with alien plant eradication programmes, such as the WFW Programme operating in the study region. These problems range from inequitable assistance given to individuals to inefficient clearing operations due to inadequate daily tasks set for labourers. Numerous individuals have asserted that the Programme is inefficient because daily tasks assigned to labourers are inadequate to keep them occupied for the entire day. Further, areas cleared by labourers are not thoroughly checked before permitting employees to leave. These problems have resulted in substantial conflict between WFW and stakeholder employees and need to be addressed.

Employment benefits associated with alien plant eradication were not quantified in this study due to the lack of accurate data as well as the uncertainties surrounding crime rates, poverty and training received by employees in the area. However, given the characteristics of the region, that is, the high levels of unemployment, crime, violence and poverty which prevail, it is anticipated that such benefits will be significant.

7.7 Cost-Benefit Analysis

An analysis of the data collected was undertaken to establish the welfare effects and hence, the feasibility of alien plant eradication in the study area. Cost-benefit analysis aids decision-making because it identifies the most important impacts flowing from eradication and in this way, focuses decisions on these critical elements. Measured benefits associated with alien plant eradication, in order of importance are: revenue from harvesting commercial alien vegetation; increased streamflow; and reduced fire management costs (refer to Appendix IX). Unmeasured benefits include increased biodiversity and employment, and these elements were incorporated qualitatively into the final analysis.

In order to compare benefits and costs realised at different times, it was necessary to convert all the impacts into common units (such as present values) by a process known as discounting. For purposes of this research project, the net present value (NPV) technique was used to compare the cost and benefit flows resulting from the eradication of alien plants. The decision rule in relation to a project's estimated NPV, is to approve any project for which NPV exceeds zero. Consequently, any project with a negative NPV would be rejected, since human welfare would be diminished by such a project over time.

It is evident from the findings that the NPV outcome is contingent upon the discount rate employed. For example, when a zero discount rate is employed a NPV of negative R1 551 529 is computed over a ten year period, whilst a five *per cent* discount rate realises a NPV of R4 047 703 (refer to table 6.8). A positive discount rate of five *per cent* was selected for this project, based on long-term interest rates for the past ten years (refer to section 5.5.1 for further details concerning this discount rate). Under these conditions alien plant eradication is desirable, since it gives rise to a positive NPV.

In estimating the NPV only the impacts resulting from alien plant eradication which gave rise to monetary losses or gains (i.e. costs of clearing, revenue received from harvesting vegetation, increased streamflow as well as reduced fire management costs) were included. Thus, non-monetary gains like increased biodiversity and reduced crime rates as a result of increased employment were excluded from this quantitative analysis. Consequently, if the non-monetary gains were to be incorporated then the desirability of alien plant eradication would escalate. In allocating resources to a project it is essential to ensure that **non-monetary** and monetary gains and/or losses are given sufficient consideration since most environmental effects cannot be quantified due to the nature of these goods.

In applying cost-benefit analysis to alien plant eradication many assumptions were taken in evaluating the cost and benefit flows connected with this activity. There is no way of knowing with certainty whether all these underlying assumptions will hold in the future and consequently, it is necessary to firstly, identify all the assumptions made and secondly, make a confidence estimate related to each of these assumptions. Those assumptions with the lowest confidence estimates will then be subject to a sensitivity analysis in order to ascertain the effects of these on the NPV outcome established above.

7.7.1 Sensitivity Analysis

A sensitivity analysis is a critical component of any CBA and was undertaken on those assumptions with a low confidence estimate (refer to table 7.1). Due to time constraints faced by the researcher it was only possible to select two assumptions with low confidence estimates. The assumptions selected for the sensitivity analysis were the anticipated increase in streamflow subsequent to eradication, and water prices that various sectors will have to face in the future.

Table 7.1: Categories of uncertainties and confidence estimates.

Assumptions made	Confidence estimates (1-10)
Daily wage rate of labourers fixed at R25.00	10
Stakeholders adopted same control methods	6
Garlon was herbicide used for eradication	2
Value of alien vegetation harvesting in the initial phase of eradication	9
Four follow-up operations were required	8
Each stage of eradication was initiated annually in order of sequence	5
Expected rate of recovery over time	8
Shrub type natural vegetation will establish	3
Anticipated increase in streamflow	1
Water supply would be used proportionally to breakdown of current allocation	7
Water prices that different sectors are required to pay will be based on current tariffs	1
Constant technology and institutional framework	5

The estimates of confidence highlighted in the table above were based on the researcher's and expert opinion. Although the assumption that Garlon was the only herbicide utilised for eradication purposes was assigned a low confidence estimate, this is one of the most expensive herbicides on the market. Consequently, any alternative herbicide utilised would reduce the costs associated with chemical control methods, further emphasising the desirability of alien plant eradication. For this reason, the assumption that Garlon will be the only herbicide used for eradication was not subject to a sensitivity analysis. The assumption that shrub-type natural vegetation will be established subsequent to alien plant eradication also has a low confidence estimate. However, based on expert opinion, it was assumed that a combination of grassland and tree species (with predominantly grassland species) would re-establish following eradication. Consequently, it is anticipated that, on average, the overall effect on streamflow will be equivalent to that of shrub-type aliens, and given this expectation, this assumption was also excluded from the analysis.

The estimate made of increased water availability associated with alien plant eradication was based on numerous uncertainties, and hence the anticipated increase in streamflow assumption was allocated a low confidence estimate and subject to a sensitivity analysis. An increase in the available streamflow to 3.7 million m^3 (that is, eighty rather than fifty *per cent* of the total increase in the streamflow per annum) was investigated. The results obtained suggest that this increase would have a positive effect on the NPV outcome, especially where a lower discount rate is used. For example, NPV increased from -R1 551 529 to R185 295 when a zero discount rate was employed (refer to Appendix XIV). In general, however, the effect of an increase in streamflow or water availability on NPV outcome was largely insignificant. Consequently, it can be concluded that the final NPV is relatively insensitive to changes in this streamflow, although this is the second most important benefit recorded in the study.

The other assumption investigated was the water prices different sectors will face in the future. It was established that the irrigation sector currently uses the largest quantity of water and yet pays a much lower water tariff than the other sectors in the region of study. Given this discrepancy, and the degree of subsidisation it reflects, it is anticipated that in the future the water price charged to the irrigation sector may increase. The effects of such a change were investigated by assuming that the price of water charged to the irrigation sector would increase from 2.08 cents/m^3 to 10 cents/m^3. At this price, the total value of streamflow to all sectors will increase by R110 434, which only marginally affects the final NPV outcome (refer to Appendix XV). It is apparent that the NPV is relatively insensitive to a large change in the water price.

7.7.2 Distribution of Costs and Benefits

Cost-benefit analysis *per se* is only concerned with the economic efficiency of a project and hence, assumes that everyone has the same marginal utility of income. Essentially this means that gains and losses, to whomsoever they accrue, are given an equal ranking in the evaluation process (i.e. equal welfare weights apply as an equity criterion). Any CBA, based on the Hicks-Kaldor criterion (refer to section 2.3) provides the rationale for selecting projects whose benefits outweigh the costs, even if those individuals who gain from a project are not the same as those who pay for it (Perkins, 1994:55). However, it is important to examine the equity criterion associated with a project or the distribution of costs and benefits because a project which is efficient may nevertheless be undesirable if this distribution is highly skewed. For example, all benefits may accrue to wealthy individuals whilst the costs are borne by poor communities (Dixon *et al.*, 1988:77). In addition, the actual decision on what policy to adopt requires not only economic theories and statistical information but also ethical or value judgements based on the distribution of impacts associated with eradicating alien plants. Without this ethical base it is impossible to ascertain what is 'good' or 'bad' for society's wellbeing. Consequently, it is necessary to establish the equity criterion when assessing the economic desirability of a project such as alien plant eradication.

From research conducted, it is evident that the costs and benefits associated with eradication in the study area are not proportionally distributed (i.e. there is an unequal distribution of the costs and benefits). In the absence of the WFW Programme and/or biological control, those individuals engaged in alien plant eradication sustain the full costs associated with this process. Although these individuals do obtain some financial gain from the commercial alien vegetation harvested and the curtailment of fire management costs, many of the benefits affiliated to eradication accrue to society in general. For example, downstream individuals can obtain monetary gain from utilising the increased water availability to augment production output and furthermore, can enjoy positive effects such as increased biodiversity accruing from alien plant eradication. Consequently, there is a definite conflict of interests which prevails, as those individuals engaged in alien plant eradication must sustain the total costs associated with clearing, whilst all groups of society can essentially benefit from this clearing.

Profit-maximising individuals typically make decisions based on market prices and only consider the private costs and benefits related to a particular project when allocating resources. Consequently, such individuals are likely to engage in alien plant eradication for the initial year only because private benefits exceed the private costs incurred in that year only (refer to Appendix IX). Thereafter this outcome is reversed and private costs outweigh private benefits for all subsequent years. This leads to the prediction that individuals will discontinue alien plant eradication until such time as there is a monetary incentive to continue. Such a prediction is substantiated by sporadic alien plant eradication patterns recorded at a national scale. Under these circumstances, those that do not eradicate alien plants will produce more than the social optimum output level, while those downstream will produce less than the social optimum (refer to section 2.5.1). In order to encourage individuals to clear alien plants from their properties, government policy intervention is required. The policies may either tax those that are not engaged in such a process, or subsidise those that are (refer to Recommendations to review specific policy suggestions).

The examination of the private and social benefits associated with alien plant eradication conducted in this research project highlights that such eradication is economically efficient in the long-term and is therefore, desirable. Consequently, sporadic clearing, which prevails in large parts of South Africa, is inefficient in the long run, since alien vegetation is never under 'proper' control and alien plant density is never reduced. Thus, so long as individuals do not embark on regular clearing of alien plants, they will have to face the initial costs associated with clearing alien plants – which are the highest costs- indefinitely.

7.8 Study Limitations

The constraints of this study can be summarised as follows:

- The costs and benefits of alien plant eradication have been analysed at a catchment or microeconomic level. For this reason great caution should be exercised in extrapolating these results to macrolevels of analysis, since this could lead to very different outcomes.

- The costs and benefits alluded to are site specific and dependent on the density of alien vegetation, which limits its application to other areas.
- Not all positive impacts flowing from alien plant removal were evaluated or discussed, only those considered to be the most important. Thus the analysis represents a minimum estimate of the benefits. Consequently, caution must be exercised when interpreting the research findings presented.
- The absence of accurate information pertaining to the average area and age class of alien vegetation in the study area as well as the commercial alien plants which could be harvested, meant that expert opinion had to be obtained and relied upon.

7.9 Conclusion

This analysis of the monetary and non-monetary gains and losses associated with alien plant eradication concludes that this process is both economically and financially viable and should be encouraged. The lack of alien plant eradication activities gives rise to negative externalities. For example, the potential production of downstream users is reduced to below the social optimum output level, which is inefficient as society in general sustains the costs of reduced output. Furthermore, it is anticipated that the uncontrolled spread of alien vegetation will have a negative impact on the positive, welfare-creating parameters chosen for the survey (i.e. streamflow amount, biodiversity and fire control) as well as on future economic growth. Consequently, it is essential that alien plant eradication is encouraged in the catchment and if need be, incentives offered in order to do so. For example, either taxes or subsidies could be introduced by government to encourage individuals to produce at the social optimum output level and eradicate alien invasive plants.

CHAPTER EIGHT
CONCLUSIONS AND RECOMMENDATIONS

8.1 Introduction

This study has outlined the impacts that alien invasive vegetation has on resource allocation in South Africa and has established the feasibility of eradicating alien plants in the upper reaches of the Mhlatuze Catchment. Results presented indicate that this eradication process is desirable over a ten-year period with the employment of either a five or ten *per cent* discount rate, and point to the importance of strictly controlling the proliferation of alien plants in catchment areas.

In practice, a small proportion of individuals were found to be engaged in regular alien plant clearing, while most adopted sporadic clearing measures. This is attributed to a number of different factors. Firstly, with regard to the costs quantified in this study, if the alien plant eradication process is considered in the short term, that is on an annual basis, it is apparent that only the initial year gives rise to a net benefit (most of which accrues to the individual's undertaking the clearing), thereafter, net costs (i.e. negative net benefits) are recorded. Profit-maximising individuals are unlikely to engage in alien invasive plant clearing when there is not a positive net private benefit flowing from this activity. Secondly, the costs and benefits associated with alien plant eradication are unevenly distributed. Downstream users (comprising rural communities, private farmers as well as industries) and society, in general, receive the largest economic benefit in the form of increased streamflow and biodiversity. In contrast, those individuals engaged in alien plant eradication sustain the costs in full, but receive no benefit from increased streamflow, and only a fraction of the social benefits. This skewed distribution of costs and benefits gives rise to a conflict of interests and because upstream individuals have not in the past been compensated for clearing, such a process is only undertaken up to the point where marginal private costs (MPC) equal marginal private benefits (MPB). Thus, too little (i.e. sporadic) alien plant clearing will be undertaken by private individuals.

Sporadic clearing is clearly inefficient because the alien plant density is never reduced to a level where it may be 'properly' controlled, and the highest costs - the initial costs associated with eradication - will be borne indefinitely.

Consequently, the issue is not whether to undertake control operations to remove alien invasive plants, but rather how to plan and execute the control operations to ensure that the resources allocated to this activity are used as effectively as possible. Furthermore, it is necessary to identify changes that may be implemented to ensure future sustainability, as well as how these changes can be achieved. Recommendations based on the study's findings are outlined and discussed below.

8.2 Formulation of policy initiatives

Greater policy emphasis on and funds for curtailing widespread invasion by alien plants in South Africa are required in order to correct for the inefficiency associated with sporadic clearing. The formulation of policy initiatives should be a participatory process which takes cognisance of all stakeholders' perceptions (including those of affected rural communities), since how people understand and prioritise issues will determine whether they support, oppose or are indifferent to an alien plant eradication programme (Hindson *et al.*, 1996).

The success of changing attitudes towards alien plant eradication depends largely on the national strategies, plans, policies and processes that are implemented in the Mhlatuze River Catchment. It is meaningful to consider the following categories of policy instruments proposed by Haughton and Hunter (1994) when establishing appropriate control operations to remove alien invasive plants:

- **Legislative:** effective legislation is essential for establishing **incentives** and **disincentives** for eradicating alien invasive plants.
- **Technological:** improvements in current techniques adopted for eradicating alien plants should be encouraged, to reduce costs in the long-term. For example, the formulation of bio-control agents must be encouraged in order to enhance the efficiency of alien plant eradication.

- **Economic:** as emphasised in this study, it is necessary to focus on market based solutions to alien plant eradication through pricing externalities and introducing price differentials (e.g. tax those individuals who have many dense hectares of invaded alien plants more heavily than others). This type of solution will be considered in more depth in section 8.3 below.
- **Education and Information:** about the impacts associated with alien plant eradication. This is important in allowing producers and governments to make decisions pertaining to the eradication process.

8.3 Removal of externalities

The lack of alien plant eradication is an example of a negative externality which imposes costs on downstream users and is a result of the marginal private costs (MPC) consistently falling short of the marginal social costs (MSC) borne by society. As a result, the output, for example timber plantations, of upstream users will exceed the socially optimal output level, whilst the output of downstream users will be lower than the social optimum. This distortion in output levels can only be corrected by internalising the external costs associated with the lack of eradicating alien invasive vegetation and closing the gap between MPC and MSC. There are two appropriate strategies which may be adopted by government to internalise these costs and hence secure efficiency, namely the introduction of a tax or a subsidy. However, before these two measures are discussed it is essential to consider the socially optimal level of alien invasive plants.

8.3.1 Definition of the optimal alien plant level

Eradication of alien plants is economically worthwhile as long as the costs of clearing are outweighed by the (total) benefits. Thus, although this project has posited the complete eradication of alien plants in the study area, as a general point it should be noted that the optimal level of infestation in any given area is not necessarily zero. Rather the socially optimal level of alien invasive plants is site-specific as well as species dependent since site and species characteristics will impact on both costs and benefits of clearing. For example, in high rainfall areas the growth and invasive ability of alien plants is generally extremely rapid and thus, alien plants will proliferate quickly and dominate these ecosystems from the early stages. In such an instance, the socially optimal level of alien infestation may be zero, because allowing any alien plants to remain in the area would lead to a rapid escalation in negative ecological impacts as well as in future costs of eradication. On the other hand, in low rainfall areas, certain types of alien plants may cause little damage and be extremely easy to control and thus, the optimal level may be positive.

Policy-makers would need to take this into consideration in trying to define an appropriate level of a tax or subsidy to correct for the prevailing distortion in output levels.

8.3.2 Levying of a tax

Government can either levy a tax on individuals who are currently **not engaged** in alien plant clearing or alternatively, on those individuals engaged in **sporadic clearing**. The imposition of such a tax will ensure producers of externalities consider the real economic cost (i.e. the marginal social cost) associated with an activity, and will ensure output of timber occurs at the socially optimal level. It is important to ensure that the tax imposed for non-eradication exceeds the MPC of clearing, since only in this event will such a charge be effective in inducing individuals to remove alien plants in the long-term. Furthermore, the tax levied must be site-specific and charged per dense hectare of invaded alien plants. Consequently, those individuals who have not engaged in any alien plant eradication will face the highest tax, whilst those engaged in regular clearing will face a minimal, if any, tax. Where no clearing has been undertaken, the tax will increase the individuals' additional costs and will ultimately reduce their net profit.

It is important to caution that taxes are only a useful means of removing the negative externality associated with the lack of alien plant clearing when there is perfect information concerning the costs of such eradication. Consequently, where information pertaining to the costs of eradicating alien plants does not exist for an area, it is necessary that further research be undertaken to establish this.

8.3.3 Introduction of a subsidy

Government can subsidise those individuals that have been engaged in alien plant clearing on their properties and/or those downstream users whose private costs are higher as a result of the negative externality. Subsidisation of those individuals currently engaged in clearing can be in the form of either monetary incentives or subsidising of certain costs (besides labour) incurred in clearing (e.g. herbicides). The subsidy, like the tax, should be site-specific and paid per dense hectare of invaded alien plants. Subsidisation of costs or monetary measures require on-going monitoring by government officials to ensure that the resources provided are being used for the appropriate purposes.

Subsidisation of downstream users can also be undertaken by government to compensate for their low output levels as a consequence of the reduced streamflow. This type of compensation may be called for where equity issues dominate. Unless this is strictly controlled, it is an inappropriate solution to the alien plant eradication problem since it may attract more individuals to locate downstream in the hope of attaining the subsidy and in addition, may cause current inefficient operations to continue operating as a result of this subsidy.

8.4 Supplementary measures

8.4.1 Fire insurance premiums

The fire insurance premium is one measure which could be used to encourage private individuals and companies to engage in regular alien plant clearing. Where individuals have removed or are in the process of removing alien plants from their land, their fire insurance premiums should be reduced because the spread of fire is much easier to control. Similarly, fire insurance premiums should be augmented where individuals have not attempted to eradicate alien invasive plants from their properties. The change in fire insurance premiums should be directly dependent on the density and degree of alien plant infestation on the property. It is anticipated that the total costs borne by insurance companies will not increase as a consequence of this additional duty, since those properties which are insured against fire are inspected annually. The change in fire insurance premiums proposed will act as an **incentive** for individuals to engage in alien invasive plant clearing.

8.4.2 Formulation of a weed management plan

All those individuals owning large areas of natural land which are prone to alien plant invasion should be encouraged by government to formulate a **weed management plan**. This plan entails the establishment of benchmarks which can be used to measure trends and progress towards achieving some reduced level of alien plant infestation. Such a plan is an important means of communicating information about progress towards goals set. Also, it will enable government to readily assess this progress at regular intervals.

The recording of progress will ensure the collection of accurate data pertaining to the location and extent of alien plant infestation. Many large companies have developed weed management plans. For example, Sappi have formulated a five-year weed plan and have mapped out how they intend to eradicate all alien invasive plants over this five-year period. Furthermore, Sappi have mapped out the areas in which eradication has taken place, along with the costs and phase of eradication in each of these areas.

The formulation of this plan might be encouraged by only offering subsidies to those individuals who have formulated weed management plans.

8.4.3 Improvements of alien plant clearing programmes

Programmes such as the WFW Programme are to be encouraged due to their potential for creating employment and thus alleviating crime and poverty, which is an extremely important aspect in a cash-strapped country facing massive unemployment. However, it has previously been established that there are numerous problems associated with this

WFW Programme. Based on the criticisms of private farmers, the following improvements to the current programme are proposed:

- To prevent animosity between stakeholders in the Mhlatuze River Catchment, it is recommended that the WFW Programme be **confined to state land** in the future.
- Stricter control of the current WFW Programme is required to reduce the number of conflicts between farm and WFW employees. For example, tasks which are sufficient to keep labourers occupied all day must be carefully planned and assigned.
- Employment created by the WFW Programme *per se* is not a sustainable solution to the unemployment situation and it is therefore essential that WFW employees are taught skills which they can apply in other activities subsequent to the termination of the WFW Programme. Examples of such skills are first aid training and acquisition of a driver's license.

Furthermore, in order to accurately assess the social impacts that the WFW Programme may have in the immediate vicinity, it is important that regional crime statistics are divided into different towns (e.g. Melmoth and Eshowe).

8.5 Further research required

8.5.1 Valuing non-market goods

The CBA procedure entails measuring all project costs and benefits. For those goods and services which are marketable, prices can be readily derived, however, when they take forms which are not easily measured in the marketplace, the analyst must approximate these. Attaching monetary values to environmental goods and services is important for two reasons. Firstly, environmental goods and services tend to be overlooked when they are not quantified. Secondly, attaching monetary values to these goods emphasises that they are not free. Consequently, it is essential to encourage further research aimed at developing and/or formulating techniques to value environmental goods and services, such as biodiversity.

8.5.2 Impact of alien vegetation on water resources

More research into the impact of alien invasive vegetation on the total available water is required. This will assist in ascertaining the actual water which could in future be reliably captured and extracted for direct use, subsequent to clearing alien invasive plants. In addition, it is necessary to compare the costs of alien plant eradication to alternative schemes (e.g. dam construction) which will augment water resources in the Mhlatuze Catchment. This is important to ascertain and will indicate which are the most cost-effective in the long-term.

8.5.3 Formulation of bio-control agents

Continued research into the formulation of bio-control agents is required. This research should be supported financially by both government and other companies, like the timber companies, who are largely responsible for the increased invasion of alien vegetation in the Mhlatuze Catchment. Further research into bio-control agents is important, especially since their development is likely to substantially reduce the future costs that individuals will have to sustain to effectively control alien infestations.

8.6 Conclusion

Strategic planning of alien plant clearing initiatives is critically important given the cost of such an exercise. It follows, therefore that policy-makers should identify policies or management options that are efficient and flexible, and hence can be applied to different areas where different characteristics pertain. Furthermore, such management options should form an important component of specific catchment management plans and in this sense be catchment-specific, since different catchments have different characteristics. Consequently, what is appropriate and effective in one catchment may not be in another and this must be considered when designing specific programmes. Before initiating alien plant eradication, it is essential to have a long-term strategy in place combined with a vision of what plant species are to replace the alien plants. If such a long-term strategy is not in place then alien plant control is likely to fail, as alien plants will out-compete any indigenous vegetation in the disturbed area and the situation will rapidly return to what it was before attempts to clear the aliens took place.

The major conclusion of this research is that there are many reasons why the eradication of alien plants is economically and socially desirable, both in terms of the efficiency and equity criteria that are generally accepted desiderata in progressive societies. The cost-benefit data specific to the Mhlatuze Catchment certainly suggest that alien plant eradication should be promoted in this area.

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Convention on Biological Diversity (1992)

Conservation of Agricultural Resources Act (Act 43 of 1983)

Forest Act (Act 122 of 1984)

Personal Communications:

Aitken, Brian (16/08/01)
Private Farmer
Melmoth

Buchler, Martin (16/08/2001)
Forestry Manager
SAPPI
Melmoth

Chandler, Gavin (17/08/01)
Private Farmer
Melmoth

Goodall, Jeremy (14/11/2000)
Project Manager
Plant Protection Research Institute

Goodman, Pete 18/05/01
Co-ordinator of biodiversity research
KZNNCS
Pietermaritzburg

Leitch, Dudley (15/08/2001)
Private Farmer
Melmoth

Le Maitre, David (30/08/2001)
Hydrologist
CSIR
Stellenbosch

Lotter, Wayne (8/11/01)
Invasive Alien Plant Manager
SAPPI
Pietermaritzburg

McKean, Steve 18/05/01
KZNNCS
Pietermaritzburg

McMurray, Raymond (12/10/2000)
Private Farmer
Melmoth

Olkers, Terry (7/11/2000)
Research Entomologist
Plant Protection Research Institute

Paterson, Bruce (14/08/01)
Silviculture Forester
MONDI
Melmoth

Perkins, James (17/7/2001)
DWAF
Durban

Schnetler, Rudi (15/08/01)
Private Farmer
Melmoth

Schramm, Edwin (31/08/01)
CTC
Pietermartizburg

Smith, Victor (15/08/01)
Private Farmer
Melmoth

Thomas, Simon (17/08/01)
Fire Chief for Melmoth District
MONDI
Melmoth

Van der Merwe, Paul (17/7/2001)
DWAF
Pretoria

Wood, James (11/09/2001)
Private Consultant
Pietermaritzburg

Appendix I: Key individuals interviewed regarding alien plant eradication.

Interviewee	Organisation	Position	Purpose
Mr James Wood	N/A	Private Consultant	Establish the total areas of dense alien invasive vegetation on both private and public sector land in the Mhlatuze Catchment.
Dr Peter Roberts	N/A	Private Consultant	Ascertain the water consumption of plantation species, such as eucalyptus, pines and wattles in the Mhlatuze Catchment.
Mr Jeremy Goodall	PPRI	Project Manager	Elicit the importance of managing and eradicating alien vegetation. To expound the most appropriate herbicides which should be employed when eradicating alien plants.
Mr Terry Olkers	PPRI	Research entemologist	Establish the future role and importance of biological control agents in eradicating alien plants.
Mr Wayne Lotter	SAPPI	Invasive Alien Plant Manager	Obtain information concerning the costs and benefits of eradicating alien invasive plants.

Note: PPRI = Plant Protection Research Institute

Appendix II: Questionnaire employed for WFW interviews.

Questionnaire (community members involved in WFW Programme): **No.** ☐

Name: ______________________________

Date: ________________________

Note: Please tick appropriate block/s when answering questions

1. **Do you live in the Mhlatuze Catchment?**
   Yes ☐ No ☐

If yes, please specify where in the catchment you live (i.e.: rural or urban areas)

____

2. **How long have you lived in the Mhlatuze Catchment?**
   Less than 5 years ☐ 5-10 years ☐ 11-19 years ☐ 20-25 years ☐
   26-30 years ☐ Over 30 years ☐

3. **Do you farm on your land?**
   Yes ☐ No ☐
   If yes, what do you farm:
   Crops ☐ Timber ☐ Sugarcane ☐ Citrus ☐
   Other: _____________________

4. **What are the three main problem/s (social, economic or physical) in the Melmoth region ?**

____

____

Please rate the following problems in the Melmoth region according to whether they are **very serious, not too serious or no problem.**

Problem	**Very serious (1)**	**Not too serious (2)**	**No Problem (3)**
Poverty			
Crime			
Unemployment			
Water quantity			
Water quality			
Erosion			
Biodiversity (loss of plants and animals)			

5. **Are any rivers located near to where you live?**
   Yes ☐ No ☐
   If yes, please specify the name/s of the river/s

____

6. **Do you use the river water?**
   Yes ☐ No ☐
   If yes, which of the following describes your water use (please tick the appropriate block/s):
   Drinking ☐
   Cooking ☐
   Bathing ☐
   Washing ☐
   Irrigation of gardens ☐
   Livestock watering ☐
   Construction ☐
   Other: ____________________

7. **Do you have access to tap (i.e.: running) water?**
   Yes ☐ No ☐
   If yes, please specify where the tap is situated (i.e.: in house, garden, etc)
   ____
   ____

8. **Have you noticed any changes in the river water quality and/or quantity in the past few years?**
   Yes ☐ No ☐

   If yes, what are these changes? (Probe)
   ____
   ____

   See if they indicate these changes:
   Decreased water quantity ☐ **OR** Increased water quantity ☐
   Decreased water quality ☐ **OR** Increased water quality ☐
   Increased siltation ☐
   Other: ____________________

   (<u>**Note**</u>: If noticed a water quality change, please describe what has changed)
   ____
   ____

9. **If there has been a change in water quality and/or quantity, what do you think has caused the change?**

____
____
____
____

10. Do you think the following have affected water quality or quantity?

Decreased rainfall ☐
Increased invasion of alien vegetation ☐
Lack of proper land management ☐

Working For Water Work:

11. Were you employed prior to your present job with the WFW Programme?

Yes ☐ No ☐

If yes, what did you do?

____

12. How long have you been employed with the WFW Programme?

Less than 6 months ☐ 6mths-1 year ☐ 1-2 years ☐
2-3 years ☐ Over3 years ☐

13. Who decides on the employment ofthe people for the WFW Programme?

____

14. How do you get jobs for the WFW Programme?

____

____

15. Have you received any training and/or attended courses since your employment with the WFW Programme?

Yes ☐ No ☐

If yes, what training did you acquire and/or what courses did you attend? (Probe)

Tick off any appropriate training/courses undertaken

Identification of alien plant species ☐
Equipment handling ☐
Methods of control ☐
Machine operation ☐
Driver's license ☐
Management skills ☐
Safety and First Aid ☐
Environmental awareness ☐
Literacy classes ☐
Health awareness ☐

Other: ______________________

16. What is your current position within the WFW Programme? (please tick appropriate block) & What is your salary per day?

		Salary per day
Supervisor	☐	________
Chainsaw Operator	☐	________
Herbicide Applicator	☐	________
General Worker	☐	________
1st Aid Officer	☐	________
Driver	☐	________
Other: ________		

Alien Clearing Programme:

17. What are the predominant alien invasive species in the Mfuli Catchment where you have been working (please tick appropriate block/s)

Bugweed ☐
Mauritius thorn ☐
Bramble ☐
Lantana ☐
Chromolaena ☐
Wattle ☐
Gum ☐
Syringa ☐
Other: ________

18. Do you think it is important to clear and manage invasive alien vegetation?

Yes ☐ No ☐

If yes, what are the four most important benefits of clearing?

____

____

Demographic Statistics:

19. Please specify your gender:

Male ☐Female ☐

20. Which of the following corresponds to your age group?

Less than 25 years ☐ 25-29 years ☐ 30-40 years ☐ Over 40 years ☐

21. Are you disabled?

Yes ☐ No ☐

If yes, please specify your disability

____

22. Is anyone else in your family employed?

Yes ☐ No ☐

If yes, tick appropriate block/s concerning the family member/s employed & specify their monthly salary (or alternatively determine household income) :

		Monthly salary
Husband/wife	☐	____________
Mother	☐	____________
Father	☐	____________
Children	☐	____________

23. Is there a pensioner in your family?

Yes ☐ No ☐

24. How many people do you personally support? (i.e.: including girl/boyfriends, etc)

None ☐
One ☐
Two ☐
Three ☐
More than Three ☐

(Note: If more than three dependents please specify the number)

____

Thank you for your time and effort.

Appendix III: Private farmers and other stakeholders interviewed regarding alien plant eradication.

Interviewee	Organisation which they represent
Mr Brian Aitken	Private Farmer
Mr Hayden Percival	Private Farmer
Mr Gavin Chandler	Private Farmer
Mr Raymond McMurray	Private Farmer
Mr Stuart McMurray	Private Farmer
Mr Victor Smith	Private Farmer
Mr Rudi Schnetler	Private Farmer
Mr Roland Labuschagne	Private Farmer
Mr Donald Leitch	Private Farmer
Mr Dudley Leitch	Private Farmer
Mr Bruce Paterson	MONDI
Mr Martin Buchler	SAPPI
Mr Edwin Schramm	CTC

Appendix IV: General questionnaire format utilised for interviews conducted.

General Questions

1. How long have you resided in the area?

___

2. How long have you owned this property/s?

___

3. What is the total size of the property/s that you own (in hectares)?

___

4. What type/s of land activities do you undertake on your farm?

___

___

5. In your opinion, have there been any changes (economic, physical or social) in the Melmoth area over the past 30 years? If so, please specify and describe these changes.

___

___

6. Do you belong to the conservancy?

___

7. Do you have a guest lodge situated on your property(s) in the Mhlatuze Catchment?
   Yes ☐ No ☐

If YES, proceed to Q8; if NO proceed to Q15.

8. What, in your opinion, attracts tourists to your lodge? (I.e.: what is the main draw card to your lodge?)

___

___

9. What 'type' of clientelè do you aim to attract? (i.e.: specify whether local/foreign)

___

___

10. What is the capacity of your guest lodge?

___

11. What are the rates you charge per person per night?

___

12. What is your occupancy rate per annum (in percentage)? OR What is the total number of people occupying the lodge per annum?

___

13. Does your occupancy rate differ seasonally? If so, when is the most popular time and why?

___

14. Do you have regular guests? If so, what percentage of guests are regular?

___

Proceed to Q15

15. In your opinion, what attracts tourists to this area?

____

____

16. To which of the following income brackets do you belong:

☐ **< R500 000 – R1 million p.a** ☐ **R1 million-R2 million p.a**

☐ **R2 million - R3 million p.a** ☐ **R3million – R5 million p.a**

☐ **R5 million – R7 million p.a** ☐ **R7 million – R10 million p.a**

☐ **R10 million – R15 million p.a** ☐ **Greater than R15 million p.a**

17. Do you think it is important and/or necessary to eradicate and control invasive alien vegetation? Reason/s (waste of time and effort, its the correct thing to do, etc).

____

____

18. Are you engaged in a programme to remove alien vegetation? If so, please specify what this is.

____

____

19. When did you begin removing alien invasive vegetation from your property? (ie: how many years ago)

____

<u>**Employment section**</u>

20. Are all the labourers you employ permanent, or are some contract (or togt) labourers?

____

21. How many labourers (permanent and contract) are currently employed, specifically for eradicating alien invasive plants on your property? (per annum)

<u>Note:</u> if do not employ labourers specifically for this purpose, how many days per annum are allocated to eradicating alien vegetation and how many labourers are utilised?

____

____

22. Are the labourers assigned different tasks (ie: herbicide applicator, chainsaw operator) according to their skills? If so, please indicate the number of labourers assigned to each task.

____

____

23. On average, how many hectares of dense (or specify) invasive alien vegetation would be eradicated (or alternatively managed) per annum?

____

____

24. What is the current wage rate of the labourers you employ? (per day/month/annum) If relevant, differentiate between permanent and contract labourers. Does the wage rate differ according to the skill of the labourer? If so, please specify these differential rates.

____

____

25. Do the labourers you employ receive any other benefits apart from their wages (e.g.: free housing, water, electricity, food rations, etc)? If so, please specify benefits and indicate whether labourers are required to contribute towards these.

____

____

26. If yes to above question, what do these benefits amount to (in rands per day/ month/annum)?

____

Herbicide Section:

27. Name the herbicide/s and define the quantities (in litres per annum/month) that you utilise in eradicating alien invasive vegetation from your property?

____

____

____

28. The litres of herbicides which you stated above, is this concentrated or mixed litres?

____

29. What is the price you pay (per litre) for each of the herbicide/s you utilise?

____

____

30. From where do you purchase these herbicides? (from local co-op, sales rep, etc)

____

____

Equipment Section:

31. Please specify the equipment (including safety equipment, chain saws, knapsacks) as well as the quantities of equipment required for the labourers you employ to eradicate alien invasive plants?

____

____

____

32. In total how much does the equipment cost you per annum?

____

33. Is a vehicle or tractor required for eradicating alien invasive vegetation?

Yes ☐ **No** ☐

If yes, what do you utilise? Please specify the make and number of days per annum that you utilise it.

____

34. If yes to above question, how much do the running costs amount to per annum? (ie: oil and petrol expenses)

____

____

Plant Clearing Section:

35. What is the average cost per hectare that you incur to clear dense infestations (ie: more than 50% canopy cover) of alien vegetation on your property?

36. What is average cost per hectare that you incur for the following:

1st follow-up =

2nd follow-up =

3rd follow-up =

4th follow-up =

Maintenance =

37. Do the costs of eradication differ for riparian zones and other areas? If yes, please specify the difference (ie: whether higher or lower in the riparian zones and ascertain a value for this).

38. What factor/s influence the costs of clearing and managing alien invasive vegetation?

39. Do you bear the full costs of eradicating and managing invasive alien vegetation on your property or are some of these costs covered by other bodies or organisations (e.g.: WFW Programme)? Explanation.

Water Quantity Section

40. Do any rivers pass through/adjoin your property/farm?

Yes ☐ **No** ☐

41. Are the rivers/streams important to you (directly or indirectly)? If so, please specify (irrigation, human consumption, livestock consumption, etc).

If YES proceed to Question 41, if NO proceed to Question 45.

42. What is the total quantity of water required (in litres/m^3) per month (or annum) to fulfil your farming activities?

43. Do you require any additional water to optimise your output? If so, how much? (in litres/ m^3)

44. What is the maximum you are WTP (per month) per 1000 m^3 of water to a Catchment Management Agency (or another institution of your choice) to increase your current water abstraction? Reason/s.

45. What is the maximum you are WTP (per month) to a Catchment Management Agency (or another institution of your choice) for the assurance that there will indefinitely be adequate quantities of water to sustain ecological activities? Reason/s.

____

____

____

Biodiversity section

46. In your opinion, is the Mhlatuze Catchment important from a biodiversity perspective (in terms of landscape, ecosystem and species diversity)? Reason/s.

____

____

47. In your opinion, would an increase in biodiversity attract more tourists to the area? Reason/s.

____

____

____

48. What is the maximum you are WTP per month (or annually) to a conservation trust fund (or another institution of your choice) which will be managed efficiently, to ensure a 10% increase in biodiversity (which includes natural fauna and flora)?

____

49. If zero, reason/s (cannot afford it, responsibility of state, protected by law, etc).

____

Fire Control Section:

50. Is fire a potential threat to your farming activities?
    Yes ☐ **No** ☐

If so, please specify.

____

51. How much does it cost you (on average) per hectare to burn?

____

52. Does the presence of alien invasive species affect the burning technique adopted? If so, please specify how.

____

____

53. Does the presence of alien invasive species adversely affect the cost of burning? If so, by what percentage do they augment the cost of burning (ie: 5%, 10% or 20%, etc?)

____

____

54. Under those circumstances where you have eradicated alien invasive vegetation from your property, are your insurance premiums reduced?

____

____

55. In your opinion, do natural riparian zones with indigenous vegetation act as a good firebreak? If so, is this better than grassland firebreaks? Reason/s.

56. How much do you pay per month for fire insurance?

Direct use benefits:

57. Is the alien invasive vegetation eradicated from your property, utilised?

Yes ☐ **No** ☐

If so, please specify for what and by whom. **Try and elicit value.**

58. What is the monetary value per kilogram (or tonne) of the trees removed (give values for different species of vegetation)

59. Are you aware of any indigenous grasses or vegetation which are harvested from the Mhlatuze Catchment and either utilised or sold for medicinal purposes? If so, please specify the name/s.

60. Are you familiar with the different plant species (and their scientific names), which occur in the Mhlatuze Catchment?

61. Have you seen some or all of the following plant species in the Mhlatuze Catchment (show pictures):
   - ☐ Scilla natalensis (inguduza)
   - ☐ Bowiea volubilis (igibisila)
   - ☐ Ocotea bullata (unukani)
   - ☐ Eucomis autumnalis (umathunga)
   - ☐ Alepidea amatymbica (ikhathazo)
   - ☐ Curtisia dentata (umlahleni)

62. Please can you rank these plant species according to whether they are scarce or abundant in the Mhlatuze Catchment and indicate whether these species have increased or decreased in abundance over the past 5 years.

63. In your opinion, do alien invasive plants adversely affect the aesthetics of the area?

64. Where would you say the invasions of alien vegetation are most predominant? (ie: in riparian zones, etc)

65. On your property, what percentage of total invasive alien vegetation is located in riparian zones (defined as 30 m on either side of rivers/streams)?

66. Why do you think many people are totally opposed to eradicating and/or managing alien invasive vegetation on their property?

____

____

67. What, in your opinion, can be done to encourage more people to clear and manage invasive alien vegetation on their property?

____

____

68. If you had to combine all your alien vegetation into one dense area, how much would it cost you on average per hectare to remove the alien vegetation?

____

____

Consider the following and indicate whether you agree/disagree/unsure:

1000 stems of wattle per hectare (at a knee height level) would take 2 litres of concentrated garlon as well as between 4-6 people to spray per day: _______________

1 hectare of dense (or solid) bramble (knee height level) would take 3 litres of concentrated garlon as well as between 6-8 people to spray per day: _______________

Thank-you for your time and effort.

Appendix V: Consumer prices and long-term interest rates (SARB, 2001).

Year	Consumer Prices	Capital Market & Related Interest Rates (10-15 years)	Real Interest Rate
1990	15.3	15.96	0.66
1991	18.9	16.66	-2.24
1992	16.8	14.9	-1.9
1993	12.6	12.2	-0.4
1994	8.9	16.8	7.9
1995	7.9	14.56	6.66
1996	7.5	16.19	8.69
1997	8.6	14.14	5.54
1998	6.9	16.36	9.46
1999	5.2	13.96	8.76
2000	5.3	12.89	7.59
Average			**5**

The **standard deviation** = 5%

<u>Appendix VI:</u> Average areas and age class of the alien vegetation located within and outside riparian zones in the study area.

The total dense area of invasive alien vegetation (i.e. 3 767ha) was divided into riparian zones **(i.e. eighty *per cent* or 3 014 ha) and** other zones **(i.e. twenty *per cent* or 753 ha).**

<u>Table 1:</u> Area and average age class of alien vegetation <u>in riparian zones</u>

	W12A	W12B	W12C	Average (W12A,B&C)
Area under **class 1** (tall **alien shrubs**)	11%	39%	34%	**28%**
Area under **class 2 (medium trees)**	89%	56%	66%	**70%**
Area under **class 3** (tall **alien trees**)		5%		**2%**
Average age **class 1** (tall **alien shrubs**)	2 years	2 years	2 years	**2 years**
Average age **class 2 (medium trees)**	5 years	5 years	5 years	**5 years**
Average age **class 3** (tall **alien trees**)		15 years		**15 years**

<u>Table 2:</u> Area and average age class of alien vegetation <u>outside riparian zones</u>

	W12A	W12B	W12C	Average (W12A,B&C)
Area under **class 1** (tall **alien shrubs**)	3%	24%	20%	**15%**
Area under **class 2 (medium trees)**	97%	69%	80%	**82%**
Area under **class 3** (tall **alien trees**)		7%		**3%**
Average age **class 1** (tall **alien shrubs**)	2 years	2 years	2 years	**2 years**
Average age **class 2 (medium trees)**	6 years	6 years	6 years	**6 years**
Average age **class 3** (tall **alien trees**)		15 years		**15 years**

Note:

*Tall alien shrubs include *Lantana camara*, *Solanum mauritianum*, *Rubus species* and *Caesalpinia decapetala*.

*Medium trees include *Melia azedarach* and *Acacia saligna* (as well as medium sized *Acacia mixed species* and *Eucalyptus species*).

*Tall alien trees include *Eucalyptus species*, *Acacia mixed species* and *Pinus species*.

<u>Appendix VII:</u> Streamflow reduction associated with alien invasive vegetation located within the study area.

Streamflow reduction for each vegetation type was calculated using the following equation:

Streamflow reduction (mm) = 0.0238 x biomass (g/m^2)

Calculation of above-ground biomass (B) and growth curves (Le Maitre *et al.*, 1996) for three categories of vegetation based on post-fire age (a= age in years):

Equation number	Vegetation structure	Biomass (g/m^2)
1	Tall alien shrubs	$b=5\ 240 \log_{10}(a)-415$
2	Medium alien trees	$b=9610 \log_{10}(a)-636$
3	Tall alien trees	$b=20\ 000 \log_{10}(a)-7060$

Tall alien shrubs <u>in riparian zones</u> (comprise 28% of riparian area=843.9ha):

Biomass Equation: $b=5\ 240 \log_{10}(a)-415$
Average age = 2 years
Thus, <u>b= 1162.4</u>

Streamflow reduction (mm): 1162.4 g/m^2 x 0.0238
= <u>27.66 mm</u>

<u>To convert mm into m^3:</u>
m^3= mm x area (ha) x 10
m^3= 27.66mm x 843.9ha x 10
= <u>233 422.74 m^3</u>

Medium alien trees <u>in riparian zones</u> (comprise 70% of riparian area=2109.8ha):

Biomass Equation: $b=9610 \log_{10}(a)-636$
Average age = 5 years
Thus, <u>b= 6081.1</u>

Streamflow reduction (mm): 6081.1 g/m^2 x 0.0238
= <u>144.7 mm</u>

<u>To convert mm into m^3:</u>
m^3= mm x area (ha) x 10
m^3= 144.7mm x 2109.8ha x 10
= <u>3 052 880.6 m^3</u>

Tall alien trees <u>in riparian zones</u> (comprise 2% of riparian area = 60.28 ha):

Biomass Equation: $b=20\ 000 \log_{10}(a)-7060$
Average age = 15 years
Thus, <u>b= 16 461.825</u>

Streamflow reduction (mm): 16 461.8 g/m^2 x 0.0238
= <u>392 mm</u>

<u>To convert mm into m^3:</u>
m^3= mm x area (ha) x 10
m^3= 392mm x 60.28ha x 10
= <u>236 298 m^3</u>

TOTAL STREAMFLOW REDUCTION <u>IN RIPARIAN ZONES</u>:
233 422.74 m^3 + 3 052 880.6 m^3 + 236 298 m^3 = **3 522 601.3 m^3**.

Tall alien shrubs <u>outside riparian zones</u> (comprise 15% of non-riparian area=112.95ha):

Biomass Equation: b=5 240 $\log_{10}$(a)-415
Average age = 2 years
Thus, <u>b= 1162.4</u>

Streamflow reduction (mm): 1162.4 g/m^2 x 0.0238
= <u>27.66 mm</u>

<u>To convert mm into m^3:</u>
m^3= mm x area (ha) x 10
m^3= 27.66mm x 112.95ha x 10
= <u>31 241.97 m^3</u>

Medium alien trees <u>outside riparian zones</u> (comprise 82% of non-riparian area=617.46ha):

Biomass Equation: b=9610 $\log_{10}$(a)-636
Average age = 6 years
Thus, <u>b= 6 842.0335</u>

Streamflow reduction (mm): 6 842.0335 g/m^2 x 0.0238
= <u>162.8 mm</u>

<u>To convert mm into m^3:</u>
m^3= mm x area (ha) x 10
m^3= 162.8mm x 617.46ha x 10
= <u>1 005 474.3 m^3</u>

Tall alien trees <u>outside riparian zones</u> (comprise 3% of non-riparian area=22.59ha):

Biomass Equation: b=20 000 $\log_{10}$(a)-7060
Average age = 15 years
Thus, <u>b= 16 461.825</u>

Streamflow reduction (mm): 16 461.8 g/m^2 x 0.0238
= <u>392 mm</u>

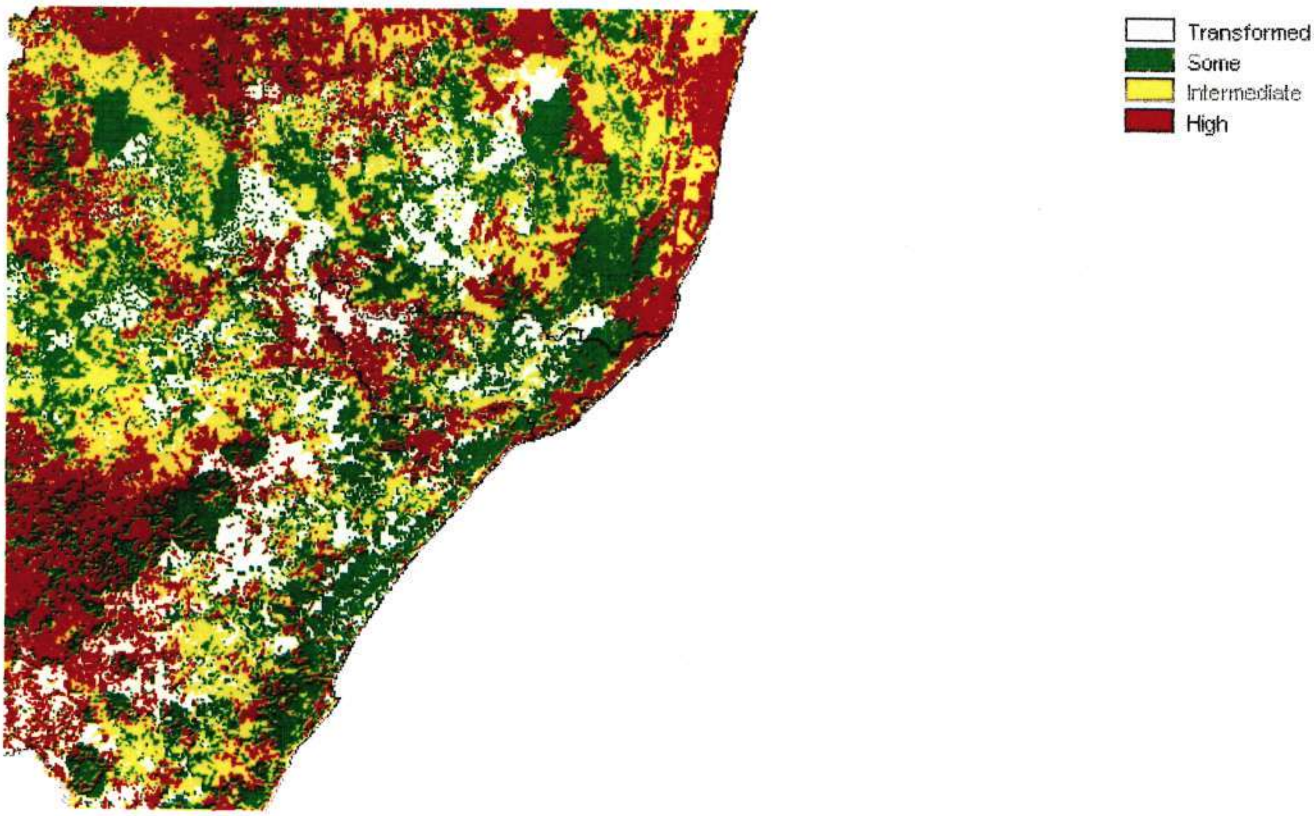
<u>To convert mm into m^3:</u>
m^3= mm x area (ha) x 10
m^3= 392mm x 22.59ha x 10
= <u>88 552.8 m^3</u>

TOTAL STREAMFLOW REDUCTION <u>OUTSIDE RIPARIAN ZONES</u>:
31 241.97 m^3 + 1 005 474.3 m^3 + 88 552.8 m^3 = **1 125 269.1 m^3**.

<u>FINAL (TOTAL) STREAMFLOW REDUCTION:</u>

3 522 601.3m^3 + 1 125 269.1 m^3 = **<u>4 647 870.4 m^3</u>**

Appendix VIII: The intrinsic biodiversity value of land in Kwazulu-Natal (NCS, 2001).



Appendix IX: Annual flow of costs and benefits associated with alien plant eradication in the upper reaches of the Mhlatuze Catchment.

Year	Revenue from harvestable timber	Revenue from increased streamflow	Revenue from reduced fire management costs	Total benefits (in Rands)	Final cost (in Rands)	Net Benefit/ Cost	NPV Discount rate 0%	NPV Discount rate 5%	NPV Discount rate 10%
1	R 11,481,400	R 422,584	R 105,476	R 12,009,460	R 7,534,000	**R 4,475,460**			
2	R 0	R 401,455	R 100,202	R 501,657	R 2,862,920	**-R 2,361,263**			
3	R 0	R 380,326	R 94,928	R 475,254	R 1,619,810	**-R 1,144,556**			
4	R 0	R 359,196	R 89,655	R 448,851	R 904,080	**-R 455,229**			
5	R 0	R 295,809	R 73,833	R 369,642	R 715,730	**-R 346,088**			
6	R 0	R 253,550	R 63,286	R 316,836	R 602,720	**-R 285,884**			
7	R 0	R 211,292	R 52,738	R 264,030	R 602,720	**-R 338,690**			
8	R 0	R 190,163	R 47,464	R 237,627	R 602,720	**-R 365,093**			
9	R 0	R 190,163	R 47,464	R 237,627	R 602,720	**-R 365,093**			
10	R 0	R 190,163	R 47,464	R 237,627	R 602,720	**-R 365,093**			
TOTAL	-	-	-	-	-	-	**-R 1,551,529**	**R 4,047,703**	**R 4,250,973**

Appendix X: Recommended herbicide dosage for alien plant control (PPRI, 2000).

Application type	Herbicide & Wetter	COST (R/l)			VOLUME (l/HA)		
	Concentration (%)	**Herbicide**	**Wetter**	**Water**	**Herbicide**	**Wetter**	**Water**
	Wattle						
Foliar-coppice (**Saplings**)	0.75% Garlon4 + 0.5% Actipron	142.23	12.40	0.06	3	2	400
Foliar-coppice (**Young trees**)	0.75% Garlon4 + 0.5% Actipron	142.23	12.40	0.06	3	2	400
	Eucalyptus						
Foliar seedlings, coppice (**Saplings**)	0.75% Garlon4 + 0.5% Actipron	142.23	12.40	0.06	3	2	400
Foliar - coppice 5 (**Saplings**)	0.75% Garlon4 + 0.5% Actipron	142.23	12.40	0.06	3	2	400
	Bugweed						
Basal bark (diesel carrier)	2% Garlon4	142.23	0	2.62	3.4	0	170
Total stump (diesel carrier)	2% Garlon4	142.23	0	2.62	3.4	0	170
	American Bramble						
Foliar - veld (1m)	0.5%Garlon4+ 0.5%Actipron	142.23	12.4	0.06	2	2	400
Foliar - coppice	0.5%Garlon4+ 0.5%Actipron	142.23	12.4	0.06	2	2	400

Appendix XI: Alien Plant Clearing Costing for Nagle Dam Project (Haynes & Gillham, 2000).

COSTING FOR INITIAL CLEARING TEAM FOR TREE TYPE ALIENS

This costing sheet details the cost of a team to clear-fell and stack alien plants

No allowance is made for the return on sale of timber

The work rate for the team detailed below should be:

0.3 ha of dense infestation per day outside riparian area

0.25 ha of dense infestation per day in riparian area

TEAM COMPOSITION

No	Description		Unit Daily rate	Daily cost	Notes
2	Chain saw Operator		R 45.00	R 90.00	
1	Knapsack operator		R 38.00	R 38.00	
8	Labourers		R 35.00	R 280.00	To match local farm labour rates
1	Vehicle		R 175.00	R 175.00	Assumed 100 kms/day @ R1,75/km
1	Supervisor		R 100.00	R 100.00	NB This supervisor handles two teams
0	Brush cutter		R 65.75	R 0.00	
2	Chain saws		R 84.35	R 168.70	
1	Knapsac sprayer		R 3.00	R 3.00	
10	Safety equipment		R 3.23	R 32.25	
	Hand Tools		R 1.50	R 1.50	
	Sub total/day			R 886.95	
	Admin cost	10	%	R 88.70	
	Contractors Profit	12	%	R 106.43	
	Herbicide			R 448.00	
	TOTAL COST PER TEAM PER DAY			R 1,530	

Estimated cost per herctare of clearing dense areas for various production rates

	ha cleared per day per team	Cost per ha
These work rates are for clearing of DENSE areas	0.25	R 6,120

COSTING FOR INITIAL CLEARING TEAM FOR SHRUB TYPE ALIENS

It is assumed that the shrub type alien is fully grown and is dense

The workers would make paths through the alien plants to allow the sprayers to spray herbicide

TEAM COMPOSITION

No	Description		Unit Daily rate	Daily cost	Notes
0	Chain saw Operator		R 45.00	R 0.00	
4	Knapsack operator		R 38.00	R 152.00	
8	Labourers		R 35.00	R 280.00	To match local farm labour rates
1	Vehicle		R 175.00	R 175.00	Assumed 100 kms/day @ R1,75/km
1	Supervisor		R 100.00	R 100.00	NB This supervisor handles two teams
0	Brush cutter		R 65.75	R 0.00	
0	Chain saws		R 84.35	R 0.00	
4	Knapsac sprayer		R 3.00	R 12.00	
12	Safety equipment		R 30.00	R 360.00	
	Hand Tools		R 1.50	R 1.50	
	Sub total/day			R 1,079.00	
	Admin cost	10	%	R 107.90	
	Contractors Profit	12	%	R 129.48	
	Herbicide			R 0.00	
	TOTAL COST PER TEAM PER DAY			R 1,316	

Estimated cost per herctare of clearing dense areas for various production rates

	ha cleared per day per team	Cost per ha
These work rates are for clearing of DENSE areas	0.3	R 5,100

<u>Appendix XII:</u> Crime statistics for the Ulundi Area extracted from the web (SAPS, 2001).

Crime per Police Area for the period January to December 1994-2000 PROVINCE : KWAZULU-NATAL AREA : ULUNDI							
Crime category	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Murder	644	603	593	547	540	597	503
Attempted murder	511	551	634	615	575	662	591
Robbery with aggravated circumstances	667	656	704	725	868	1,066	950
Common robbery	168	175	253	281	336	402	553
Public violence	5	5	3	4	4	4	5
Illegal strikes	1	0	1	0	1	0	0
Rape and attempted rape	547	563	675	619	610	722	806
Intercourse with a girl under the prescribed age and/or female imbecile	4	3	2	5	30	60	36
Indecent assault	18	38	21	27	10	22	37
Cruelty towards and ill-treatment of children (excluding sexual offences, assault and murder)	16	14	10	20	18	16	22
Kidnapping	56	49	40	28	42	54	48
Abduction	42	28	27	54	32	45	54
Assault with the intent to inflict grievous bodily harm	2,421	2,304	2,726	2,699	2,827	3,219	3,464
Common assault	1,590	1,702	1,735	1,592	1,667	1,999	2,497
Burglary - business premises (including attempts)	828	860	835	822	934	804	849
Burglary - residential premises (including attempts)	1,731	1,909	2,277	2,067	2,263	2,640	2,693
Stock-theft	1,430	1,608	1,632	1,655	1,729	1,960	2,009
Shoplifting	622	579	673	613	424	579	681
Theft of motor vehicles and motorcycles	376	402	423	452	407	396	429
Theft out of or from motor vehicles and motorcycles	647	535	770	747	752	833	888
Theft not mentioned elsewhere	3,490	3,547	3,296	2,977	3,317	4,546	5,933
Arson	477	328	345	281	300	259	249
Malicious damage to property	840	819	927	833	935	994	1,177
All fraud, forgeries, malappropriations, embezzlements, etc.	444	302	392	434	425	409	520
Drug related crime	550	441	476	500	329	312	347
Driving under the influence of alcohol or drugs	127	131	125	109	92	118	138
Illegal possession of firearms and ammunition	340	289	469	384	358	419	493
Explosives act	6	2	1	4	0	0	1
Carjacking*	-	-	75	75	122	171	88
Hijacking of trucks*	-	-	31	40	65	82	42
Robbery of cash in transit*	-	-	4	10	13	8	6
Bank robbery*	-	-	5	5	2	2	5
* These crimes have already been accounted for under robbery with aggravating circumstances							

Appendix XIII: The tonnes traded and values of medicinal plants in Kwazulu-Natal (KZN) region (Mander, 1998:89).

Scientific Name	Tonnes traded per year and value per kg				Plant numbers used per year and part used
	Tonnes	**RG**	**Street**	**S,H**	
Scilla natalensis	95.5	R 1.89	R 6.50	R 6.80	432 000 (bulbs)
Eucomis autumnalis	73.17	?	R 6.20	R 10.60	428 000 (bulbs)
Boweia volubilis	43	R 11.70	R 14.00	R 27.80	386 000 (bulbs)
Alepidea amatymbica	31.23	R 11.70	R 16.00	R 17.80	1 820 000 (roots)
Ocotea bullata	25.25	?	R 6.67	R 27.70	2104 (bark)
Curtisia dentata	23.9	R 3.28	R 7.61	R 23.80	1993 (bark)

RG = price obtained by the rural gatherer
Street = price obtained by street traders
S,H = price obtained by shops, healers

Appendix XIV: Effect on NPV outcome when water availability is assumed to be eighty *per cent.*

Year	Revenue from harvestable timber	Revenue from Increased streamflow	Revenue from reduced fire management costs	Total benefits (in Rands)	Final cost (in Rands)	Net Benefit/ Cost	NPV Discount rate (0%)	NPV Discount rate (5%)	NPV Discount rate (10%)
1	R 11,481,400	R 676,135	R 105,476	R 12,263,011	R 7,534,000	R 4,729,011			
2	R 0	R 642,328	R 100,202	R 742,530	R 2,862,920	-R 2,120,390			
3	R 0	R 608,521	R 94,928	R 703,450	R 1,619,810	-R 916,360			
4	R 0	R 574,715	R 89,655	R 664,369	R 904,080	-R 239,711			
5	R 0	R 473,294	R 73,833	R 547,128	R 715,730	-R 168,602			
6	R 0	R 405,681	R 63,286	R 468,967	R 602,720	-R 133,753			
7	R 0	R 338,067	R 52,738	R 390,805	R 602,720	-R 211,915			
8	R 0	R 304,261	R 47,464	R 351,725	R 602,720	-R 250,995			
9	R 0	R 304,261	R 47,464	R 351,725	R 602,720	-R 250,995			
10	R 0	R 304,261	R 47,464	R 351,725	R 602,720	-R 250,995			
TOTAL	-	-	-	-	-	-	R 185,295	R 4,348,896	R 4,528,482

Appendix XV: Effect on NPV outcome when price of water for irrigation sector increases from 2.08 cents/m^3 to 10cents/m^3.

Year	Revenue from harvestable timber	Revenue from increased streamflow	Revenue from reduced fire management costs	Total benefits (in Rands)	Final cost (in Rands)	Net Benefit/ Cost	NPV Discount rate (0%)	NPV Discount rate (5%)	NPV Discount rate (10%)
1	R 11,481,400	R 533,006	R 105,476	R 12,119,882	R 7,534,000	R 4,585,882			
2	R 0	R 506,356	R 100,202	R 606,558	R 2,862,920	-R 2,256,362			
3	R 0	R 479,705	R 94,928	R 574,634	R 1,619,810	-R 1,045,176			
4	R 0	R 453,055	R 89,655	R 542,710	R 904,080	-R 361,370			
5	R 0	R 373,104	R 73,833	R 446,937	R 715,730	-R 268,793			
6	R 0	R 319,804	R 63,286	R 383,089	R 602,720	-R 219,631			
7	R 0	R 266,503	R 52,738	R 319,241	R 602,720	-R 283,479			
8	R 0	R 239,853	R 47,464	R 287,317	R 602,720	-R 315,403			
9	R 0	R 239,853	R 47,464	R 287,317	R 602,720	-R 315,403			
10	R 0	R 239,853	R 47,464	R 287,317	R 602,720	-R 315,403			
TOTAL	-	-	-	-	-	-	-R 795,139	R 4,178,873	R 4,371,829