A COST BENEFIT ANALYSIS FRAMEWORK FOR THE NATIONAL WORKING FOR WATER PROGRAMME

Christo Marais, Jane Turpie, Dawie Mullins, Beatrice Conradie, Ahmed Khan,
Jacqui Goldin, Hugo van Zyl, Erick Grobbelaar, Nick Vink & Victoria Ndzinge

December 2001

Sega #34 Socio-economic evaluation of Working for Water projects

Insert photo

Prepared for:
Insert logos etc.

1. INTRODUCTION

1.1 BACKGROUND & RATIONALE

The Working for Water Programme (WfW) is a multi-departmental initiative co-ordinated through the Department of Water Affairs & Forestry (DWAF) since 1995. The main aim of WfW is to eradicate invading alien plants from rivers, mountain catchments and other natural area to improve runoff, conserve biodiversity and restore the productive potential of the land. Although the initial emphasis of WfW was on water conservation, it also has significant environmental benefits, and it makes a significant contribution to the welfare of its labourers and their families, who are often from very poor rural communities. In many cases, it contributes a significant proportion of the cash income of those communities and has the potential to provide members of the communities with opportunities for investment.

The problem of alien infestation is country-wide, and alien vegetation is estimated to be responsible for massive losses of water as well as losses of biodiversity. Indeed, alien vegetation is seen as the single greatest threat to the biodiversity of the Cape Floral Kingdom, the world's smallest and richest floristic kingdom. The success of the WfW Programme is widely acknowledged, and, given the extent of the alien problem in South Africa, its services are in demand throughout the country. Thus the programme managers are in a position where they have to prioritise the potential projects, which usually operate at a quarternary catchment-level, for implementation.

Project appraisal is usually carried out by means of Cost-benefit Analysis (CBA) or Multi-Criteria Decision Analysis (MCDA), the former being the most common method, a relatively straightforward comparison of economic costs and benefits. However, CBA is conventionally applied to projects without taking environmental and social benefits into account. In the case of the WfW projects, both environmental and social benefits are a major output of the projects, and it is thus imperative to take them into consideration in a project appraisal process.

The fields of welfare and environmental economics have grappled with the problems of expressing such external costs and benefits in conventional (monetary) terms, and have been coming to the fore as acceptable, and indeed, desirable, elements of project appraisal in the last decade or two. Moreover, the advancement of the trans-discipline of ecological economics has led to the development of ecological-economic modelling, in which the linkages between ecosystem functioning and economic outputs are explicitly described. This project applies a similar rationale to the development of an appraisal system for WfW projects which takes the full costs and benefits of these projects into account.

1.2 AIM

The overall aim of this project was to develop a ecological-economic model which incorporates environmental and social benefits of the WfW projects into a CBA framework for appraisal and comparison.

1.3 STUDY APPROACH

This study was a desktop exercise, in that it relied entirely on existing information on ecosystem functioning, economics values, costs of clearing, etc. The emphasis was more on the development of a model framework for analysis than on the collection of new data. It is envisaged that the model can be populated with more accurate data when applied to decision-making on particular catchment areas. Thus, the overall approach was to build a *generic* ecological model of an invaded catchment system for evaluating the costs and benefits of clearing programmes.

2. COMPONENTS OF THE MODEL

The model, built in an MS Excel spreadsheet, incorporates the following components:

1. **The ecological-economics components**

This part of the model incorporated the functioning of the natural ecosystem within the catchment, incorporating the growth of natural vegetation, the growth and spread of alien vegetation, hydrological functioning, and the production of ecosystem products such as wood or flowers. This included the following main components:

   a. The invasion of catchments by aliens
   b. Supply and value of water
   c. Use and value of natural vegetation goods (products) & services (tourism)

2. **The management components**

This part of the model was based on data on the costs and effectiveness of clearing operations and the costs of fire management activities under different levels of alien infestation, with the following main components:

   a. Clearing of alien vegetation
   b. Fire management
   c. Links to the ecological components

3. **Human development (training) component**

This part of the model attempted to put an economic value to the socio-economic benefits associated with the training of usually previously disadvantaged, and unemployed, staff recruited by the working for water programme. The main components of this included:

   a. Improved citizenship
   b. Improved earning potential

4. **Secondary industries component**

This component attempted to incorporate the economic benefits derived from the utilisation or processing of alien vegetation after it has been cleared from the catchment areas.

5. **The Cost-Benefit Analysis component**

This component aggregates the costs and benefit of each of the above aspects of the model and expresses them in different ways that allow comparison of the relative benefits of different projects.

The basic outline of the model is illustrated in Fig. 1.

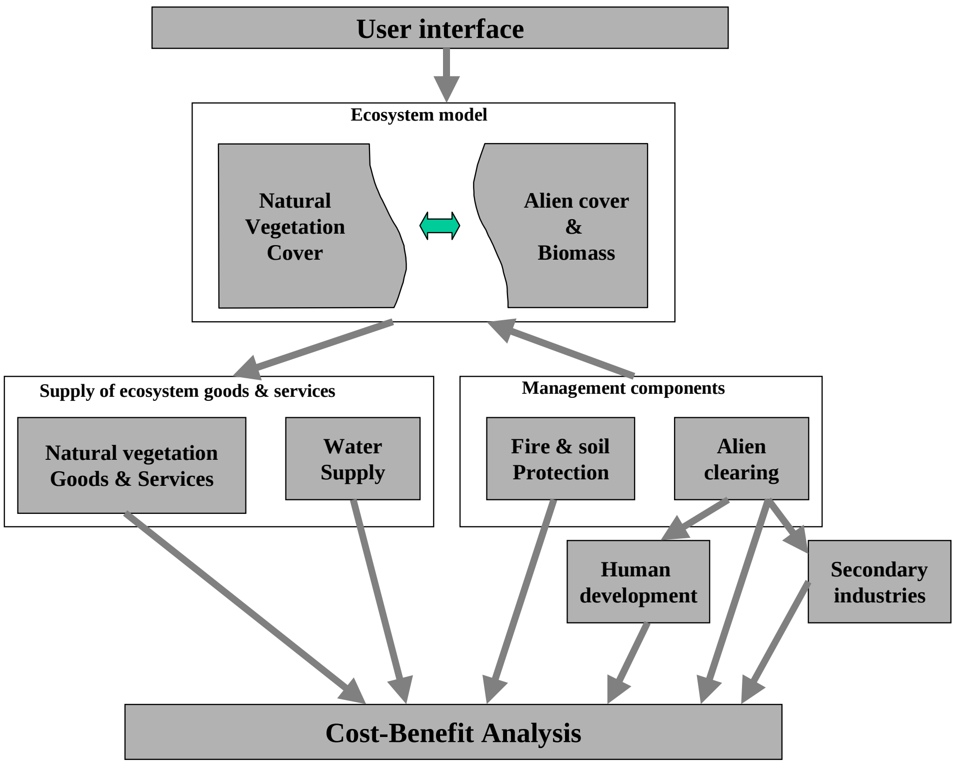

Figure 1. Schematic layout of the main sectors of the model and the linkages between sectors.

The time frame of the entire model is 100 years. The rationale and considerations of each of the model components is described in detail in the following sections.

3. ECOLOGICAL-ECONOMICS COMPONENTS: ECOSYSTEM FUNCTIONING AND SUPPLY OF GOODS & SERVICES

Christo Marais, Jane Turpie, Beatrice Conradie & Ahmed Khan

Construction of the overall model began with the construction of an ecosystem model for the catchment, incorporating the growth of natural vegetation, the growth and spread of alien vegetation, hydrological functioning, and the production of ecosystem products such as wood or flowers. These parts of the model aimed to reflect the impact of aliens on natural vegetation and the supply of goods and services, and to quantify the latter supply in monetary terms.

The specific aims of the ecological-economics components of the model were as follows:

- To quantify the spatial spread of aliens in a catchment over a 100-year period, with or without clearing effort, and the change in area of natural vegetation;
- To quantify the change in alien biomass in a catchment, with or without clearing effort;
- To quantify water runoff, taking into account the amount intercepted by aliens, and to estimate the monetary value of this runoff in terms of its value for use in agriculture, industry and domestic consumption; and
- To quantify the value of goods and services provided by natural vegetation.

3.1 THE INVASION OF CATCHMENTS BY ALIENS

Considerable research has been carried out on the invasion of catchments by aliens, which has led to a relatively good understanding of the way in which different species invade different types of catchment areas. The assumptions made in the model, regarding the spread and growth of aliens, are derived from this body of literature.

All calculations are made on the basis of the condensed area of aliens. In other words, an area which is lightly infested with a 5% cover of aliens would be converted to 5% of the area under 100% cover of aliens, and the remainder is taken to be uninvaded. The condensed area in each vegetation type is allowed to grow using the following growth equation:

$$\textit{Initial area} + r\,(1 - \textit{Initial area}/\textit{total natural area}) \times \textit{Initial area}.$$

Where r is the intrinsic growth rate. This growth rate is obtained for the literature and is set independently for each different vegetation type, on the basis of the growth rate of the typical species that invade that vegetation type. There is currently no interaction between the vegetation types in the model. In other words, alien spread in one vegetation type will not enter a second vegetation type in the catchment. This is a shortcoming, particularly if some vegetation types currently contain alien vegetation while others do not.

3.2 THE SUPPLY OF WATER

3.2.1 THE INTERACTIONS BETWEEN PRECIPITATION, RUNOFF AND ALIENS AND THEIR IMPACTS ON WATER SUPPLY

3.2.1.1 Precipitation and runoff

Total natural water runoff in a catchment, or the amount of water entering stream flow, is determined primarily by the amount of precipitation and the degree to which this precipitation is intercepted by plant biomass and thereby lost to evapo-transpiration. Runoff thus varies in response to seasonal and inter-annual variation in rainfall, the latter taking place within approximately 9-year cycles of wet and dry years. Seasonal variation is pronounced throughout most of the country, with the rainy season coinciding with the summer growing season for most of the country, with the exception of the winter-rainfall area which encompasses most of the fynbos biome.

Total annual runoff can be divided into two main components: low flows and high flows. Both components are vital to the ecological functioning of rivers, the maintenance low flows securing the habitat of aquatic organisms, and the high flows (floods) providing a scouring function which maintains the physical characteristics of the river system.

3.2.1.2 Runoff and water supply

Runoff may be captured in dams ranging from large-scale reservoirs to small farm dams, or may be abstracted directly from rivers (using pumps and weirs) or from groundwater (with boreholes and windmills). All of these methods of water supply are used for agriculture. Industrial needs are met almost entirely from large-scale reservoirs, and domestic supplies are mostly from large schemes and boreholes.

Seasonal and inter-annual variability of rainfall has an important effect on the water supply of a catchment. In large schemes, reservoir levels are filled mostly by high flows during the rainy season, and replenishment during high rainfall years may provide water for several years into a dry cycle. Large water supply schemes are constructed taking this variability into account, such that a dam is expected to meet water demands for 7 out of 10 years, on average. A decrease in average runoff would thus lead to increased number of years in which water shortages occur, a situation which can only be prevented by increasing the capacity or number of dams in the catchment (and only up to a point). Note that the decreased capacity of large dams to supply water needs may also arise from sedimentation due to excessive erosion in the catchment, or from increased water demands, as well as from decreased stream flow.

Small dams, often constructed on non-perennial streams, are also usually filled by high flows during the wet season. Because of their small capacity, these dams do not benefit from further high flows, which run over the top. Thus small dams rely on sufficient flows to replenish them each year. Direct abstraction from rivers may only occur when rivers are flowing. Farmers using this means of supply are thus most vulnerable to changes in low flows, as they rely on water abstraction mainly during the dry season. Borehole water supplies are only affected by extended droughts over periods of years.

The analysis of only a part of a catchment (e.g. Upper Breede) may be problematic in that instream flow leaving the study area boundary is a benefit to areas beyond the partial catchment, and these need to be captured in the model. Further complexities may in catchments with interbasin transfers.

3.2.1.3 Impacts of aliens on runoff

The interception of catchment runoff by alien biomass has been well described, particularly in the fynbos biome. In fynbos, the higher biomass per ha resulting from the presence of alien vegetation leads to a higher evapo-transpiration rate per ha, and hence loss of water from the catchment. In other biomes, this effect is mainly confined to riparian habitats where most alien invasives are concentrated.

It has been estimated that a fully-invaded fynbos mountain catchment may lose up to 30% of its mean annual runoff. However, much less work has been done to investigate how this reduction in runoff affects ecosystems and water supply. Whether analyzing the impacts of this runoff reduction on ecosystems or on economic systems, it is necessary to understand which types of runoff are affected and when, and how the reduction in runoff translates to a reduction in water supply. Because of the rapid movement of water through a catchment during high rainfall events, plant biomass probably intercepts a relatively small proportion of high flows compared with the interception of normal low flows. High flows do not move through catchments totally unimpeded, however, as it has been shown that aliens do have a measurable effect on high flows (C. Brown, pers comm.). Thus plant biomass primarily intercepts low flows, an effect which will be particularly important during the dry season.

This means that a 30% loss in mean annual runoff could translate into a major loss of low flows and a relatively minor loss of high flows, depending on the nature of water movement through a catchment.

The model calculates the loss of runoff due to aliens based on Scott's (19xx) model:
1. The biomass of alien vegetation is calculated in terms of biomass per ha, separate growth equations for tall shrubs, medium trees and tall trees.
2. Alien tree stands in different parts of catchment can be assumed to be different ages. The model assumes that the distribution of ages is normal, thus overall biomass is always at average level.
3. Water loss is taken to be a constant proportion of biomass: 1.735mm per m3 biomass.
4. Average water loss per ha is calculated on basis of average biomass per condensed ha of each type of alien.

3.2.2 WATER SUPPLY AND THE ENVIRONMENTAL RESERVE

Under the new Water Act (Act 36 of 1998), an environmental reserve will be defined for all aquatic resources, which determines the quantity and quality of water that must be retained in a system after abstraction of the remainder for other (agricultural, industrial or domestic) uses. Thus of the total amount of runoff supplied by the ecosystem, only a portion can be abstracted from the system. The size of the environmental reserve is determined by the desired health of the system, in turn decided on the basis of its conservation importance.

The upper Breede catchment considered in this case study is already fairly severely impacted, and it has been recommended that it is only allocated a minimum environmental reserve required to maintain ecosystem functioning. It will thus remain a 'hard-working' system rather than one in which biodiversity conservation is a priority. In this catchment, preliminary estimates suggest that the reserve will comprise maintenance low flows of about 20% of mean annual runoff (MAR) and maintenance high flows of about 5% of MAR. Technically, this means that most of the MAR can be legally extracted from the system for other uses. A sensitivity analysis needs to be carried out to test the sensitivity of the model to the size of the reserve.

3.2.3 IMPLICATIONS OF A LOSS OF RUNOFF

We thus hypothesise that, depending on the relative proportion of low and high flows in a catchment, losses of low flows may have relatively small impacts on large or small dams which may still be replenished by annual high flows, but drastic impacts on direct water supply from rivers and on ecosystem functioning.

In order to model these interactions more accurately, it is necessary to understand the relative contribution of high and low flows to mean annual runoff and to overall water supply in a catchment. For example, in the upper Breede catchment:

- low flows are estimated to make up about 60% of the mean annual runoff;
- there are no large dams (no industry or large towns) within this study area; and
- farmers rely largely on direct abstraction from rivers.

Therefore, in this particular catchment area, most water use is agricultural, and farmers are highly vulnerable to changes in low flows.

A loss of runoff can have varying implications for water supply to economic sectors, depending on the assumptions made. Water demands from a catchment can be met by managing supply or demand. Supply management includes both the development of new infrastructure (infrastructural supply management) as well as clearing aliens to increase runoff into dams (environmental supply management). Demand management involves recognizing water as a scarce resource and treating it as such through more appropriate pricing schemes, i.e. raising the prices faced by consumers and thereby encouraging more efficient use of water. There is substantial scope for the improvement of efficiency in water use in all three sectors considered.

Environmental supply management and demand management are proactive measures in response to impending water scarcity, while infrastructual supply management is a reactive measure. The choice between proactive and reactive measures can often be explained in terms of risks and uncertainty. Uncertainty often leads to a reactive strategy, as has happened up to now, due to a lack of understanding of the consequences of alien infestation. The high costs of alien clearing may be considered to be risky in terms of its returns, since these are not well understood at present. With increased understanding of the ecological impacts of aliens on catchments, it now remains to attempt to quantify the economic consequences of these impacts so that investment in proactive strategies to alleviate water scarcity can be evaluated against reactive strategies.

However, strategies employed are not only influenced by long-term economic considerations. Despite increasing recognition of the environmental rationale for prioritizing demand management, political factors dictate that supply management will usually be favoured, and that within this, short term solutions such as improved infrastructure will be favoured over longer-term solutions such as clearing aliens and minimizing soil erosion.

3.2.4 SUMMARY OF RATIONALE AND ASSUMPTIONS USED IN THE MODEL REGARDING WATER SUPPLY

In short, it is complex to model the response of the environment, catchment managers and consumers to a change in runoff due to aliens. This model makes the following assumptions about water supply and the chain of responses when a catchment is invaded by aliens (no clearing effort):

1. Water supply from high flows is partially dependent on the storage capacity of water schemes in the catchment and therefore only partially affected by inter-annual variation in precipitation. Supply from low flows are fully influenced by inter-annual variation in precipitation, coupled with effects of aliens and water supply infrastructure.
2. Water allocatable to industry, agriculture and domestic consumption is equal to the base flow minus the base flow required for the environmental reserve, plus the runoff (high flows – floods flows) that cannot be captured by the dams in the catchment.
3. All allocatable water is captured by users either by private or public infrastructure (*this is a weak assumption*). A decrease in allocatable water supplies thus translates directly to a decrease in supply.
4. Water losses due to alien biomass only affect base flows, not floods, and these losses thus affect allocatable water supplies.

3.3 THE VALUE OF WATER

3.3.1 ECONOMIC IMPACTS OF REDUCED WATER SUPPLY

If the spread of aliens had a significant impact on allocatable water runoff in a catchment, then small-scale sources of water would diminish, and government would either spend more on public infrastructure for bulk water supplies or implement demand management programmes which included higher priced water. Bulk water supplies used by industrial, domestic and agricultural users would increase in price irrespective of whether improved infrastructure or demand management approaches are used. Farmers, faced with either a reduction in water supply from small-scale sources or a higher price from large schemes, would respond firstly by increasing expenditure to improve efficiency of water use. Intensification of the problem would lead to reduction in the value of outputs, either by reduced productivity of existing crops or due to a switch in crops grown. Industry would similarly incur higher costs of improving water savings technology, which would be reflected in a lower net value of outputs. Domestic users would be more likely to spend the same, and thus decrease consumption as price increases, assuming a stepped pricing system was in place.

The cost of securing private supplies would increase, and the increased cost of provision would result in higher prices faced by consumers. These increases in costs would lead to a more rationale use of water, leading to a change in demand through market forces rather than by strategic demand management. The benefits of a proactive demand management strategy, on the other hand, would be to achieve greater efficiency in advance of increasing water supply, increasing government revenues, which in turn could be put to use in catchment management (environmental supply management) and obviating the need for premature government expenditure on water supply schemes.

With alien clearing, on the other hand, water runoff would be restored to pristine levels and future losses avoided. The improved runoff would mean that, in the absence of demand management, the intended lifespan of public dams would be better secured, and private dams and other sources of water would be better able to meet user demands.

3.3.2 APPROACH FOR ASSIGNING A VALUE TO WATER

Inclusion of all of the above interactions would require a highly complex and data-hungry modeling exercise. A much simpler approach was thus taken, in which all allocatable water yielded by the catchment was assigned a unit value. The currently charged tariffs are not appropriate:

> *"In spite of the mounting evidence of scarcity, water is treated as a free resource in that no charge is imposed for withdrawing water from a surface or groundwater source. Users pay for the transport of water from its source to its place of use, and perhaps for treatment of the water and disposal of the return flows. But there is seldom any charge to reflect the opportunity costs of putting water to one use at the expense of another."*
>
> Kenneth D. Frederick in Gibbons (1986)

Water is a scarce economic resource, yet its price usually includes only the costs of extraction, transport and treatment, and not value of the commodity itself. Scarcity and the need to take opportunity cost into account when society thinks about resource allocation clearly call for a reliable methodology to estimate the value of water as an input to economic activities such as agriculture. Water values are incorporated into a broader theoretical framework which says that if a resource is scarce and society's objective is to maximise net benefits from that resource, marginal benefits should be equal across all users (Sampath, 1992). When water's marginal value is identical across all users, there is no opportunity to improve net social benefit by redistributing water among users.

Assuming properly-behaved production and utility functions, the marginal benefit functions in all water sectors are downward sloping so that reducing allocation to a particular sector will increase its water value at the margin. Simply put, as a resource grows scarcer to a particular user that user will attach a greater benefit to one more unit of the resource, or as long as the dams are full nobody is too concerned about dripping taps.

Sampath (1992) also provides the condition for creating new capacity, or maintaining existing capacity as in the case of Working for Water. Additional developments are justified if the additional social benefits outweigh the additional social costs.

The theory for maximising net social benefit from water is so appealing that much of the literature as proceeded to the "how to" question of estimating marginal resource values. Gibbons (1986) goes a long way towards providing a menu of methodologies. In the model, the value of water was estimated to be that of its current marginal value as an input into irrigated agriculture. The method for estimating irrigation water value discussed in the present paper builds on and critiques the Gibbons approach to irrigation values.

3.3.3 THE STANDARD APPROACHES TO ESTIMATING IRRIGATION WATER VALUES

Gibbons (1986) discusses two main avenues of investigation, namely production function and crop budget analysis. Crop budget analysis is used to calculate average or marginal water values. The production function approach produces a marginal value product function for water, including the marginal benefit of the current allocation. Simple budgeting typically produces only a single water value, but by changing the water constraint on more complex programming models, a range of water values similar to a marginal value product function can be derived.

3.3.3.1 Crop function analysis

For crop function analysis the marginal productivity of water has to be known, and is usually taken from controlled crop experiments (Gibbons, 1986). Crop-water relationships are estimated for a given treatment consisting of soil, variety, labour input and fertiliser application, to name a few. The result is what Gibbons calls an "on-site" water value, and can be either marginal or average values. The main drawback of crop function analysis is that it relies on the physical relationship between yield and output, making it more data intensive than programming models.

3.3.3.2 Simple budgeting to calculate average values

Crop budget analysis is used when the actual productivity of water is not known. Using the theory of Ricardian rents, a maximum willingness to pay for water is estimated from a standard crop or farm budget. The budget approach uses a single point, or small range, on the crop-water production function to calculate a margin above specified costs. By Ricardo's theory factor payments completely exhaust total revenue if one assumes perfect competition. If no other inputs except water need to be rewarded from the profit, the residual is the total value of water.

Gibbons (1986) explains that if the residual is calculated without taking water procurement costs into account, the answer is an "on-site" value, while incorporating water rates allows direction comparison between irrigation and instream values.

The total residual divided by the total amount of water used produces a maximum average value for water. If fixed costs are included the answer is a long-run maximum average value for water, and if not, the maximum average value of water only applies in the short run. Thus *ceteris paribus*, long-run average water values are lower than short-run average water values.

Howe (1985) provides a recent example of using simple budgeting to estimate the potential for a water market for the American West. Gross margin budgets for eight crops and eight river reaches provide rough estimates of willingness to sell in $/acre-foot for irrigation water in the Colorado River.

Gibbons (19986) mentions a second average value calculation where the value of water is defined as the difference between the total residual of irrigated agriculture and dryland farming in the same area. The difference in profits is *ceteris paribus* due to the availability of water, and divided by the total volume of water applied, the answer represents an average value product of water. Louw and Van Schalkwyk (1997) implement this approach for the Olifants River basin in South Africa in conjunction with a programming model. The approach is not widely used, but interesting because it abstracts from assumptions about overhead costs for example returns to management (Gibbons, 1996).

3.3.3.3 Programming models to calculate marginal values

In his discussion of average water values for the Colorado River Howe (1985) cautions:

> "*Ideally, we would compute these prices and quantities from a multiperiod programming model that would permit us to take crop rotations, crops substitutions, and input substitutions into account. …The present method tends to overstate the reservation price … by ignoring substitution possibilities…*"

Multiperiod programming models are constructed from enterprise budgets, and are usually set up to maximise farm-level net returns subject to a range of linear resource constraints. Howe (1985) refers to crop rotation and infrastructure constraints and Gibbons (1996) mentions acreage limitations to incorporate risk, input requirements and available technologies.

The way in which the water constraint is specified determines whether the model produces an average or a marginal water value (Gibbons, 1986). If the model is set up so that an unlimited water supply can be rented in at varying costs, the resulting factor demand function represent average water values. It is more customary to use a parametric tightening of the water constraint to generate a range of shadow prices on a binding water constraint. A tighter water constraint *ceteris paribus* will lead to a higher shadow price, and the shadow price is a farm level marginal value product for water. If an entire region is modelled as a single farm, the shadow price of water is a regional estimate of marginal net benefit of irrigation water.

A large literature estimating water values using the linear programming approach developed since the early 1990s. An important strand of this literature started in the American West with Booker's 1990 basin-wide model of the Colorado River. Michelsen and Young (1993) investigate potential transfers from irrigation to municipal use in the Colorado River, and Booker and Young (1994) examine the possibility of upstream water rights holders selling to downstream rights holders in the Colorado River. Taylor and Young (1995) still study the Colorado River and potential water markets, but refine the irrigation dimension to allow for deficit irrigation. Turner and Perry (1997) extend the same basic idea to instream flows as a beneficial use.

The standard approach to modelling water capital substitution is to incorporate is use combinations of crops and irrigation technologies. The substitution allowed for in most models is a straight capital-water substitution, but some models allow water-labour or water-management substitution, for example Gardner and Young (1988).

3.3.3.4 Marginal and average value products

As stated above, optimal resource allocation relies on allocative efficiency, which in turn requires marginal value products to be equal across all users at the margin. Since average value for water is much easier to calculate than a marginal value, it raises the question if average value is a good approximation for marginal value.

Table 1 below, taken from Conradie (forthcoming), reports marginal and average water values for seven typical irrigation farms in the Fish-Sundays scheme in the Eastern Cape. The farm level water residual in column two is net of payments to all fixed factors including returns to land, management, own capital and risk. It is also net of water procurement costs. The resulting estimated water value is still an upper limit on willingness to pay for the resource, but since a complete set of inputs have been accounted for, the estimated value overstates the true value by as little as possible. Also compare Nieuwoudt et al (1976) for a similar argument.

Table 1: Selected average and marginal water values at the present allocation for the Fish-Sundays scheme in South Africa

Farm description	**Residual R/farm**	**Average value**	**Marginal value**	**Marg./avg.**
		cent/m^3/year		
Middelburg – Cradock				
Irrigation farm	3208	0.2796	0.1080	0.39
Dairy farm	47228	4.1157	4.1160	1.00
Stock farm	9250	0.8061	0.6740	0.84
Farm business	21189	1.1211	1.0580	0.94
Kirkwood				
Small mixed farm	39811	15.2533	15.2530	1.00
Large stable citrus farm	35451	3.5170	3.5170	1.00
Large growing citrus farm	76388	4.3526	4.3530	1.00

The average value of water is the residual divided by the present allocation and marginal value is the shadow price on the water constraint, again at the present allocation. Positive marginal values indicate that the present water allocation is binding in all cases. Column five reports the ration of marginal to average values.

The evidence in table 1 suggests that on the whole average water values are good proxies for marginal water values. Marginal and average values are virtually identical for dairy farms and citrus farms. For farm businesses there is a minor difference and marginal values on stock farms are about 16 percent lower than average water values. Irrigation farms in the Middelburg-Cradock area are the only case where marginal values significantly overestimated by average values.

While average values are good indicators of marginal values under most scenarios, there is not a consistent ratio between average and marginal values across all farms. The difference is due to elasticity of demand for water. If the demand for water is elastic, average and marginal values are close to each other, because the farm is either in production or out of production, with limited options in between. As explained above, capital-labour substitution is modelled by duplicating crop activities for a range of irrigation technologies. Since most orchards in South Africa have already been converted to some form of micro irrigation system, it is not realistic to introduce less efficient technologies such as sprinkler and flood irrigation. Subsequently, the demand for water on fruit farms are highly inelastic, causing the farm to either be in production or out of production depending on the value of water. It is therefore not surprising that the marginal and average values of water on fruit farms are identical.

Contrast this to irrigation farms, where flood irrigation still dominates. As water constraints tighten farmers are expected to move into water saving technology, causing the marginal value of water to increase as water is reallocated away from irrigation farms. Irrigation farms have the flexibility to release water at the margin, so that allocative efficiency can be achieved through reallocation. The problem is that the cases where do expect a marginal adjustment is water use patterns the average value of water is a very poor indicator of the value of marginal productivity.

3.3.4 USING MARGINAL VALUES

The best way to derive basin-wide marginal irrigation values is by using a linear programming model (Howe, 1985). Indeed, this is a growing field of research, mainly for the purposes of illustrating the potential for a market for water.

As long as one is trying to illustrate the potential for reallocation via markets, simplifying assumptions are justified, and it not important how far an upper limit on willingness to pay overestimates true value. If, however, the intention is to derive a shadow price to be used as a demand management tool, an accurate estimate of price elasticity of demand becomes essential to achieve an optimal allocation. The latter objective is not feasible given the complexity of assumptions and the enormous data requirement of a basin-wide programming model of irrigated agriculture.

A good case in point is risk. Gibbons (1986) mentions the effect of risk, and the impact on marginal water values is further explored in Conradie (forthcoming). Risk is a cost of production, which reduces the residual that can be claimed as a water value. Any model, even a model producing marginal values, failing to incorporate risk therefore overestimates irrigation water values.

Secondly, models of orchard crops are noticeably absent from the literature. Exceptions are Mallawaarachchi, et al (1992) which models water values for a region growing citrus and wine grapes according to two irrigation technologies, namely furrow and drip irrigation, and Louw and Van Schalkwyk (1997) who include some orchard crops alongside irrigated and dryland field crops. In Louw and Van Schalkwyk's paper field crops allow some flexibility to increasing water constraints, but the fruit component of water demand is completely inelastic. Mallawaarachchi et al 1992 focus on fruit exclusively and get their model's flexibility by internalising the replant decision and then following the adjustment to water saving irrigation equipment. The latter is an important contribution to our understanding of how fruit producing regions value water, and will adjust to higher water prices and needs further research. A model of fruit production that reflects a truly elastic demand for water will produce average values above marginal values.

As long as an estimate of agricultural water values is used as a back of the envelope calculation to predict direction of reallocation expected to result from free market activity, such studies serve a useful purpose.

When the technique is thought of as providing an accurate estimate of marginal benefit, but values are not updated regularly we are pretending that the tool can be used to do things the original authors never claimed it can. The result of redistribution derived from basin-level studies of irrigation water values done once every few years is likely to be as far from allocative efficiency as the original situation, and becomes a flimsy excuse for taxing some groups to benefit others.

The way forward involves an urgent choice between the market and central management as the preferred institution for achieving allocative efficiency. This paper argues that demand management is impossibly data intensive, and therefore inappropriate for a developing country such as South Africa. On the other hand the market adjusts automatically and subjectively values returns to risk, returns to management, land and water. However, markets require information to function properly, and the research conducted in this Working for Water Evaluation provides the kind of information on which markets rely. Crude average and marginal value estimates are adequate to provide information on which market decisions can be based, but if DWAF decides in favour of demand management, better estimates are needed. More accurate estimates will cost more and can potentially exhaust the entire efficiency gain of redistribution.

3.4 THE SUPPLY AND VALUE OF NATURAL VEGETATION PRODUCTS & SERVICES

3.4.1 THE SUPPLY OF NATURAL VEGETATION

In addition to their impact on water, increasing cover and biomass of aliens in a catchment displaces natural vegetation. Thus alien invasion results in a diminishing of stocks of natural resources, and has a significant impact on biodiversity, often contributing to the extirpation or total extinction of species.

The model makes provision for the inclusion of 12 vegetation types: Mountain fynbos, lowland fynbos, thicket (including strandveld), renosterveld, highveld grassland, mountain grassland, arid savanna, moist savanna, nama karroo, succulent karoo, forest and riparian forest. This feature is easily flexible within an analysis, as the names of the vegetation types can be changed.

The quantity of natural vegetation is a simple function of the difference between the original extent of natural vegetation and the condensed area of aliens. In reality this is a simplistic assumption as applied to the provision of goods and services, as these and the ecosystem functions upon which they depend, may be disrupted by the proximity to aliens or their impacts on hydrology, fire and microclimate. The loss of natural vegetation goods and services due to aliens may thus be underestimated in the model. More research is needed to understand these interactions sufficiently for their incorporation into a model such as this.

3.4.2 THE VALUES OF NATURAL HABITATS AND BIODIVERSITY

Areas of natural vegetation have a number of types of value:

- **Consumptive use value**: the value from harvesting natural resources such as flowers, medicinal plants etc.
- **Non-consumptive use value**: the recreational and tourism value of natural areas
- **Indirect use value**: e.g. livestock grazing, the pollination services provided to the fruit industry by bees partially dependent on natural vegetation

- **Existence value**: the utility that people gain from knowing that areas are conserved and that future generations can experience this biodiversity, etc.
- **Option value**: the future, unknown and as yet unrealized, value that may be gained from exploiting biodiversity, e.g. for horticulture, ecotourism, medicine.

These values can be estimated by a number of valuation methods, ranging from collection of market data for estimating consumptive use values, to the use of somewhat controversial contingent valuation methods for estimating option and existence values. It is generally easier to find or collect data on direct consumptive and non-consumptive use value than to estimate indirect, option and existence values.

Existing data on these values in South Africa is scarce. Few studies have been carried out in South Africa to estimate the economic value of natural systems, with most work concentrating in the fynbos biome (on all types of value) and the savanna biome (consumptive use value only). No studies have been carried out specifically in the case study area.

Existing data on direct consumptive use values are taken from unpublished literature and used to provide default data for the model. However, all of these values are average values for large areas (the entire range of the vegetation type), despite the fact that the source of some of these values could be quite localized. Ideally, one should use marginal values which are specific to local areas. Thus the default values may be highly inaccurate when applied to localized study areas such as the Upper Breede catchment. Thus it is anticipated that the model user attempts to refine these estimates, either through pilot studies or professional opinion.

The non-consumptive use value of natural vegetation is currently only given in the model for natural vegetation in the Western Cape. Tourism value for the province has been estimated by KPMG, and this value is divided into general nature-based tourism value and ecotourism on the basis of unpublished surveys carried out in the Agulhas plain area (JKT). The value of nature-based tourism is defined as the contribution of appreciation of the province's natural resources such as scenery to the total expenditure by tourists in the province. Ecotourism value was estimated on the basis of the proportion of tourists that were engaged in specialist biodiversity-based pursuits. Again, these estimates could provide average values per hectare for the whole province, but it is recognized that much of this value is concentrated in a relatively small area. We thus make estimates as to the spread of these values over the seven tourism regions of the Western Cape, and then divide these by the approximate natural vegetation area in each region, to provide broad estimates of tourism value per ha of natural vegetation for each region.

The model does not include indirect, option and existence value due to the almost total lack of data and the fact that option and existence values are not values affecting conventional measures of economic performance, and hence still not taken seriously by conventional decision-makers. Indirect values may, however, be highly significant. For example, river flow in the Breede affects the export of nutrients into the marine area beyond the estuary, affecting fishery productivity. These types of values cannot be generalized for a model, and usually cannot be estimated rapidly.

Again due to a total lack of primary research, the model contains assumptions as to how direct use values are altered by the invasion of aliens. In the case of consumptive use value, the relationship is assumed to be a simple one, with value decreasing in direct proportion to the decrease in natural vegetation cover, although it is acknowledged that value may decline more steeply due to a reduction in accessibility to remaining areas. Thus an area with 50% cover of aliens is assumed to retain 50% of its original value. The change in recreational/tourism value in response to aliens has not been investigated. On the whole, it is assumed that nature-based tourism is relatively insensitive to alien vegetation, with a decline in value only occurring after a catchment is 80% invaded. Beyond that we assume that some tourism value remains even after it is 100% invaded. Ecotourism value is assumed to be far more dependent on vegetation quality, and a sharp decline is assumed to occur beyond about 50% invasion of a catchment.

4. MANAGEMENT COMPONENTS

4.1 THE COSTS OF ALIEN CLEARING

4.1.1 CLEARING EFFORT, HUMAN AND FINANCIAL COSTS.

Clearing effort is measured in terms of the number of person days required to treat one hectare. The management data of the Fynbos Working for Water Project (Fynbos Project) in the Western Cape was used to obtain cost estimates in the model. Table 2 illustrates the total expenditure for the Fynbos project for 1998/99 including an estimated distribution of expenditure per item.

Table 2. Expenditure patterns of the Fynbos Working for Water Project

Allocation	Amount	% expenditure per item
Personnel	R42 324 494	61
General Administration	R1 375 204	2
Transport	R13 935 090	20
General stores	2 833 173	4
Clothing	2 211 654	3
Chemicals	1 993 087	3
Equipment	1 959 480	3
Professional services	3 043 268	4
Total allocation	R69 675 453	
Median cost per productive person day		R101
Estimated current cost (2001 rands)		R108

Management data in the Fynbos project has been recorded according to the dominant IAP genus present and the density class applicable to the specific treatment. The four most common genera treated in the Western Cape are *Pinus spp., Acacia spp., Hakea spp.* and *Eucalyptus spp.* These are being used as a case study to estimate the impact of invading alien plants on water resources. Table 3 shows the effort required to treat the above mentioned genera as recorded (not audited) by the Fynbos project during the 1998/99 financial year.

Table 3. Effort in person-days per hectare to treat different densities of invading alien plants.

Density class	***Pinus***	***Acacia***	***Eucalyptus***	***Hakea***
0-1%	0.1	0.7	No data	No data
1-5%	0.53	1.75	No data	1.3
5-25%	4.58	10.47	No data	9
25-50%	8.2	11.28	21.62	16.54
50-75%	15.76	21.81	28.13	19.78
75-100%	25.02	29.88	22.31	31.84

Follow up spraying of *Acacia spp.* and *Eucalyptus spp.* in the first growing season after initial clearing and prescribed burning was assumed to be part of the initial treatment effort. This is done for two reasons. Firstly, the activity takes place within one calendar year of the initial treatment and therefore forms part of that year's investment. Secondly, it accommodates the difference in follow up treatments between sprouting and non-sprouting species as well as the reduction in density, and hence the workload of follow up treatments.

Part of the treatment process of invading plants is the reduction of biomass through burning. In the case of Acacias, burning normally takes place during the first autumn or early winter after treatment. The fire stimulates the germination of the seed bank, with a resultant "dog hair" stand of seedlings. The seedlings are then sprayed with herbicide. Figure 5 shows the ranges of effort recorded by projects in Mpumalanga and the Western Cape for the spraying of seedlings after the initial treatment. The Mpumalanga data was included in this part of the study because of good quality data recorded by the Mpumalanga Working for Water Projects and the shortage of follow up spray data from the Fynbos projects.

The average person days per hectare needed for follow up spraying were added to the density classes 25 – 100% as there was very little variation in the effort needed for spraying across the different density classes. The average value of 3.29 person days per ha (*total number of person days of all observations / total area of all observations*) was used to add the effort needed for follow up spraying.

The process is not the same for non-sprouting species (*Pinus* and *Hakea spp.*). In the latter case the cleared material is left for 18 months to three years before burning takes place. The waiting period allows seeds to germinate and the seedlings to be killed by the fire. Using the above, the weighted management (production) effort needed for the different genera was calculated. The average weighted clearing costs per density class can thus be calculated.

The following range of formulae was used to calculate the estimated weighted effort required and ultimately the cost of clearing for the different density classes:

$$E = \Sigma(E\_spp. \times C\%\_spp.)$$

Where E = weighted effort needed in person days/ha for the catchment, E_spp. = average effort in person days/ha recorded by the Fynbos project for the specific species during 1998/99, and C%_spp. = the weighted % contribution of a specific species to the total infestation density.

$$C\%\_spp. = CF\_spp./\Sigma(CF\_spp.)$$

Where CF_spp. = The Contribution Factor for the species in question.

$$CF\_spp. = DF \times AF$$

Where DF = density factor contribution and AF = area factor contribution of the species in question.

$$DF = RI\_spp./RI(Total)$$
$$AF = A\_spp./A$$

Where RI_spp. = The relative infestation density recorded for a specific species, RI(Total) = The total relative infestation recorded, A_spp. = the area over which the specific species has been recorded and A = Total area of infestation (or catchment).

Figure 2 shows the estimated weighted effort needed to clear IAP in the George Catchments. Is it is typical of Western Catchments this can be applied to the model.

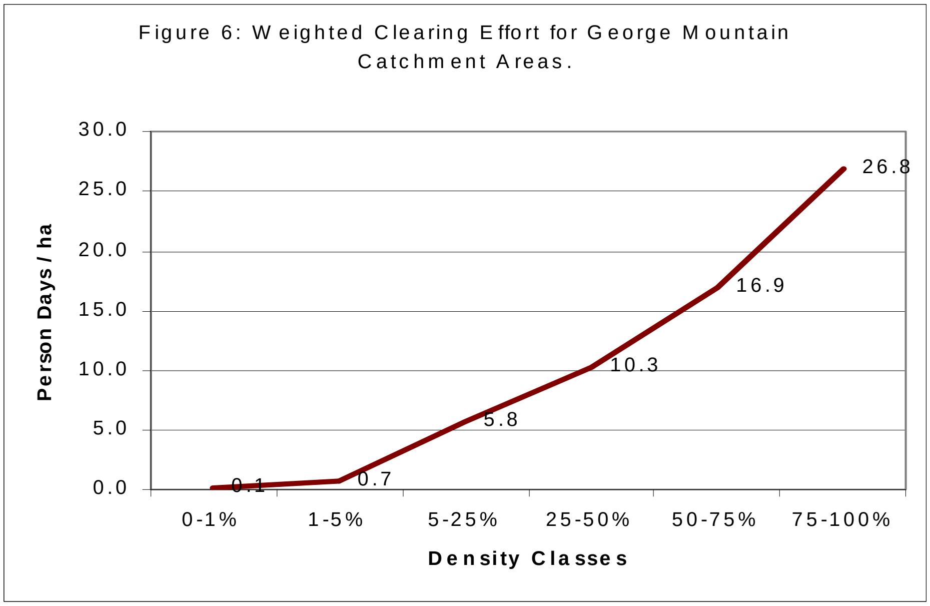

Figure 2. Weighted clearing effort for George Mountain Catchment Areas.

4.1.2 CLEARING EFFICIENCY

Clearing efficiency is the difference in density (= workload) before and after a treatment. In the model an area is promoted from a higher to a lower density class after treatment. A preliminary assessment was done on 1995 – 1997 management data of the Fynbos project to determine the impact on IAP plant density (cover) after treatment. A number of follow up treatments recorded in monthly reports by Fynbos project managers were selected according to the site name recorded by the project manager. These were compared with previous treatments at that specific site (Marais 1998). Sites were selected where it could be assumed with an acceptable level of accuracy that the two sites reported were indeed the same. For the purposes of the analysis, the density class and person days/ha effort were recorded to determine the assumptions for clearing efficiency. A determining factor for the accuracy of the follow-up treatment was the dominant species treated, as well as, (in only a number of cases) the applicable density class. In certain cases the density classes might not have been reported accurately. In such instances the reduction in the clearing effort in the follow up treatment was used as an indicator.

Field experience in the Fynbos project showed that greater effort is required to treat *Acacia spp.* than *Pinus* and *Hakea spp*. (Marais 1998). This result showed that the assumptions relating to clearing efficiency in the model should be weighted according to the relative infestation of the different genera in an area. For the purposes of the Marais (1998) study this area was taken to be the declared Mountain Catchment Areas (MCA) of the Western Cape.

The weighted value for the effort to reduce the density by 1% is therefore calculated as follows:

$$E1 = W_{(Pinus \ \& \ Hakea)}*0.65 + W_{(Acacia)}*1.449$$

where, E1 = Effort to reduce density by one %, $W_{(Pinus \ \& \ Hakea)}$ = the weight *Pinus & Hakea spp*. (Relative Infestation) contribute to the total infestation in the MCA and $W_{(Acacia)}$ = the weight *Acacia spp.* contribute to the total infestation in the MCA.

The weighted effort for the entire MCA is 0.778 person days for a 1% reduction in density. To apply this to the model, the percentage reduction in density must be calculated using the person days per hectare allocated to the different density classes. The results from Marais (1998) showed that it would take an initial treatment plus two to three follow up treatments for an area to be cleared from being 75 – 100% infested to be relatively uninfested.

The model assumes that alien clearing programmes are implemented fully, such that:

- Each hectare is cleared four times over a ten-year cycle; and
- Clearing is fully funded so as to maximize the efficiency of each clearing event.

If it is a clearing year (year 1, 2, 6 or 8), and if the condensed area of aliens in the previous year is <X% of total natural area, the area in the previous year is multiplied by the proportion remaining after a clearing effort for that density (X%), else the condensed area is allowed to grow as per the growth equation described in the ecological component of the model.

The model at this stage does not offer the option of evaluating the benefits of a lesser investment in clearing a catchment (*this would be good*).

4.2 FIRE MANAGEMENT COSTS

The impact of invasive alien vegetation on fire frequency and intensity, or on fire management costs, varies depending on the characteristics of the vegetation of the area. For example, fire frequency may increase as a result of alien invasion in certain non-fire prone vegetation types such as Eastern Cape Thicket, strandveld and riverine forest, but not in normal fire pone environments. In the latter, alien vegetation might even reduce the frequency in some cases where it takes longer to build up a litter layer.

This model is based on statistics collected within the fynbos biome, and may need to be adjusted when applied to other biomes. In the fynbos biome, alien invasives usually lead to increased costs, either in the fighting or prevention of fires. In the absence of fire protection, a higher density of aliens would lead to a greater frequency and intensity of fires, including damaging runaway fires. The model assumes a situation in which fires are kept under control due to the appropriate level of protection, and that increased alien densities increase management costs. Costs of fire protection generally increase as the density of aliens increases, because fires are more intense, fire breaks have to be wider and one needs more resources, human, financial and capital to control the more intense fires associated with increasing alien density. Two forms of fire protection costs are the maintenance of fire-breaks and control burns. Using data collected from various public protected areas within the fynbos biome, these relationships were established for use in the model.

The costs of control burns are a function of burn area and alien density. The relationship between burn costs and burn area was estimated using fire management data collected from 23 nature reserve areas in the Western Cape. For reserves with intermediate densities (25-75% cover) of alien vegetation, the following relationship was found:

$$\text{Ln Costs/ha} = -0.7535 (\ln \text{area}) + 7.2116 \quad \text{……………………(1)}$$

According to this relationship, costs rise very steeply if the burn area is smaller than 50 ha.

Next, the relationship between fire control costs and alien density was determined on the basis of expert opinion. Four managers were interviewed and asked about the increase in number of staff required to implement a control burn with dense infestation of aliens, for areas of different sizes (Table 4).

Table 4. Results of an expert survey enquiring as to the number of people required for manning a burn, with no aliens or with dense aliens, for different sized burn areas.

Manager	1000 ha No aliens	Extra	% extra	100 ha No aliens	Extra	% extra	10 ha No aliens	Extra	%extra
Mark Johns	50	25	50%						
Jaco Rheeder	50	20	40%	30	10	33%	20	10	50%
Piet van Zyl	30	20	67%	20	20	100%	20	20	100%
Tony Marshall	40	20	50%						
Average % increase			52%			67%			75%

Thus costs of clearing as a factor of those for vegetation areas with a low cover of aliens can be compared in Table 5. Costs for intermediately invaded areas were interpolated.

Table 5. Factor increase in costs of clearing areas with different densities of aliens

	Low density	*Intermediate density*	High density
10ha	1	*1.38*	1.75
100ha	1	*1.34*	1.67
1000ha	1	*1.26*	1.52

Cost ratios were then recalculated using the cost for intermediate alien levels as the base, and with costs of clearing lower and higher alien density calculated as a factor of this (Table 6)

Table 6. Cost factors in relation to clearing costs for areas of intermediate levels of infestation.

	Low density	*Intermediate density*	High density
10ha	0.73	1	1.27
100ha	0.75	1	1.25
1000ha	0.79	1	1.21

Using the above cost factor estimates, a continuous relationship between the cost factors and area was developed for areas with low and high density alien invasives:

$$\text{Low density areas: Cost rel to med aliens} = 0.0144\ln(\text{area ha}) + 0.6903 \quad \ldots\ldots(2)$$

$$\text{High density areas: Cost rel to med aliens} = -0.0144\ln(\text{area ha}) + 1.3097 \quad \ldots\ldots(3)$$

The model then calculates the costs of control burns using equation 1 and multiplies costs by the factors calculated by equations 2 and 3 or by a factor of 1, depending on alien density of the area.

The cost of maintaining firebreaks is a function of firebreak length, width and clearing costs per m^2. The average clearing cost is approximately R0.23 per m2 per year, but there is provision in the model to alter this figure. Firebreak length was estimated to be a quarter of the total perimeter length of fire control areas in the catchment. This was derived by first halving the aggregated length to account for shared boundaries, then halving this again to account for the fact that approximately half of boundaries do not require firebreaks due to the adjacency of short vegetation, crops or other landuse types. Data taken from nature conservation areas in the Western Cape showed a significant increase in the width of firebreaks cut in relation to the density of aliens in that area (Fig. 3). The regression equation was used to estimate required firebreak width in the model.

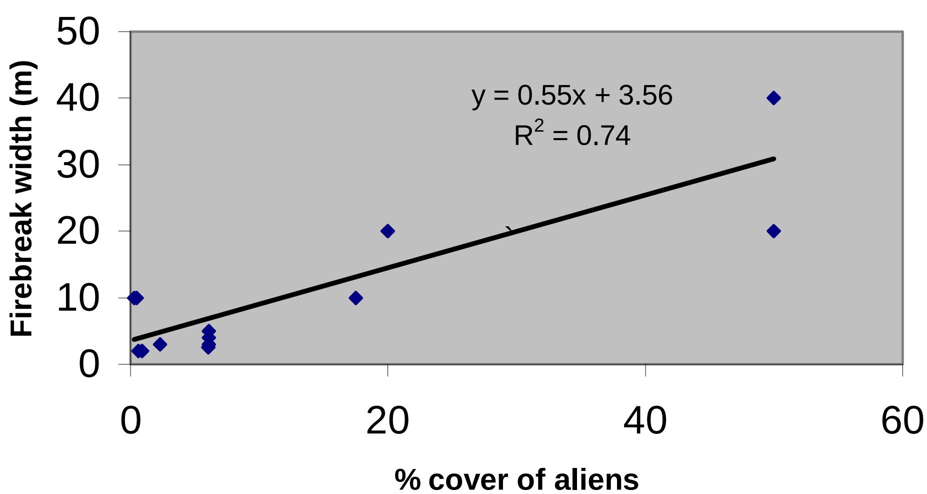

Figure 3. The relationship between density of aliens and required width of firebreaks

4.3 THE COSTS OF SOIL EROSION DUE TO ALIENS

Alien invasion results in a decrease in ground cover, with the result that after burns, which are also more intense, greater quantities of soil are exposed and washed away in subsequent rains. These soil losses do not impact much on agriculture, as they generally occur in natural areas with low agricultural potential, but the main impact lies in the increased sedimentation of rivers. In cases where natural areas are utilized through some form of consumptive use (e.g. grazing, flower picking, thatch or biomass from woodlands) the soil loss could be quantified and valued if the loss of soil can be linked to a decrease in production.

Sediments build up in dams and shorten their lifespan, thus necessitating either dredging or the expansion of water supply schemes. In order to calculate these costs, it is necessary to understand the difference in sedimentation rates with different levels of infestation, as well as the costs of the prevention of dam siltation. Very little research has been carried out to assess the movement of soil through catchments due to invasive aliens, nor on the costs of this phenomenon.

In some cases soil movement could cause major damage to infrastructure. On the Cape Peninsula it was found that the soil movement under invaded areas was dramatically higher than under natural Fynbos areas. No net change (soil movement was recorded under natural Fynbos while 113 m3/ha (147 tons/ha) moved under invading alien plants, and double that in areas where large volumes of dead biomass was stacked. Although the movement is not only dependent on the absence or presence of invading alien plants we do know that a combination of fire severity, biomass load and soil type influences soil movement (Euston-Brown 2000).

It is not possible to quantify how much soil ends up causing damage to infrastructure (as in the case of Chapmans Peak Drive after the 2000 fires in the area, and mudslides causing damage to houses in Glen Cairn during 1999). Some soil may be deposited 1 – 20 m away with no economic consequences. All these cannot be quantified therefore it is extremely difficult to estimate the impacts of soil movement. We thus exclude estimates of soil losses from the model. We do however recognize that it has an economic impact and that further work should be done on this.

5. HUMAN DEVELOPMENT (TRAINING) COMPONENTS

Jacqui Goldin

5.1 OBJECTIVES

The human development component of the model aimed to:

- quantify the realised economic benefit of training as a non-wage benefit, per hectare in terms of life earnings per worker[1];
- break down this realised benefit into three distinct categories:
    - Production workers;
    - Administrative workers;
    - Management workers; and
- calculate the training costs per individual as presented in the improved citizenry module.

1.1 RATIONALE AND CONSIDERATIONS

1.1.1 PUBLIC WORKS PROGRAMME AND TRAINING

Although short-term poverty alleviation is one objective, South African public works programmes are mainly seen as a stepping stone to sustainable jobs and economic development (Adato *et al.* 1999). The training component of the Programme has the potential to create non-wage benefits for the poor. Public Works Programmes (PWPs) are designed as part of poverty reduction and poverty alleviation strategies. Their goal is to provide employment and to build infrastructure. The Working for Water Programme (WfWP), within the context of the PWPs does not create infrastructure (a non-wage benefit). In this respect it differs from the majority of PWPs both in South Africa and elsewhere. The programme, as a labour intensive programme, has, however, been exemplary in its emphasis on training. This satellite, stands side by side with other satellites within the SEGA 34 project[2], as part of the broader evaluation

[1] To be discussed in Section 2: life earning calculations
[2] Water (Domestic, Industrial, Agricultural), Consumptive use of Natural Resources, Non-Consumptive Use (Tourism), Fire Management and Secondary Industries.

of the WfWP. It aims at assessing these non-wage benefits per individual per hectare.

The Programme's achievements can be measured in terms of how many jobs have been created and how many hectares of land have been cleared. The Saldru/IFPRI research project[3] research project, showed that, in relation to other South African public works programmes, the WfWP fares well, in rand terms per person days of labour and percentage costs allocated to labour (73% of total costs). The percentage of costs to training however are low. 1% compared to the 18% stipulated in the actual programme budget. In the light of the Contractor Development Programme the training budget has been increased. This increase in training costs is not truly reflected in the expenditure as a training cost, but as a management cost.

1.1.2 HUMAN CAPITAL

Economic growth and human development go hand in hand in achieving sustainable improvements in the quality of life of all South Africans. Economic growth and human development are best achieved through enhancing the capabilities of disadvantaged communities, households and individuals (Clark: 2001). The work of Nobel Prize-winner Amartya Sen (1994[4],1996) has helped to further our understanding of the development process by focussing on individuals as ends rather than only means of growth. This 'capabilities' approach concentrates on those factors which enable the human to develop to the full potential over time. The long term objective in any development agenda must focus on this aspect of human development if it is to achieve its macro-economic stability. Training and capacity building of individuals goes hand in hand with legislation that provides equal access to opportunities to exercise this potential. First and foremost, however, is that opportunity to enhance individual capacity.(May:2000, p8). Growth and human development, therefore, are linked and are mutually reinforcing. Growth and economic development can only be reached when individual capability is enhanced.

[3] Southern Africa Labour and Development Research Unit (Saldru), based at the School of Economics, University of Cape Town and the International Food Policy Research Institute (IFPRI), Washington DC. This study focused on seven public works programmes covering 101 completed public works projects in the Western Cape Province. Together, the 101 projects in the seven programmes represent a census of all labour–intensive public works projects initiated and completed in the period from 1993/94 to 1997/98

[4] Sen (1994) sees human beings as people with rights to exercise, not as part of a 'stock' or a 'population' that passively exists and must be looked after.

It is therefore appropriate to devote a concerted effort into measuring whether or not the WfW programme can be said to be enhancing human capacity. Is the programme building human infrastructure, in the place of investment in physical assets, thus increasing the potential of citizens to participate, in a meaningful way, in the economy and opportunities of their country. If this were true, then the programme would be successful in enhancing human capacity and thus minimising the individual's vulnerability to extreme poverty. (May: 2000, p16)

The social cost-benefit analysis of the training component of the WfWP is designed as a research tool to evaluate non-wage benefits to the poor. This research will inform and assess whether the programme is justified as a job development, rather than only a job creation programme. The improved citizenry module, within this training satellite, is aimed at measuring only human investment or capital whereas the main part of the module focuses on its potential to create sustainable jobs and thus generate income.

5.1.1 LITERATURE SURVEY

Cost benefit analysis literature is available (see bibliography) but the challenge of putting a rand value to human quality and thus measure the effect of training on citizen, is a difficult one. This project will provide a unique contribution to the existing literature on social cost benefit analysis. Analysis of PWPs has successfully evaluated the cost of training and provided some useful insights into the benefits to the individual (Goldin and Adato 2000, Adato 1999). The improved citizenry worksheet reflects this training cost, estimated together with ranked benefits to give a value index. The robustness of the model, however, lies in its ability to go beyond an improved citizenry module and to link the training to improved earnings, calculated at any point in time over a period of forty years.

1.2 MODELLING APPROACH & CONSTRUCTION

The training component of the model is multilevel and is organised into six worksheets:

- Production workers: improved earning potential
- Management: improved income[5] potential
- Administration: improved income potential
- Improved earnings: figures and calculation
- Improved earnings: graphic representation
- Improved citizenry

The construction of the model separates fixed or locked cells and active cells. All highlighted cells, red, yellow and blue, are locked and cannot be used on site. They can only be changed by an informed programmer in head office. The white cells are interactive data input cells. User-friendly text formatted cells are provided. The complex process is therefore made accessible to the inputer step by step.

The worksheet is divided into two sections as presented below.

[5] The distinction between improved earning and improved income is that production workers assume a wage based remuneration whereas improved income is based on a salary

Section One:

TRAINING CATEGORY BASED FOR INTERNAL COURSES	
	Potential Trainable Production Workers =
INDUCTION FUNCTIONAL	WORKING for WATER TRAINING: TOTAL
	Basic Invading Alien Plant Clearing Methods
	General SAFETY (NOSA)
	General Herbicide Awareness
	Numeracy
	Fire Protection & Control Services training
	Rehabilitation
ENVIROMENTAL	ENVIRONMENTAL EDUCATION TOTAL
	Plant Identification : Group work, use of plants, Import of plants and Location of plants
	Fauna/Habitat : Reptiles(Talk and Demo), Danger and Benefits related to reptiles and Protection of habitat and animal behaviour
	Water 1 : Water Cycle and Managing water (Saving)
	Water 2 : Water Testing Activity
	Soil Theory and Practice : Soil erosion, Soil types, Soil activity, Compost and Protection of paths
HEALTH & SAFETY ONE	HEALTH & SAFETY TOTAL
	First aid (Level 1)
	Occupational health and Reps
HEALTH & SAFETY TWO	First aid (Advanced level)
	Advanced driving
HERBICIDE	HERBICIDE TOTAL
	General Herbicide Awareness
	General applicator
MACHINERY	MACHINERY TOTAL
	Chainsaw operator
	Brushcutter operator
	Chainsaw/Brushcutter mechanic
MOUNTANEERING	MOUNTAINEERING TOTAL
	Mountaineering Induction
	Rope work
	Map work
	Hellicopter skills

This section shown above is divided into training categories for internal courses as follows: induction functional, environmental education, health and safety one and two, herbicide, machinery and mountaineering. The categories in the worksheet improved income potential for administration and improved income potential for management differ slightly from the improved earnings for production worker worksheet shown above.

The numeric allocations fall under the following headings:

Nr. Of People Training	Person Days Training (only relevant for improved citizenry)	Gross Earning Advantage per Person	GROSS ADVANTAGE

The Gross Advantage per Person cell is linked to the worksheet earning potential calculated over a period of 20 years. Figure 4 illustrates the accumulative income potential for production workers. This shows the potential income advantage of a trained person in a particular category compared with an unemployed person who has the very minimum earning potential.

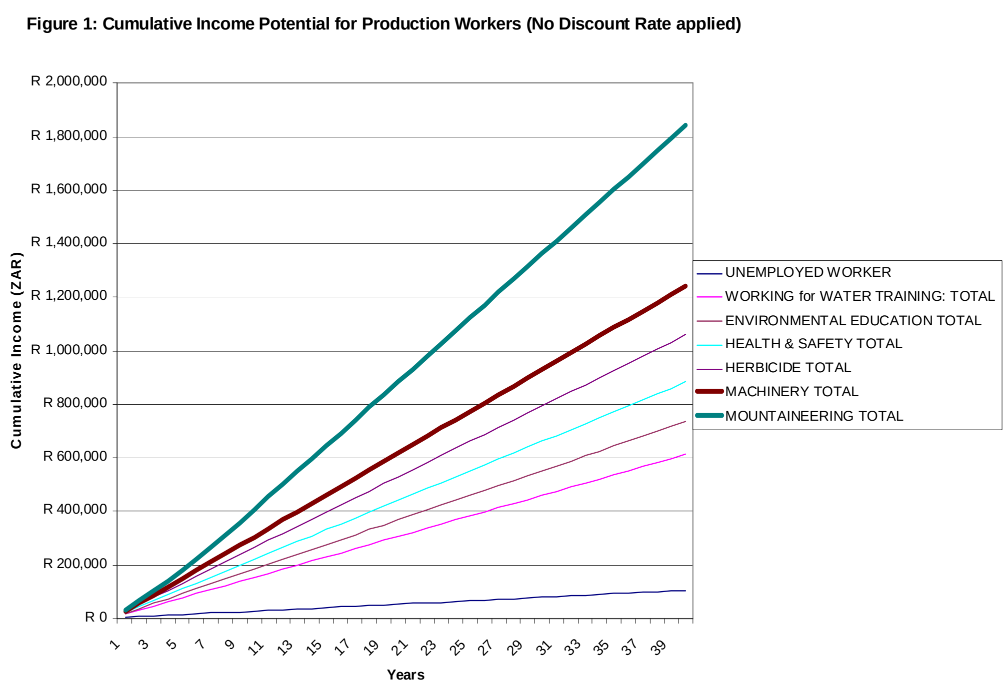

Figure 4. Cumulative income potential for production workers (without discounting)

Section Two: Ranking

BENEFITS WEIGHTED & RANKED

5	10	4	6	8	<== RANKING	33
Certificate or diploma	Accreditation (SETA)	Quality of Training Course	Applicability & Usefulness (Capacity Building)	Employment Rate per Skills Level	APPLICABILITY COEFFICIENT	REALIZED BENEFIT

The allocated numeric value for the first two column is 10 for True (that is given a certificate or accreditation), whilst the value is 1 for False (that is no certificate or no accreditation). These columns have been weighted 5 and 10 respectively. The other three columns are subjective values given, for example 4, 6 and 8. This weighting means that those values which are less real and depend on the random allocation of the input officer, do not undermine fixed numeric values where minimum input error is possible. The employment rate per skills level ranks second to certification and is given the weight eight. The applicability coefficient is the sum of the total weighted averages of the benefits divided by the sum of the total reference weighted benefits multiplied by 10, when all rankings are at their maximum value (10) the coefficient = 1.

The gross potential benefit is the result of the product of the gross advantage per person per day multiplied by the number of people who were trained in a given training category. The gross potential benefit for a given category multiplied by the applicability co-efficient of that same category, gives the realised benefit for the training category in question. Let us take a few examples from the production worker worksheet to illustrate these points more clearly.

5.1.2 OPERATING THE MODEL: IMPORTANCE OF RANKING COEFFICIENT

Assume that the mountaineering training course, completed by five members of the WfW team gives a realised benefit per individual of R150 367, that is per 5 workers a total of R751 837. Assume now that this course was done extremely well, that the individual received a certificate (benefit maximised 10 out of 10), that the certificate was accredited (another 10 points) the quality therefore being maximum of a further 10 points, that the usefulness of the course is 10 and that there are ample jobs in that field, scoring another 10. As the realised benefit is the product of the gross advantage multiplied by the applicability coefficient, being at its maximum value in this example = 1, the realised benefit is going to be equal to the gross advantage. The more the applicability coefficient deviates from 1 (towards 0) the realised benefit becomes smaller and smaller impacting negatively on the gross advantage. It is the ranking that determines whether or not a given training category is viable.

The total gross advantage for each training category is obtained by multiplying the total number of people training in that category (column E) multiplied by the gross advantage per person (column F) which is obtained from the worksheet improved earning potential. This gross earning advantage per person is based on an average of active work per person over twenty years[6] compared with an unemployed person who earns sporadically during the same lifespan.

The key, then, to the model is the interaction between the ranking and the cost. In order to maximise the efficiency of this model it is necessary to differentiate between the independent variables presented in the benefits part of the equation. The more complete the input data for the ranking equation, the more precise the rand cost benefit output. The cells in column K labelled applicability and usefulness have a real market related value. The more rigorous the input data the more real the output as affecting the applicability co-efficient and the subsequent realised benefit per hectare. The importance of input precision is thus key to the robustness of the model. The applicability coefficient in the production worker worksheet, for a particular training category e.g. machinery is obtained by is the sum of (H52 to L52) divided by the sum of (H5 to L5)[7] multiplied by 10. The applicability coefficient for another training category e.g. mountaineering is obtained by the sum of (H61 to L61) divided by the sum of (H5 to L5) multiplied by 10. The total for each weighted ranking (e.g. accreditation) is obtained by the average of the weights for the subcategories in that training division multiplied by its weight.

In the case of this pilot model, input for employment was taken from labour market statistics. Input data needs to take into consideration further the occupation within specific sectors in order to ensure precision and thus maximise the potential of this model to produce numeric allocations which reflect the externality. Despite this increased probability of precision of numeric allocation, certain rankings remain dependant on the aptitude of the

[6] The worksheet calculated over 20, 30 and 40 years but the calculations for the 20 year period were used.
[7] H5 to L5 are the standard references pre-weighted and fixed: in the model presented here this addition equals 33

inputer[8] to assess and rank efficiently. This applies particularly to labels: quality of training, quality of certificate where precision is minimised. In order to maximise precision, the rankings were weighted and certain input data given priority: this applies to certification (10), accreditation (10) and employment rate per skills level which was also rated highly (8).

The realised benefit for each training category (column N) depends, then, on the accuracy of the applicability coefficient. It is reached by multiplying the applicability coefficient by the total gross advantage (column G) for each training category. For a given total gross advantage, the smaller the applicability coefficient, the smaller the realised benefit. The numeric value of the applicability coefficient for a given gross advantage is the determinant of whether or not a particular training category is relevant in the programme. This applicability co-efficient is therefore the key to deciding whether or not the programme is able to achieve its objectives of building human infrastructure (assets) and creating long-term sustainable jobs, either within the context of the Contractor Development Programme or within the context of a broader labour market reality.

5.1.3 THE IMPROVED CITIZENRY MODULE

This worksheet differs from the production workers earnings and the administrative and management improved income worksheets. It does not reflect the potential earnings or income but rather reflects the actual cost implication of the training of any given category. The cost implication for a training category in conjunction with the value index gives a comparison index. This comparison index indicates whether the cost investment is justified. The comparison index is the product of the value index and the full cost of training in any given category. The value index is derived in the same way as the applicability coefficient. This worksheet, presented below, relates to those training categories that do not provide jobs in anyway but do improve the worker or have the potential to make better citizens. In this worksheet the rankings certificate or diploma, accreditation or employment rate are not relevant. There are therefore only two weighted rankings that impact on the full cost of the training, resulting in the comparison index.

---

[8] It is probable that each project manager would fill in the data. It is also probable that certain cells will be locked and that their values will be predetermined and constant, varying only from province to province and not project to project.

INDUCTION LIFE SKILLS	Working for Water Background
	Terms and Conditions of employment
	Race
	Gender
	Disability
	Masekhane (Community Development)
	Personal Finance
	Labour relations
	Worker's compensation awareness
	TOTAL INDUCTION LIFE SKILLS
HEALTH AND NUTRITION	HIV/AIDS
	STD' s
	Primary Health Care (TB, etc)
	Nutrition
	Hygiene
	Substance abuse
	TOTAL HEALTH & NUTRITION
	Water 1 : Water Conservation Awareness
	Other
	Other
	TOTAL ENVIRONMENTAL

5.1.4 PROBLEMS AND PROCESS

The progression of the stages of the model was indicative of the problems facing a modelling exercise of this magnitude. Although the literature search provided several informative sources on cost-benefit analysis (see references) there was no existing model which could serve as a reference for this project. The modelling process is in this sense pioneering. The first attempts at this model was to collapse the benefit of the training and cost of the training. This is an inaccurate attempt for although the ranking concept was helpful and produced a figure this did not take into consideration the potential earning capacity measured over the lifespan of a worker. It merely calculated the maximum value of training per person (or per hectare). This concept developed into worksheet six i.e. improved citizenry. The other worksheets became elaborate modules which measured earnings and income.

5.1.5 WEIGHTING

A further problem experienced in the building of the model was that ranking categories were given equal values. This meant that the quality of training was given equal importance as the employment rate per skills level. The concept of weighting the benefits adds finesse and accuracy to the applicability coefficient and thus impacts positively on the probability of the realised benefit being an accurate reflection.

5.1.5.1 Distinction between improved earnings and improved citizen

Improved citizenry calculates only the costing of the training and not the impact of earnings. In the case of an unemployed worker, (either one who is non-labour participant or one who is unemployed[9]) who does not enter the labour market, these calculations are satisfactory. They are not relevant for the active labour market person. The improved citizen has a capital investment (to the citizen) and an expense (to the state). This saving or investment does not necessarily impact on earnings. It was this distinction that motivated the improved citizenry worksheet as an important complement to the earnings worksheets. It completes the model.

5.1.5.2 Double counting

First attempts at the model were double counting the number of people training. The model was refined to ensure that there was no further double counting. This meant that workers completing categories were only counted for their maximum earning advantage per person. [10] Input data allowed for the decision of the manager to qualify team members for further training categories. Thus, a worker might not qualify for machinery and only benefits then from the previous category he/she completed.

---

[9] The distinction between non-labour participant and unemployed is defined by Dr Nicoli Nattrass and was used in the Labour Market Survey (Survey 2000: SALDRU). Non-labour participant is a citizen who is unemployed but who is not actively seeking work. An unemployed person is distinguished by job-seeking activities. Both unemployed and non-labour participants do not include categories of casual workers or those individuals who earn in activities, friends or family. For further information on definitions of work or job see International Labour Organisation (Anker, R: 1988)

[10] This aspect of the model needs further refinement. For a worker with a maximum earning potential as a mountaineer, for example, there might be an impact if that person has induction training or has not. This is still questionable.

5.1.5.3 Additional incorporation of workers in training categories

This concept of incorporating additional workers in training categories, who did not form part of the initial team, became necessary once the model was piloted in the field. It became evident that the training input data needed to be more flexible and allow for additional workers who might be incorporated at any given training stage. This means, for instance, that a worker might be brought in to do First Aid but not have completed the previous training category.

5.1.5.4 KPI[11] and practical training categories

The piloted project brought to light further questions about the practicality of presetting categories prior to input. The training categories on the ground did not reflect the categories which had been compiled in-house with the KPI manual. This tension between the in-house categories and the field experiences needs to be resolved. Many of the training categories were adapted accordingly.

5.2 CONCLUSION

This social-cost benefit analysis model is a robust one. Its success lies in the accuracy of the input data, particularly for arriving at a meaningful applicability coefficient which will allow for a realistic realised benefit. The model needs to be tested in the field and the categories should be aligned with working models on the ground[12]. A decision should be taken as to which cells will be locked and which cells remain active. Furthermore, it is as yet unclear how the data will be managed both at the input level as well as analysis level. Further research is needed to test the model in the field and to test its function in relation to other components of the overall model.

[11] Key Performance Indicators

[12] Quotation packages for contractor development entrepreneurs do not advocate the same categories which have been determined from the regional office (KPI manual). This mismatch would cause unnecessary delays in input data. The model should be flexible enough to incorporate site specific organisation and training processes.

6. SECONDARY INDUSTRIES COMPONENT

Hugo van Zyl & Erick Grobbelaar

6.1 OBJECTIVES & SCOPE

This component of the model aimed to set up a framework for the determination of financial benefits (income) that will be derived from secondary industries to be added to other benefits in the overall WfW CBA model. Ideally, complete business plans should be used to determine financial viability and income. However, these are seldom available. In their absence broad predictions of income still need to be made though, which is what the framework in this study assists with. It is thus strategic in nature as it attempts to analyse broad opportunities as opposed to assessing known benefits (such as in the case of water savings).

There are two potential commercial benefit streams from WfW projects. One is the benefit derived from the use and processing of the alien plant material itself and the other is the opportunity that is created for commercial developments based on the new opportunities afforded by the cleared land (e.g. industries based on the vegetation that succeeds aliens once they are cleared, increased eco-tourism potential). Potential for the use of vegetation that succeeds alien infestation is captured elsewhere in the CBA model under 'restoration of productive potential' falling under the environmental benefits category in the model. In order to avoid double counting, this aspect will not be taken further here.

6.2 SECONDARY INDUSTRY PRODUCTS

Currently known secondary industries products can be divided up as follows:

- Firewood
- Charcoal
- Eco-logs
- Whitewood for pulp
- Wood chips for smoking
- Wood-chip cement panels and building blocks

- Wooden poles for fences, etc.
- Droppers
- Saw timber (e.g. planks for flooring etc.)
- Dowels
- Broom handles
- Bark for tannin
- Mulch (organic compost) for cultivation
- Furniture
- Crafts (incl. walking sticks, baskets, decor ornaments, etc.)
- Garden screens
- Edible plants used for foods (for humans and animals)
- Medicinal uses

This list only gives an indication of what products are presently being produced or under consideration in South Africa. New product ideas are likely to continue emerging with time. Continued investigation of the uses of aliens in their native countries and other countries is likely to bear fruit in this regard. An example of this is the use of Mesquite in the Northern Cape for secondary industries that was developed after the uses of the wood in the United States was investigated.

6.3 THE EVALUATION PROCESS

6.3.1 VIABILITY EVALUATION WHERE BUSINESS PLANS EXIST

Where proper business plans exist, evaluating secondary industries proposals should involve a simple financial cost benefit analysis using projected cash flows contained in the plans. If this CBA shows a positive net benefit this can be added to overall WfW project benefits. If it shows a net cost, then the proposal should either be revised to make it viable (if this is possible) or scrapped.

The following steps are recommended:

6.3.1.1 Identify and date the flows of expenditures

Identify and estimate all direct financial expenditures in present value Rands needed for each secondary industries venture and the points in time at which it is expected that they will be incurred. These need to be separated from overall

WfW project costs and include construction costs, management and maintenance costs, operational expenditures, and cost of eventual closure. Only expenditures that are additional to normal clearing expenditures should be included here. For example, alien plants have to be removed after clearing anyway as they pose a threat to infrastructure during floods. Thus the 'harvesting' and removal cost of any further beneficiation is already captured. Sources of variation in these costs including failure of expected demand to materialise, thus lengthening the repayment period on the initial capital, all need to be identified and used to estimate expected costs.

6.3.1.2 Identify and date the flow of revenues

Identify and estimate all financial revenues in present value Rands from each venture and the points in time at which it is expected that they will be received. These include any income that is received from the sale of secondary industry goods.

6.3.1.3 Calculate the Present Value (PV) of expenditures and revenues

The aim here is to calculate the PV of the stream of costs and revenues through the life of each project. In order to do this the current real interest rate should be used to discount these streams to present values for comparison.

6.3.1.4 Subtract PV expenditures from PV revenues to get a Net Present Value (NPV)

Now that the present values of costs and revenues have been determined, costs can be subtracted from revenues to show expected NPV. If this figure is positive, the project should be viable with the amount indicating the PV of gross profit.

6.3.1.5 Sensitivity analysis

Uncertainty in determining the viability of projects stems mainly from uncertainty about cost and revenue levels. This necessitates proper sensitivity analysis to test what happens to viability results when certain assumptions change. In order to perform sensitivity analysis, first a list of assumptions that may change should be drawn up. Then the implications of changing each of these assumptions (or a combination of them) for the financial estimates should be determined so that the cost benefit analysis can be revised with the new figures to determine a new NPV. In this way alternative viability outcomes are explored allowing for a more realistic analysis.

Among the assumptions that should be tested are:

- Cost changes. Expenditures have tendency to escalate as unforeseen difficulties arise.
- Revenue changes. Revenue levels are usually difficult to estimate as they are based on sometimes tenuous assumptions about demand levels for products.
- Interest rate effects. Interest rates are not stable over time making it important to check the effects of different rates on viability.

6.3.2 VIABILITY EVALUATION IN THE ABSENCE OF BUSINESS PLANS

Some secondary industry proposals will be well thought through by private sector entrepreneurs with proper projections of costs and revenues based on a comprehensive business plan. In these cases it is a relatively simple matter to apply the above methodology to assess viability as all the information necessary for this will be supplied by the entrepreneur and would just need to be verified. It also needs to be borne in mind that it is usually easier to have confidence in success when projects are driven by private sector entrepreneurs who have the necessary skills and experience in business as they would not be willing to invest time and money in a venture unless they were fairly confident of success. The IDC Lord secondary industries evaluation report cites the lack of involvement by private entrepreneurs as one of the primary reasons for secondary industry failures (IDC Lord, 1999).

Situations where detailed business plans exist are likely to be the exception. Instead, at least for the near future, WfW officials will have to generate their own estimates of what is likely to be viable from among a broad range of possible secondary industries. WfW officials will thus have to generate their own information and then evaluate whether secondary industries are likely to be viable. This report makes a start with the collection and generation of information and an accompanying evaluation framework for this purpose. The framework is not intended for use in the development of full business plans, but rather as a tool that can give a fair indication of viability and income. As such it contains assumptions that could not be thoroughly tested, but are deemed acceptable for the purposes of this study.

The evaluation framework was developed involving the following steps (elaborated on below) for a given alien species in an area where secondary industry opportunities are under consideration:

- Possible products per alien species
- Utilisable biomass available for processing
- Utilisable biomass per product based on minimum stem diameter requirements for each possible product
- The balance between revenues and expenditures to determine potential income
- Prioritisation of the use of biomass for different products based on profitability
- Probability of financially successful operations based on broad constraints and market conditions
- Final calculation of income

6.3.2.1 Possible products per alien species

Each alien species has characteristics that allow for the making of certain secondary industry products. Once the alien species is specified, the model allows only for the further analysis of products that can be made from the species.

6.3.2.2 Utilisable biomass available for processing

Not all alien plant biomass can be converted into secondary industry products. This step allows for the determination of the quantity of biomass available for conversion to all possible products based on age, density, accessibility and utilisable percentage of the alien stand.

6.3.2.3 Utilisable biomass per product based on minimum stem diameter requirements for each possible product

Each product has a minimum stem diameter that is used to determine utilisable biomass for each separate possible product.

6.3.2.4 The balance between revenues and expenditures to determine potential income

Each product for which biomass is available in the stand is subject to broad financial viability analysis. This analysis is based on generic expenditure and revenue models that are applicable throughout South Africa adjusted for local conditions in terms of transport costs. The figures contained in these models are based on WfW's limited experience supported by selected forestry industry norms. They cannot be considered highly accurate due to low levels of experience with secondary industries and the catchment-wide scale of evaluation, but are sufficient to generate broad estimates. After this stage is complete, the amount of biomass available for each product and the potential profit from it will be known.

1.2.1.1 Prioritisation of the use of biomass for different products based on profitability

At this point the question of prioritising products arises. Taking a simple two product example, a situation may arise were there is only enough demand to make charcoal out of 50% of an alien stand and further demand to make furniture out of the remaining 50% of the stand. There is thus no need for making a decision on which product to investigate further as both can be accommodated. However, if there is enough demand to make furniture or charcoal out of 100% of the stand a decision is needed on how the benefits from the stand can be optimised. The model handles this question by simply allocating the available biomass to the products with the highest profitability first.

1.2.1.2 Probability of financially successful operations based on broad constraints and market conditions

Clearly it is not realistic to expect financial success without consideration of constraints and market conditions. This step allows for the incorporation of these considerations in order to attach probabilities of success to each product. It does so at a broad level as generating mores accurate probabilities would require the kind of extensive study not provided for in this project.

The following sequential questions aimed at clarifying market conditions can be used as a guide in the process of making judgements on the probability of success:

If ***potential markets exist*** based on the following 3 questions for investigation then assume 30% demand. If they don’t, assume 0% demand

1. Are there markets for the product (e.g. local towns, nearby cities, international)?
2. Are these markets large enough to potentially absorb the production volumes envisaged?
3. If there are no existing markets can they be created?

If potential markets exist based on the preceding 3 questions and ***practical constraints are not present*** based on the investigation of the following 2 questions then assume 60% demand. If constraints are present, assume 30% demand

1. Distance to market is acceptable particularly for bulk products
2. Are the entrepreneurial and business management skills required for success available?

If potential markets exist and practical constraints are not present based on the preceding 5 questions and if ***market conditions are favourable*** based on the 2 following questions for investigation then assume 80% demand. If they are unfavourable, assume 60% demand.

1. What is the state of the competition (their strengths, weaknesses and market share)? How will the competition react and can their reaction be countered?
2. Have contracts, commitments or interest been established with potential customers?

1.2.1.3 Final calculation of income

The profit associated with each product is multiplied by the probability of financial success to arrive at a figure for income for insertion in the benefit section of the overall WfW model.

6.4 EXPLANATION OF USER INPUTS

The user input sheet supplied with the model allows users to provide the necessary information for the model to function. Most of the input requirements are self-explanatory, but the following input variables are explained here to avoid any possible confusion:

<u>Accessibility (%):</u> An estimation of the % of the total biomass that is accessible for further processing (i.e. close enough to vehicle access).

<u>Utilisation (%)</u>: An estimation of the % of the accessible biomass that is utilisable (i.e. meets the minimum specifications for different products).

<u>Access (E = Easy, M = Medium, D = Difficult):</u> A subjective opinion of the relative ease of access.

Extraction distance: The one-way distance to move the biomass before it becomes accessible to transport (i.e. at the roadside that can be used by trucks).

Lead (m): One-way transport distance from the roadside to the plant for further processing or depot for direct sale.

Payload: The legal load capacity of the vehicle.

Road class: Subjective evaluation, class 1 – main paved road, class 2 – main unpaved road, class 3 – farm road, class 4 – off-road track.

Road condition: Subjective evaluation of state of road, 1 – good, 2 – average, 3 – poor.

6.5 CONCLUSION

The secondary industries benefit stream has the potential to play an increasingly important part in the overall benefit derived from Working for Water projects. The model presented here lays a solid foundation for the estimation of secondary industry benefits based on existing knowledge. However, it needs to borne in mind that estimates remain broad at this stage. Only once more experience is gained in the establishment of secondary industries and more research is undertaken in the field will it become possible to improve estimates.

7. COST-BENEFIT ANALYSIS COMPONENT

Dawie Mullins & Jane Turpie

The relative merits of alternative potential catchment clearing projects can be assessed on the basis of a comparison the net benefits of each project, given as the Net Present Value of the project over a set period of time, or of other economic indicators such as the Benefit-Cost Ratio and the Internal Rate of Return over a set period. In both cases, the costs and benefits associated with a particular catchment clearing project are aggregated, albeit in slightly different ways. The costs and benefits considered in the model include:

- the costs of management (clearing, fire and soil protection)
- the costs and benefits of the full potential use of natural vegetation
- the costs and benefits of the utilisation of water supplied by the catchment, and
- the social benefits of clearing programmes

7.1 NET PRESENT VALUE AND THE DISCOUNT RATE

The net present value of the clearing programme is considered to be the difference between the net benefits of the catchment without clearing and with clearing. These costs and benefits are compared over a set time span and at a defined discount rate. The net present value of one clearing project can then be compared with that of potential alternative projects. Note that, whereas the overall net benefit is the difference in the net benefits yielded by the catchment in the two alternative scenarios: with clearing and without clearing, there are also a range of possible clearing options that lie in-between the two extremes.

Defining time spans is often contentious in ecological-economic models, because most ecological models run over long time periods, while economic models are generally concerned with values accruing within 20 years. The model runs over a 100 year period, although the length of time over which net benefits are assessed is dependent on the discount rate used. The analysis is thus performed over five different time periods ranging from 10 years to 100 years.

The discount rate is a measure of the relative worth of values accruing in the future versus the present. If it is far more important to receive benefits in the present than in the future, then the discount rate is high. This is usually the case for private individuals, especially when the future is uncertain. Society in general, on the other hand, places slightly more value in the future, as it is concerned with the wellbeing of future generations. Analysis of government programmes such as Working for Water therefore have to take a society perspective, and hence apply a relatively low discount rate. Some might argue that no discount rate should be applied at all when analysing societal issues, and some might go even further to argue that environmental values in the future are more valuable than in the present, hence subject to a negative discount rate. Because discount rates are not fixed, and vary according to philosophy, it is necessary to present results in terms of a range of values. We thus examine results in terms of three discount rates as follows:

1. 'Private' discount rate: **8%** = real rate of interest, future values much less important than present values. This is the official (2001) discount rate.
2. 'Social' discount rate: **3%** = future values only slightly less important than present values, ie are given more weight than the above case.
3. No discounting: **0%** = ambivalent between values in present or future

Discounting is used to represent a stream of values over time as one net present value. With a discount rate of zero, this is equal to the sum of values over time, whereas with a positive discount rate, the net present value is less than the sum of undiscounted values.

7.2 BENEFIT-COST RATIO

The Benefit-Cost Ratio is the ratio of the present value of the benefits relative to the present value of the costs. A project will only be considered for funding if the Benefit-Cost Ratio is greater than 1.

7.3 INTERNAL RATE OF RETURN

The model also calculates IRR as a measure of the return on the investment made to clear the catchment. Again the result is presented in terms of five different time frames, ranging from 10 years to 100 years. The Internal Rate of Return in the discount rate at which the present values of costs and benefits are equal. Only projects with an internal rate of return higher than the discount rate, which forms the lower limit, will be considered for funding. Obviously this cut-off is highly dependent on the size of the discount rate, and usually a higher, or 'private' discount rate' of around 8-10% is the cut-off.

8. REFERENCES

ABELSON, PW: 1979. Cost Benefit Analysis and environmental problems. Famborough, Saxon House

ABELSON, PW: 1996. Project appraisal and valuation of the environment. General principles and case studies in developing countries. MacMillan Press, New York

ADATO, M, HADDAD, L, HORNER, D, RAVJEE, N, HAYWOOD, R: 1999: From Works to Public Works: The performance of labour-intensive public works in Western Cape Province, South Africa. International Food Policy Research Institute, Washington DC, Southern Africa Labour and Development Research Unit, University of Cape Town

ANKER, R, KHAN, M AND GUPTA, R. 1988. Women's participation in the labour force. International Labour Office. Geneva

BOOKER, JF AND RA YOUNG. 1994. Modeling Intrastate and Interstate Markets for Colorado River Water Resources. *Journal of Environmental Economics and Management* 26: 66-87

BOOKER, JF. 1990. *Economic Allocation of Colorado River Water: Integrating Quantity, Quality, and Instream Use Values*. Unpublished PhD dissertation, Department of Agricultural and Resource Economics, Colorado State University.

BROWN, C.A. & FOWLER, J.L. 2000. *Preliminary assessment of the Breede River Basin*. Draft report, Southern Waters Ecological Research and Consulting.

CLARK, D: 2001. Development ethics: a research agenda. Soas Working Paper, No 110. University of London

CONRADIE, B.I. Forthcoming. *The Value of Water in the Fish-Sundays Scheme of South Africa.* Report to the Water Research Commission, Pretoria.

DEMERY, L, SQUIRE, L: 1996. Macroeconomic adjustment and poverty in Africa: an emerging picture. The World Bank Observer, vol. 11, no 1 (February 1996), pp 39 –59

EUSTON-BROWN, D. 2000. *The influence of vegetation type and fire severity on catchment stability after fire: a case study from the Cape Peninsula, South Africa*. MSc project.

GARDNER, RL AND RA YOUNG. 1988. Assessing strategies for conrol of irrigation-induced salinity in the upper Colorado River basin. *American Journal of Agricultural Economics* 70: 37-49.

GIBBONS, D. 1986. *The Economic Value of Water*. Resources for the Future, Washington, DC. John Hopkins University Press.

GROSSMAN, JB, 1994. Evaluating Social Policies: Principles and US Experience. In World Bank Research Observer, 9 (2): 159-80

HECKMAN, J . 1997. Instrumental variables. A study of implicit behavioural assumptions used in making program evaluations. In Journal of Human Resources, 32 (3): 441-461

HIGGINS, S.I., TURPIE, J.K., COSTANZA, R., COWLING, R.M., LE MAITRE, D.C., MARAIS, C. & MIDGLEY, G. 1997. An ecological economic simulation model of mountain fynbos ecosystems: dynamics, valuation and management. *Ecological Economics* **22**: 155-169.

HOWE,CW. 1985. Economic, legal and Hydrologic Dimensions of Potential Interstate Water Markets. *American Journal of Agricultural Economics* 67: 1226-1230.

LOUW, DB AND HD VAN SCHALKWYK. 1997. The true value of irrigation water in the Olifants River basin: Western Cape. *Agrekon* 36(4):551-560

MALLAWAARACHCHI, T AND N HALL AND B PHILLIPS. 1992. Investment in Water Saving Technology on Horticultural Farms. *Review of Marketing and Agricultural Economics* 62(2): 191-204.

MANSKI, C AND GARFINKEL, I (eds), 1992. Evaluating welfare and training programmes. Cambridge, Mass: Harvard University Press

MARAIS, C., 1998 An Economic Evaluation of Invasive Alien Plant Control Programmes in the Mountain Catchment Areas of the Western Cape Province, South Africa. Dissertation Presented for the Degree of Doctor of Philosophy in the Faculty of Forestry University of Stellenbosch.

MICHELSEN, A.M. AND R.A. YOUNG. 1993. Optioning agricultural water rights for urban water supplied during drought. *American Journal of Agricultural Economics* 75 (November 1993): 1010-1020

NIEUWOUDT, WL, JB BULLOCK AND GA MATHIA. 1976. An economic evaluation of alternative peanut policies. *American Journal of Agricultural Economics* 58: 485-495.

PEARCE, D: The Social Appraisal of projects: a text in cost-benefit analysis

RAVALLION, M. 1999. Evaluating interventions. The mystery of the vanishing benefits: an introduction to impact evaluation. World Bank. Washington, D.C

RAVALLION, M: 2000. Poverty Comparisons: A guide to concepts and Methods. LSMS Working Paper No 88. World Bank. Washington, D.C.

SAMPATH, RK. 1992. Issues in Irrigation Pricing in Developing Countries. *World Development* 20(7): 967-977

SEN, A: 1994. Liberty and Poverty

SQUIRE, L: 1975. Economic analysis of projects. John Hopkins University Press for the World Bank

TAYLOR, RG AND RA YOUNG. 1995. Rural-to-Urban Transfers: Measuring Direct Foregone Benefits of irrigation Water under Uncertain Water Supplies. *Journal of Agricultural and Resource Economics* 20(2): 247-262

TURNER, B AND GM PERRY. 1997. Agriculture to Instream Water Transfers under Uncertain Water Availability: A Case Study of the Deschutes River, Oregon. *Journal of Agriculture and Resource Economics* 22(2): 208-221.

TURPIE, J.K. & HEYDENRYCH, B.H. 2000. Economic consequences of alien infestation of the Cape Floral Kingdom's Fynbos vegetation. pp 152-182 in Perrings, C., Williamson, M. & Dalmazzone, S. (eds) *The economics of biological invasions*. Cheltenham, U.K.: Edward Elgar. pp. 214-261.

TURPIE, J.K., HEYDENRYCH, B.J. & LAMBERTH, S.J. in prep. The economic value of terrestrial and marine biodiversity in the Cape Floristic Region.

WINPENNY, JT: 1995. The economic appraisal of environment projects and policies: a practical guide