Valuing Namaqualand's Natural Resources

The costs and benefits of communal, commercial and conservation land use practices in Namaqualand incorporating ecological, economic and social values

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PREFACE

Namaqualand is a semi-arid region on the west coast of southern Africa and comprises about 50 000 km^2. It is a region of extraordinary biological diversity and is recognized internationally as a biodiversity hotspot. There are several small towns in Namaqualand but it is largely rural with a population that has a rich cultural heritage and a long history of livestock grazing.

About 45% of region's population live in six communal areas comprising about 25% of the area of Namaqualand. Livestock production and to a lesser extent crop production occurs in the communal areas as well as on the privately-owned farms of Namaqualand. The amount of land available to communal area farmers has expanded considerably since 1994 under South Africa's land reform programme. The relatively high stocking rates associated with communal areas have transformed large areas of Namaqualand, particularly the low-lying valley bottoms where heavy grazing, cropping and settlement occurs most frequently. Because of this there is concern that an expansion of the communal areas will impact negatively on the biodiversity of the region.

Conservation areas which comprise about 6 % of the region have also expanded since 1994 in recognition of the need to protect the region's biodiversity. Natural resources, however, are used extensively by people living in the communal areas of Namaqualand. The expansion of conservation areas and the exclusion of people from large parts of Namaqualand, therefore, also have significant implications for people's livelihoods. What is not known, however, is the relative costs and benefits of each land use practice.

This report contains the findings of a resource economics workshop held in Kamieskroon, Namaqualand from 22-29 April 2002. The workshop addressed some of the issues outlined above. It was organised by the Leslie Hill Institute for Plant Conservation, University of Cape Town and the Terrestrial Ecology Research Unit, Nelson Mandela Metropolitan University and funded in part by the Global Environment Facility (GEF), (administered via the South African National Parks) and Conservation International through its Succulent Karoo Ecosystem Programme (SKEP).

The vision for the workshop as contained in the project proposal was for the development of explicit models that can demonstrate the costs and benefits of different forms of land use in Namaqualand and that explicitly incorporate ecological, economic and social values.

Two major outcomes were envisaged:

1. A series of scientific papers published in a special issue of a technical specialist journal (e.g. *Ecological Economics*) detailing the outcomes of specialist working group analyses and the integrated modeling approach;
2. A popular, easily read document summarizing the key findings of the workshop which will be disseminated to all interested and affected parties working in Namaqualand.

Twenty three people, comprising both international and national participants attended the workshop and are acknowledged in the author list on the cover page. What follows is a summary of the key findings of the workshop. It is anticipated that each report will be published separately in due course.

We would like to thank all those whose work in Namaqualand has contributed toward this study. Our appreciation is also extended to the Mazda Wildlife Vehicle fund for the use of a courtesy vehicle. Much of this report is based on data from the MAPOSDA research project funded by the European Commission under INCO-DC: International Cooperation with Development Countries (2000-2004), Contract No. ERBIC18CT970162. However, the European Commission does not accept responsibility for any information provided or views expressed. BIOTA South is also acknowledged for the significant contributions they have made to this study and to research in Namaqualand in general.

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EXECUTIVE SUMMARY

BACKGROUND

- Namaqualand is a region of extraordinary biological diversity and is home to a large number of rural people with a rich cultural heritage. Both conservation and communally managed areas have expanded significantly since 1994, largely at the expense of privately-owned, commercial farms.

- Because of the fundamentally different ways in which natural resources are used in communal, commercial and conservation areas, changing tenure regimes have important implications for people's livelihoods as well as for the biodiversity of the region. In order to make informed decisions, policy makers, planners and politicians need to know what the relative value and potential long-term impacts are for each approach.

- To inform this debate the cost and benefits of communal, commercial and conservation land use practices were evaluated in a workshop held in Kamieskroon from 22-29 April 2002. This document details the findings of this workshop and is divided into a popular synthesis and four separate reports.

- The popular synthesis summarises the main findings from the workshop while the first report details the costs and benefits for a communal area in Namaqualand. The second report outlines the recreational value of the Namaqua National Park and in terms of its contribution to the region. The third report explores the value and sustainability of the three land use practices for the region (communal, commercial, conservation) . It is based on an integrative model developed at the workshop. The final section investigates the outcome of four different scenarios for the communal areas of Namaqualand under three different management systems.

REPORT 1: Valuing the natural resources in a semi-arid communal area in Namaqualand, South Africa.

- The resource use production system in Paulshoek, a 20 000 ha communal rangeland in the semi-arid northwestern region of South Africa, was investigated.
- Plant resource use and livestock farming as carried out by the approximately 800 inhabitants of the village were valued using the household income approach (HIA) and the natural habitat value (NHV) methods. HIA estimates the household income generated through the use of a "free" natural resource and is therefore an estimate of the contribution the natural resource makes toward sustaining rural livelihoods while NHV places a value on the "free" resource itself.

- Crop production, livestock (sheep and goats) production and medicinal plant and firewood use were valued. In addition, the contribution made to this value by domestic and feral donkeys was also assessed.
- Total annual values for the area were $29178 and $23443 for the HIA and NHV methods respectively (where, according to 2001 monetary exchange rates, $US1 = R10).
- The most important contributors to this value were firewood use ($17867 for both methods), livestock production ($11813 (HIA) and $6728 (NHV)) and medicinal plant use ($3360 for both methods). Crop production ($195 (HIA) and -$580 (NHV)) and domestic donkeys ($451 (HIA) and $576 (NHV)) contribute little to the village economy while feral donkeys are a net drain on the economy consuming grazing to the value of $4508 per annum (both methods).
- Per ha values of $1.46 and $1.18 for the HIA and NHV evaluation methods are significantly lower than those obtained for other more productive, higher rainfall ecosystems which are frequently 10 to 50 times higher.
- However, the annual per household values of $390 and $225 for the HIA and NHV methods respectively are similar to those obtained for savanna woodlands in southern Africa largely because of the significantly lower population density in Paulshoek.
- This study supports the view that when valued appropriately, communal area natural resource based production systems are as productive as neighbouring private farm production systems. However, the latter generate cash while communal area values are a combination of cash and transfer values generated through bartering, gifts, and other non-cash transactions. Such transfer values are often not as easily realised outside of the communal areas.

REPORT 2: The value of flower tourism at the Namaqua National Park, South Africa.

- In this study, a model was developed which used the travel cost method (TCM) to estimate the recreational value of flower viewing at the Namaqua National Park (NNP), a 70 000 ha conservation area near Kamieskroon, Namaqualand.
- An extensive discussion of the theoretical assumptions of the TCM is presented and the difficulties of valuing visits to a recreational area are outlined. Several variants of the TCM are discussed and reasons for choosing the zonal TCM are explained. The formula for calculating the consumer surplus (CS) is presented. This represents the value of the recreational experience to visitors, which is used as a proxy measure of the site's value.
- Baseline data for the model were collected from people who visited the NNP during the 2002 flower season. Statistics indicate that 87% of the 9 707 visitors to the NNP were South African nationals. While as many as 14% of these visitors arrived at the park by bus, the remainder travelled in their own car. Detailed demographic, time, expenditure,

site preference ranking and route information was collected from interviews with 160 SA nationals who visited the NNP in their own car.

- The average age of people in this group was 56 years; 95% were white and 60% were Afrikaans-speaking. More than 90% of visitors lived in the urban centres of South Africa with 45% travelling from Gauteng and 23% from Cape Town. They were relatively wealthy with an average annual income above $US17 800 (where $US1=R10).
- Flower viewing was the main reason for being in Namaqualand for nearly 99% of those interviewed. On average, 3.6 sites are visited during a trip to the region. More than 70% of the respondents were visiting the park for the first time and less than 1% visited the park more than once a year. People travelled an average round trip distance of 1 844 km, and although 95% spent less than 5 hours in the park itself, they spent an average of 4.7 days in the region. Visitors to the park spent an average of $US108 on transportation and $US84 on accommodation in the region.
- The influence of rainfall on visitor number was analysed from data from the Goegap Nature Reserve for the period 1995-2001. Nearly 80% of the variance could be explained by a regression model which suggested that an increase of 1 mm of rainfall in winter will result in an increase of nearly 17 visitors two months later. There are also strong seasonal rainfall effects.
- A detailed description of the parameterisation of the zonal travel cost model (TCM) as well as an alternative 'willingness to pay' (WTP) model is presented. The outcome of both approaches suggests that the recreational value of flower viewing at the NNP is far larger than the annual net loss of $US50 000 suffered by the park makes when only the expenses of the park and revenue of the gate takings are considered. Reasonable estimates of the value of the NNP to the region range from $US282 506 and $US548 593 (roughly R2.8 to R5.5 million) per annum.
- However, this range in values is an underestimate since the contribution of foreign tourists and local bus visitors have been ignored in the analysis as have the park's contributions to the local economy and social services of Namaqualand. The most important finding of this study, however, is that even a fraction of the parks value (the recreational value) to the broader Namaqualand region is greater than the cost of running the park.

REPORT 3: The sustainability and valuation of three land use production sectors in Namaqualand, South Africa.

- Namaqualand is a region of high biodiversity and forms the focus of an internationally led conservation initiative to protect more of the region from the impacts of private and communal land use practices. However, little is known of the value and long-term sustainability of each of these sectors in the region.
- Using a model developed initially in a collaborative workshop, this article firstly describes the model in detail and provides equations for each of the six sub-models developed. Next, the general model is used to investigate the change in primary and

secondary production over thirty years and the per ha and Net Present Value (NPV) for the three sectors (communal lands, privately-owned land, conservation) in the Upland Succulent Karoo region of Namaqualand.

- Results indicate that when recommended stocking rates are adhered to, as in private farming systems, edible plant production and animal quantity and quality are sustained over 30 years.
- Communal area farmers, however, generally stock at twice the recommended rate. Results indicate that while edible plant production and animal production and quality are significantly lower than in private farming areas, they do not continue to decline appreciably over time. Because of the poor forage quality, however, communal farmers are much more likely to suffer from drought and post-drought cold weather, than is the case for private farmers.
- Since the conservation areas in Namaqualand have no domestic livestock they show the highest levels of edible plant production over time.
- Per ha values were broadly comparable for communal and private farming areas at around \$1.5 $ha^{-1}.yr^{-1}$. Profit (defined as revenue less running costs) for the conservation sector was always negative. However, if external funding and the wider contribution of visitors to the regional economy were considered, then the conservation sector showed the highest values at around \$1-\$11 $ha^{-1}.yr^{-1}$.
- The problem of comparing values across different sectors is raised, particularly since cash values are not the same as bartered or other non-cash transactions. Each sector values its transactions differently and it is not always possible to compare across sectors as different as those examined in this report.

REPORT 4: The effect of three livestock management strategies within four planning scenarios on plant, animal and economic indicators in a communal area of Namaqualand.

- What is the most effective livestock management strategy for Namaqualand's changing environmental, political and economic landscape? This article compares the ecological, agricultural and economic sustainability over 30 years of three management strategies (tracking strategy (TS); conservative strategy (CS); opportunistic strategy (OS)) under four scenarios for the region. The scenarios include (1) maintaining the status quo on the communal rangelands; (2) increasing livestock by 20% (3) decreasing livestock by 20% and (4) a climate change scenario which decreases rainfall by 20% and increases the variability of rainfall by 25%.
- The same model that was described in Report 3 was used to assess the change in biomass production ($kgDM.ha^{-1}.yr^{-1}$), the number of adult animals and the Net Present Value ((NPV) for the three management strategies under the four scenarios.
- Biomass production increased from 200 to 500 $kgDM.ha^{-1}.yr^{-1}$ over 30 years under CS for the first three scenarios while it declined slightly under both TS and OS. There is, however, no evidence of ecological collapse in the latter two management approaches

for the status quo, increasing livestock and decreasing livestock scenarios. All management approaches showed a significant reduction in vegetation biomass under the climate change scenario.

- Following the initial decline, animal numbers remained constant at recommend stocking rates under CS for the first three scenarios. Animal numbers declined slightly for both TS and OS under the status quo conditions in response to the declining production of vegetation biomass. The initial once-off increase or decrease in animal numbers in scenarios (2) and (3) did not last for more than a decade for TS and OS management strategies. Animal numbers returned to values similar to those for the status quo scenario after about 10 years. This suggests that investment in livestock by retrenched mineworkers will not be sustained over the long term and neither will any intervention aimed a one-off reduction in livestock numbers on the communal lands. Under the climate change scenario, animal numbers declined over 30 years, for all strategies even CS. This highlights the potential devastation of declining rainfall amounts for Namaqualand.
- NPVs were all positive for all scenarios and either increased or were stable suggesting that all management systems were economically feasible over the 30 year period even OS. They were highest for CS under all scenarios followed by TS and OS. If capital savings were also considered in the economic valuation, however, TS would be the best approach to adopt since the large herd sizes possible under this strategy provide considerable capital savings for farmers. Under TS mortality rates are also relatively low and fecundity and offtake rates are relatively high resulting in a reasonable income for livestock owners.

Valuing our heritage - The costs and benefits of communal, commercial and conservation land use practices in Namaqualand.

BACKGROUND

There are few environments in the world that can boast either the rich cultural heritage or the internationally-recognised biological diversity that is found in Namaqualand. This desert region of about 50 000 km^2 comprises a patchwork of land use practices (mining, cropping, grazing, conservation) that have changed considerably over the centuries in response to social, economic and political influences.

The last decade has been as changeable as any in the last 350 years. Since 1994 a substantial amount of land has been transferred to previously-marginalised farmers from the six main communal areas in the region. There has also been a significant expansion of the conservation areas as a more complete understanding of the biodiversity of Namaqualand and potential threats to it is developed. But which land use practice should be encouraged by government and by people living in the region and what criteria should be used to support the expansion of one practice over another? What will happen, for example, to the region's economy if significantly more land is purchased for the expansion of conservation areas and livestock production on privately-held farms declines? Does it make more sense, both socially and economically to expand the communal lands at the expense of other forms of land use?

Understanding the regional impact of different land use practices is important for administrators, planners, politicians and for the growth of the regional economy. However, in deciding on which land use to support in a particular area a number of factors need to be considered. One such factor is the economic value of each land use practice. Knowledge of the economic value of communal areas, privately-held farms and conservation areas would help decide which land use practice (or combination of land use practices) to support in the region. In addition, if one knew the costs and benefits of each it might also place limits on the expansion of one practice over another.

FINDINGS OF THE MODEL

With this in mind a mixed group of economists, ecologists, social scientists and conservators met to develop an ecological-economic model for the three important land use sectors in Namaqualand. These are: commercial agriculture on privately-owned farms; commercial agriculture and subsistence natural resource use on communally-managed areas; conservation activities on formally protected areas.

A number of important insights have developed from this work. Firstly, when the full range of resources that are used on communal areas are valued, then these areas may be considered as productive as neighbouring privately-owned farms. When firewood and medicinal plant use and crop and livestock production are included then an average value of about R15 per ha is recorded. However, while communal areas may be considered equivalent in value to private farms the form of this value is vastly different between the two. Most commercial farmers can use the cash they receive for the sale of sheep outside the immediate location of their farm. The value of the natural resources in communal areas, however, is often in the form of in-kind transfers which are not easily exchanged outside of the immediate vicinity of the village or settlement.

A second insight from this work is that the conservation areas contribute significantly to the regional economy of Namaqualand. Results from a survey of visitors to the Namaqua National Park indicate that the expectation of flower viewing is the chief reason for people visiting the park. Of the 9 707 visitors to the park in the spring of 2002, 87% were South Africa citizens. The typical profile of these local visitors suggests that they are in their mid-fifties, predominantly white and from the urban centres of Gauteng and Cape Town. Visitors typically only spend about five days in the region and their contribution to the local economy is conservatively estimated to be in the order of R2.8-R5.5 million rand annually. While the park itself does not generate a profit, its contribution to the local economy is important.

A third aspect to this investigation suggests that all three land use sectors are ecologically and economically sustainable over 30 years. Vegetation production is obviously greater in the conservation sector, lower on private farms and significantly lower in the communal areas. However, after an initial decline in vegetation production in the communal areas, as a result of high stock numbers, production stabilises at a lower yet more variable level in response to the erratic rainfall in the region. This obviously renders livestock production more vulnerable to the vagaries of climatic fluctuations such as drought and cold which characterise this desert.

Finally, the response of vegetation and the economy to four different scenarios under three different management strategies in the communal areas of Namaqualand was also investigated. The results suggest that retrenched mine workers who might invest in livestock will be wasting their money as higher animal numbers cannot be sustained beyond a few years on the communal areas in their current condition and under current climatic conditions. However, the results also suggest that a once-off reduction in livestock numbers will also not provide much relief for the environment as they will quickly build to current levels unless the reduction is enforced. The implications of a reduction in rainfall are also explored in the model which suggests that even a 20% decrease in annual rainfall will be devastating for all livestock production activities, whether on communal land or on privately-owned farms in the region.

CONCLUSIONS

The models developed within this programme set out to explore the differences in economic value between three widespread and competing land use options in Namaqualand. Initially it was thought that by developing the correct economic models with the best data available it would be possible to advise planners and policy makers on economically-justified land use options for the region. Useful models were developed and broad figures for the economic value of the three land use options were determined. However, this is the easy part. For example, in terms of a per ha value, private farming and resource use in communal areas is broadly similar at around R15 per ha. But is this a fair comparison? In addition, the value of the conservation sector is either significantly lower that the other two options and always negative, or nearly ten times higher depending on whether external cash injections from donors and conservation agencies are considered and whether the full benefit of the site to the local economy is considered. The real challenge, therefore, lies not in deriving an economic value for a particular land use option but in deciding on the real value of in-kind services and exchange networks that are common in so many of the communal areas of rural South Africa today. This points to the need to decide on which variables to include in an economic model so that fair comparisons between different land use sectors can be made. Ultimately, value is about much more than the derivation of a simple rands and cents number.

REPORT 1

Valuing the natural resources in a semi-arid communal area in Namaqualand, South Africa.

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INTRODUCTION

In many rural areas of southern Africa, natural resources are not sold in formal markets but consumed by households directly, bartered or given away as gifts. The primary objective of many of these production processes is not the generation of profit (for example, the production of livestock for status or as a "store of wealth") and the use of formal economic methods to evaluate these systems has resulted in them being viewed as unproductive and low in value (Scoones, 1992). Resource and environmental valuation studies, on the other hand, attempt to place monetary values on all the resources rural households use in an attempt to prove that these systems are not unproductive, that they hold great value to rural households and that there is an opportunity cost associated with preventing people from using them (Scoones, 1992; Cousins, 1999; Shackleton *et al.,* 2000; Shackleton *et al.*, 2001; Cavendish, 2002). The earliest valuation studies were on tropical rainforests for which reported values were high. Peters *et al.* (1989) reported values of \$422 ha^{-1} but subsequent studies have refined valuation techniques to such an extent that a median tropical forest value of \$50 ha^{-1} has been established (Campbell *et al.,* 1997). Within Southern Africa early valuation studies examined environmental resources for which formal and informal markets existed (Cunningham, 1988, 1989a, 1989b and 1990; Shackleton, 1990; Shackleton, 1993). More recent studies have focused on valuing both market and non-market resources (Scoones, 1992; Campbell, 1993; Campbell *et al.*, 1997; Cousins, 1999; Shackleton *et al.,* 2000; Shackleton *et al.,* 2001; Cavendish, 2002; Ntshona, 2002). However, these studies were undertaken in savanna woodland regions and to date few studies have comprehensively valued ecosystem products and services from arid or semi-systems.

This study values the resources used in the semi-arid communal area of Paulshoek, Namaqualand, South Africa. Two main questions are addressed:

- What are the values of the resources used both at a household level but also for the communal area as whole?
- How do these values compare with other communal areas in savanna and forest environments and with neighbouring private farmers in the area?

STUDY AREA

Natural environment

The communal area of Paulshoek consists of a village with 138 households and 20 000 ha of rangeland. It is located in the south eastern corner of the greater Leliefontein communal reserve in Namaqualand, South Africa. Lying in the Kamiesberg mountain range (1000-1400 m above sea level) summer temperatures seldom exceed 35 °C but winter temperatures can fall below zero. The region receives an average annual rainfall of 200 mm, predominantly during winter (May – September). Ground water (boreholes, wells and springs) supplies the bulk of the water used by households and livestock farmers. However, this supply varies with the amount of rainfall received and often reaches critically low levels in the village in summer.

Topographically, more than 60% of the communal lands are steep sided hills. The remaining area is comprised of uplands (narrow valleys and convex summits) and flatter low-lying areas (less than 15% of total surface area). Paulshoek falls within the Succulent Karoo Biome. In the lower lying areas, plant communities are dominated by Succulent Karoo species while Mountain Renosterveld species dominate the upper elevations (Petersen, 2004).

Socio-economic conditions

The World Bank defines the human development of Paulshoek's population as equal to that of people in "least developed nations" (May *et al.,* 1997; Rohde *et al.,* 2003) and is typical of rural Namaqualand (Anseeuw, 2001). Paulshoek has approximately 800 inhabitants but the population fluctuates dramatically with the movement of migrant workers (predominantly men) who return to the communal area for weekends and holidays. May *et al.* (1997) found that of the permanent population, there are 30% more women than men between the ages of 15-39, 48% of the population is below 18 years of age and of the remaining population, 52% are over the age of 65. Average monthly income ranges from $84 to $228 for poor and wealthy households respectively. Government pensions and cash remittances by members of the community working outside the area contribute 61% to total village income. The remaining village income accrues from casual labour (12%), permanent labour (20%), self-employment (5%) and livestock sales (2%) (May *et al.*, 1997; Rohde *et al.* 2003).

METHODS

Inaccurate methodological descriptions and the lack of a standard approach to valuation exercises (allowing for cross study comparability) have hampered the advancement of the discipline (Cousins, 1999; Wollenberg, 2000; Shackleton *et al.,* 2000; Shackleton *et al.,* 2001; Campbell and Luckert, 2002). This study provides detailed descriptions of valuation techniques and follows the general approach outlined by Campbell and Luckert (2002).

Calculating resource values

When rural natural resource based production systems are valued there are two related values that can be calculated. These are the household income approach (HIA) and the natural habitat value (NHV). HIA estimates the household income generated through the use of a "free" natural resource and is therefore an estimate of the contribution the natural resource makes toward sustaining rural livelihoods while NHV places a value on the "free" resource itself (Cavendish, 2002). Both values are estimated from revenue less cost calculations, with revenue and costs calculated as:

- Product revenue = quantity produced * replacement price;
- Labour costs = hourly or daily wage * time spent working;
- Capital costs = initial capital investment depreciated over time to obtain an annual rental value;
- Materials cost = price per unit * the quantity of units used.

Communal area production systems in the region differ from conventional production systems in that natural resources are generally free, capital costs are relatively small since access to capital is limited. In addition, labour is usually the only significant input and the cost of labour is significantly reduced as most of the labour used stems from the household (Gittenger, 1982; Campbell, 1993; Dasgupta, 1996; Shackleton *et al.,* 2000; Campbell and Luckert, 2002). The distinction between the NHV and HIA methods is that the NHV subtracts household labour and capital input costs from total revenue while the HIA does not.

Price data

Underlying all economic analyses is the assumption that prices reflect value, or can be adjusted to do so. Buyers engage in transactions as long as their subjective value (utility) of a good is more than the price charged and stop when it is not. Where transactions produce third party effects the market price may deviate from the marginal social value of the good (Gittenger, 1982; Chopra, 1993; Campbell *et al.,* 1997; Campbell *et al.,* 2002). Notwithstanding the externality problem, market prices are still the most acceptable method and are used where available. When no market price for the final product exists the market price of a substitute good is used. While it is difficult to argue substitutability in certain cases, replacement values still provide an estimate value when no other values can be derived (Boxall and Beckley, 2002). Furthermore, farm gate prices (the market price less transportation and processing costs) are considered a better estimate of a goods use value than the price the good is traded for at the market (Gittenger, 1982). Thus, where available, farm gate prices have been used and when appropriate, market prices have been converted to farm gate prices. This is done by subtracting transportation costs from the market price when households act as sellers and adding the transportation costs when households act as buyers. However, it cannot be assumed that ever year households will consistently buy or sell a specific good at a specific formal market. Farm gate prices were therefore only calculated in those instances where it was proven that households behaved in a constant manner over time. The price of labour is the most significant factor affecting the value of production. Determining the value of labour is problematic as much of it stems from the household and even when it does not, payment most often involves non-monetary exchange (gifts, bartering, and sharecropping). This paper uses the methods prescribed by Shackleton (1990), Scoones (1992), Campbell (1993), Campbell *et al.* (1997), Shackleton *et al.* (2000), Wollenberg 2000 and Cavendish (2002) and uses the local daily wage rate as a proxy for the price of labour.

Resource use data

Resource use patterns in Paulshoek are well documented. Detailed descriptions of the harvesting of medicinal plants (Archer, 1994; May *et al.*, 1997 and Goldberg, 1998), firewood collection (Archer, 1994; Solomon, 2000), the use of donkeys (Vetter, 1996) and construction materials (Evans, 2001), and crop and livestock production (May *et al*., 1997; Rohde *et al.* 2003) are available as theses, reports and unpublished long-term data sets. Where necessary interviews were used to supplement the resource descriptions in these sources.

Calculating household income statements

To avoid double counting the benefit that households derive from the commons, environmental products were placed into use categories. These include: sold and consumed own-collected, harvested or produced environmental goods; own-collected environmental goods that are used as inputs into other household production processes and environmental goods purchased from other members of the community (Cavendish, 2002). Consumed and sold products are credited to the respective households' balance sheet but purchased products are credited to the seller and debited to the buyer. Environmental products used as inputs are treated differently for the NHV and HIA methods. With the former method inputs are treated as separate production processes and their value is therefore subtracted from the value of the final product. Each resource is therefore credited with its own value. The HIA method ignores the intermediate product's revenue as this benefit is captured in the value of the final product but it treats the costs of the intermediate products production as a cost to the production of the final good. All values are reported in 2000 $US ($US=R10) and rounded to the nearest dollar.

RESULTS

Crop production

Agricultural production in Paulshoek occurs in the form of cereal production, primarily for animal fodder. Wheat, barley, oats and rye are grown in 19 distinct croplands or fields consisting of 33 production units that are each approximately 3 ha in size. Access to croplands is restricted by a common practice whereby a piece of land is allocated to an individual who retains the rights to the cropland as long as the annual rental of $19 is paid. There seems to be no scarcity of available land as most fields have been lying fallow for many years and new lessees have recently been able to secure croplands. This study values the crop production for the year 1999 when six of a total of 28 farmers sowed 288, 70, 35 and 20 kg of oats, wheat, rye and barley respectively. At the low sowing densities prevalent in the area (50 $kg.ha^{-1}$) this converts to 8.25 ha of land sowed. A total yield of 6040 kg (0.73 $tonnes.ha^{-1}$) was reported with oats, wheat, rye and barley contributing 4350 kg (0.76 $tonnes.ha^{-1}$), 1000 kg (0.71 tonnes.ha^{-1}), 360 kg (0.51 tonnes.ha^{-1}) and 330 kg (0.83 tonnes.ha^{-1}) respectively. There is very little selling of produce. Local or farm gate prices vary substantially and farmers often quote commercial prices even when they have no intention of selling to the mills. Thus, transport costs are not removed from the market price of \$0.12 kg^{-1}, \$0.16 kg^{-1}, \$0.115 kg^{-1} and \$0.13 kg^{-1} for oats, wheat, rye and barley respectively and gross income was estimated at \$766.

All grains are grown in the same way. Farmers keep their own seed, use mostly donkeys for ploughing (although tractors are used on occasion) and harvest the grain with sickles before threshing it on traditional threshing floors. Fertiliser and pesticides are not used but seeds are treated with sulphur. Crop production costs excluding labour were calculated as:

- sulphur seed treatment: \$1.6 per 50 kg bag of seed * 8.25 bags;
- maintenance of equipment: \$15 per farmer * 6 farmers;
- fodder for donkeys: \$7.5 per kg * 8. 25 ha;
- donkey draught power: number of ha ploughed * \$4.5 (which is the per ha replacement value);
- plot rental: \$18.85 per plot * 6 plots.

Total out of pocket expenses for crop production in Paulshoek and Leliefontein range from \$52 to \$59 per bag of seed sown. Of this, total cash wages contribute \$32 –\$39 per bag. The daily wage rate is \$2. 50 and the total labour requirement is 50 days per hectare to clear the land, sow seed, plough, harvest, thresh and store crops. This implies that family labour contributes 35.8 days per bag or per ha. Labour costs were therefore estimated as:

- cash wage: \$35.5 per ha * 8.25 ha;
- family labour: \$2.5 per day * 35.8 days * 8.25 ha.

Table 1.1 summarises the household benefits from crop production. Under the HIA method crop production is profitable. However, when the cost of family labour is included (NHV) crop production incurs a net household loss of \$97. Crop production is an input, hence for the HIA household balance sheet the costs are subtracted from the value of the livestock production process and the gross income is ignored. For the NHV method the net loss is subtracted from the final value of the livestock production process to avoid double counting. Land rental for those 24 farmers who did not sow crops in 1999 is treated as a cost of livestock production for both methods.

Table 1.1. Revenue and costs (in $US) of crop production for six households who sowed during 1999 in Paulshoek using the household income approach (HIA) and natural habitat value (NHV) methods. A further 24 farmers had to pay an annual tax to lease the land although they did not sow any crops during 1999 and for them the cost of keeping crop production as an option has been calculated.

Item	HIA	NHV
<u>Revenue for different crops</u>		
Oats	522	522
Wheat	160	160
Rye	41	41
Barley	43	43
TOTAL REVENUE	766	766
<u>Costs of crop production</u>		
Seed treatment	13	13
Maintenance	90	90
Donkey feed	62	62
Donkey draught power	-	37
Land rental	113	113
Cash wages	293	293
Family labour	-	738
TOTAL COST	571	1 346
PROFIT	195	(580)
Per household	33	(97)
Per hectare of Paulshoek	0.01	(0.03)
<u>Cost of maintaining the option to produce crops</u>		
Land rental	(452)	(452)
Per household	(19)	(199)
Per hectare of Paulshoek	(0.02)	(0.02)

Livestock production

Unlike private farmers who produce livestock with the single production objective of maximising meat production for sale, communal farmers have multiple production objectives (Tapson, 1990; Scoones, 1992; Cousins, 1999; Shackleton *et al.*, 2000). In Paulshoek, farmers produce livestock as a store of wealth from which funds can be appropriated during times of need and for the consumption and selling of meat, milk and hides (Rohde *et al.* 2003). A total of 28 herds owned by people from 72 households are run on the commons although 50% of the households in Paulshoek own 94% of the animals (May *et al.*, 1995). This paper examines the livestock production system in Paulshoek from August 1999 to July 2000. Flocks consist of a mixture of Boer goats and indigenous sheep crossbred with commercial breeds. Herd size varied over this period between 13 and 173 small stock units (SSU) with a mean herd size of 82 SSU. The total number of sheep and goats in 1999 were 828 and 1839 respectively, or 950 and 2302 SSU respectively (Meissner, 1982). These totals represent a stocking rate that is roughly 2.5 times the carrying capacity recommended by the Department of Agriculture (Hoffman *et al.*, 1999; Todd and Hoffman, 2000). Herds are based at 28 stock posts located around the communal rangeland. Each stock post generally contains one herd and herder and consists of a sleeping shelter, cooking shelter and makeshift kraal (corral).

Revenue from sheep and goat farming accrues from local sales, market sales, own consumption (including animals dying naturally) and milk production. Local sales, market sales and home consumption are all valued using an average, on the hoof, market price and ignoring transport costs. Animals that died were valued at 50% of the average home consumption price (Campbell *et. al.*, 2000)**.** Reproductive rates in 1999/2000 were low compared with commercial benchmarks. Goats and sheep had a weaning rate of 60% and 50% respectively. Table 1.2 shows the off take, deaths, prices and revenue from goats and sheep for the 1999/2000-production year. In terms of total off take of goats home consumption contributed 37%. This was followed by losses due to death (26%), market sales (21%) and local sales (15%). Goat ewes contributed the most to off take. Goat kids contributed 50% to the total number of goat deaths recorded over the period of study. Goats are also a source of milk. Households consumed 6165 litres of goats milk at the per litre price of $0. 15. For sheep, deaths contributed the most to off take (65%) followed by local sales (13%), market sales (10%) and home consumption (10%). Again, ewes contributed significantly toward total off take. However, many lambs were also sold, eaten locally or died.

Livestock farmers in Paulshoek have relatively low but significant input costs associated with fodder provision, veterinary costs, shelter construction, labour and land rental costs. The cost of providing fodder has already been outlined in Table 1.1 and is used for the HIA. For the NHV method, total crop value is used.

Veterinary costs include the dipping of animals against ticks, dosing against internal parasites and vaccinating against pulpy kidney amongst other diseases. Between August 1999 and July 2000, 38 animals were dipped (at a unit cost of $0.042 per animal), 629 animals were dosed ($0.026 per animal) and 3515 animals were inoculated ($0.144 per animal).

Table 1.2. Off take (number of animals), prices and income (both in $US) for goats and sheep in different age and gender classes in Paulshoek for the period August 1999 to July 2000.

Stock type	Market sales		Local sales		Home consumption		Death losses	
	Goats	Sheep	Goats	Sheep	Goats	Sheep	Goats	Sheep
<u>Off take</u>								
Kids/Lambs	14	16	6	4	7	16	78	94
Yearlings	4	7	12	5	12	7	32	34
Ewes	93	15	59	44	156	15	44	145
Castrates	11	5	11	3	43	5	3	2
Rams	4	1	4	1	2	1	0	3
TOTAL	126	44	92	57	220	44	157	278
<u>Price</u>								
Kids/Lambs	10	10	7	8	7	8	4	4
Yearlings	15	18	10	10	10	10	5	5
Ewes	25	25	22	24	22	24	11	12
Castrates	23	25	20	20	20	20	10	10
Rams	30	35	25	25	25	25	13	13
<u>Income</u>								
Kids/Lambs	140	160	42	32	49	128	273	376
Yearlings	60	123	120	50	120	70	160	170
Ewes	2325	375	1298	1034	3432	353	484	1704
Castrates	248	125	220	60	860	100	30	20
Rams	120	35	100	25	50	25	0	38
TOTAL	2893	818	1780	1201	4511	676	947	2308

Cooking shelters are an important form of shelter at stockposts. They are circular in shape and constructed by packing bushes one on top of another within a wooden framework. Cooking shelters last as long as buildings provided they are maintained annually by adding more shrubs to compensate for weathering and decay. There are three types of cooking shelter used at the 28 stock posts: those with a full roof (n=12), those with half a roof (n=10) and those without a roof (n=6) (Evans, 2000). Households in the village have separate cooking shelters outside their homes. These are generally constructed from corrugated iron sheets and purchased creosote poles. Hence, the replacement cost of a cooking shelter was estimated as the value of a corrugated iron sheet and creosote pole structure with an identical volume. The average volume each type of cooking shelter provided was estimated from Evans (2000) and the cost of a replacement structure with the same volume was estimated. Final values were depreciated linearly over 25 years to obtain an annual value (Van Zyl, 1988). The total annual replacement cost of the cooking shelters at the 28 stock posts in Paulshoek was $248 calculated as follows:

- full roof: 12 shelters * $10. 30 (annual replacement cost) = $124;
- half roof: 10 shelters * $8. 20(annual replacement cost) = $82;
- full roof: 6 shelters * $7. 00(annual replacement cost) = $42;

Sleeping shelters are made from corrugated iron sheets and creosote poles and are located adjacent to the cooking shelters. The annual replacement value of a full roof cooking shelter was used as the replacement value of a sleeping shelter which amounted to a total value of $288 for the 28 stock posts. Maintenance costs were ignored as shepherds maintain the shelters as part of their herding duties. Sleeping and cooking shelter costs are capital costs and are therefore ignored by the HIA but included for the NHV method.

According to Anseeuw (2001) a third of the herders earn a cash wage of $300 per year. The remaining herders (19) are paid through a non-cash social transfer system which we have valued at the cash wage of $300 per year. This social transfer is a form of family labour and is not included in the estimate of HIA.

Table 1.3 summarises the value of livestock production in Paulshoek. Two-thirds of the income is from goats and one third from sheep, which is proportional to the average stock numbers (1588 goats and 768 sheep) for the season. Goats contributed a further $925 per year through milk production. For both the HIA and NHV methods total profits were positive but the lower NHV value indicates how important social arrangements and family labour are to rural resource production systems.

Donkeys

There are approximately 175 feral and 50 domestic donkeys in Paulshoek. Households use domestic donkey carts to provide transport to neighbouring towns and to collect firewood. Four households use donkeys to provide transport. The average monthly trip distance is 60 km and would cost $9.60 ($0.16 per km) if a vehicle and driver were hired. Three households use donkeys to collect firewood. Two trips with an average distance of 10 km are made monthly and are valued using the $0.16 per km rate. The total revenue for transport services provided by donkeys was valued as the number of teams * trips per year * value per km * average trip distance. The costs associated with donkey transport services include labour and labour costs. Capital costs for each cart were established by depreciating the cart value ($50) over a 15 year productive lifespan to yield an annual value of $3.3 per cart (Van Zyl, 1988).

Donkeys are also used for ploughing in Paulshoek. A neighbouring private farmer charges $4.5 per ha to plough fields with a tractor. This replacement value was used to estimate the value of ploughing as the number of ha ploughed times the per ha replacement value.

Table 1.3. Revenue, costs and profit of small stock production (goats and sheep) for the 72 households that graze their livestock on the 20000 ha of Paulshoek for the period August 1999 to July 2000. Prices are shown in $US for the Household Income Approach (HIA) and the Natural Habitat Value (NHV) valuation methods.

Item	HIA	NHV
Livestock production		
Local and market sales	6692	6692
Home consumption	5187	5187
Value of death losses	3255	3255
Milk	925	925
TOTAL REVENUE	16059	16059
Input costs		
Fodder production	571	(580)
Veterinary costs	523	523
Cooking shelter cost	-	248
Sleeping shelter cost	-	288
Cash wages	2700	2700
Family labour	-	5700
Land rental	452	452
TOTAL COST	4246	9331
PROFIT	11813	6728
Per household	164	93
Per ha of Paulshoek	0.59	0.34

No individual costs are associated with the ownership of donkeys as they graze for free on the commons. While most of the domestic donkeys supply transport and ploughing services the feral donkeys compete for grazing without contributing to the village economy. According to Meisner (1982) an adult donkey displaces 9.6 SSU, or 7.36 sheep ewes. The value of the grazing benefits foregone due to the feral donkeys can be estimated if it is assumed that only sheep ewes will take the additional space, that these ewes have a reproductive rate of 50%, and that lambs are sold locally for $7. Based on these assumptions, the annual value of the grazing lost per feral donkey is $25.76 or $4508 for all 175 feral donkeys.

Table 1.4. The annual value that donkeys provide for different services for a number of households in Paulshoek and the value of the grazing consumed by the 175 feral donkeys which is lost to the 72 households who would otherwise have this resource available for their livestock. Prices are shown in $US for the Household Income Approach (HIA) and the Natural Habitat Value (NHV) valuation methods.

Service and cost	HIA	NHV
Transport		
Total value	451	438
Per household (n=4)	113	109
Per ha	0.02	0.02
Firewood delivery		
Total value	-	101
Per household (n=3)	-	34
Per ha	-	0.005
Ploughing		
Total value	-	37
Per household (n=6)	-	6
Per ha	-	0.002
Total value of services provided by donkeys	451	576
Per household	113	149
Per ha	0.02	0.03
Cost of feral donkeys		
Total value of grazing consumed	4 508	4 508
Per household (n=72)	63	63
Per ha	0.23	0.23

The final values obtained for donkey services and the cost of the feral donkey population are shown in Table 1.4. Crop production and firewood collection service revenues provided by donkeys are ignored by the HIA method since they are inputs. Furthermore, the costs associated with these services include capital and household labour costs that are also ignored by the HIA method. Hence, only the transport function is discussed. The cost of the feral donkey population in terms of the value of the grazing lost to domestic small stock is $4508. This significantly out weighs any benefit the domestic donkeys convey to the village as a whole.

Medicinal plants

Archer (1994), May *et al.* (1997) and Goldberg (1998) have investigated the use of medicinal plants in Namaqualand but no previous attempt has been made at valuing this resource. Goldberg (1998) found that in Paulshoek 15 plants species were considered important for medicinal purposes. She also noted that these species were abundant and easily accessible and that 70% of the village population, or approximately 97 households (560 people), made regular use of medicinal plants. Knowledge about the plants, where to find them or what they treated was common amongst all households surveyed and there were no restrictions on harvesting. On average each person used each species for two doses a year (where a dose was defined as an amount of each species that would be used for one treatment). The replacement cost of a conventional medicine was used assuming that it was a perfect substitute with regard to dosage, effectiveness and compatibility. Substitute marketed products were found by identifying pharmaceutical products a medical doctor would prescribe to treat symptoms that would normally be treated by medicinal plants in the village. For three of the plants no appropriate substitute could be found and they were ignored in further analyses. However, nine of the 15 medicinal plants commonly used could be replaced by non-prescription medicines containing ingredients such as paracetamol which is available over the counter in the village. Its price of $0.12 per adult treatment was used to describe the value of these nine plants. A further three species could be replaced by prescription drugs and the use of these plants was valued at the cost of a visit to the state's mobile clinic that operates in Paulshoek every two weeks. Each visit costs $2.3 if a person is employed and is free if he/she is unemployed. Since only 28% of Paulshoek's inhabitants have some form of employment (May *et al.* 1997) the effective clinic cost is $0.64 per treatment. No harvesting costs were calculated since labour costs couldn't be estimated as medicinal plant collection occurs whilst people perform other activities. There are also no processing costs. Medicinal plant values are a gross value and were estimated as:

- paracetamol equivalent: 2 treatments * 560 people * 9 species * $0.12 per treatment;
- prescription equivalent: 2 treatments * 560 people * 3 species * $0.64 per treatment;

Table 1.5 describes the final values obtained. Medicinal plants annually contribute $0.168 per ha to the rangelands' value and support annual household income by $35.

Table 1.5. The annual value of medicinal plants in Paulshoek used by the approximately 97 households in the village. Prices are shown in $US for the Household Income Approach (HIA) and the Natural Habitat Value (NHV) valuation methods.

Item	HIA	NHV
Medicinal plants		
Non-prescription equivalent	1210	1210
Prescription equivalent	2150	2150
TOTAL REVENUE	3360	3360
Collecting cost	-	-
Processing cost	-	-
TOTAL COST	-	-
PROFIT	3360	3360
Per household	35	35
Per ha	0.17	0.17

Firewood

Solomon (2000) investigated the use and sale of firewood in Paulshoek. The values obtained in Table 1.6 are derived from this study and from interviews with residents. Firewood accounts for 75% of the net energy consumed in Paulshoek as all households (n =138) and stock posts (n =28) use firewood (Solomon 2000). Firewood is bought or collected with collection being unrestricted. Residents may collect as much of any species as they wish provided it is dead material. Households have preferences regarding which species of firewood to employ in different uses but these choices are often not realised, as preferred species have become scarce. *Rhus undulata* (Taaibos), a long-burning wood that forms good coals, is the most preferred species. However, its use is largely restricted to outlying stock posts (where it is collected) and wealthy households (that can afford to buy it). Seasonal household firewood use is 792 kg, 655 kg, 282 kg and 400 kg for winter, spring, summer and autumn months respectively (Solomon 2000). Annual firewood consumption was calculated as 2.1 and 294 tonnes for each household and the entire village respectively. Stock posts (n=28) use similar quantities of wood to those used by households in the village. Hence, annual stock post firewood consumption was estimated at 59 tonnes. A market for *R. undulata* has developed in Paulshoek. This market price is used to value all categories of firewood (*R. undulata*, poor quality firewood and stock post firewood), thereby, ignoring differences in quality and scarcity between firewood species. Notwithstanding these problems, this method is still considered less problematic than the next best option of using the opportunity cost of labour (Campbell, 1997; Wollenberg, 2000 and Cavendish, 2002).

Firewood is sold in approximately 14 kg bundles and by donkey carts which can transport up to 70 kg at a time. Prices vary with seasonal demand and per kg prices are lower for donkey carts than bundles. Prices between delivery modes were averaged to obtain prices of $0.1355, $0.1015, $0.0915 and $0.132 for winter, spring, summer and autumn respectively. Seasonal firewood revenue was estimated as the seasonal quantity of firewood per household * 166 household units (138 village households + 28 stock posts) * average seasonal price. Total revenue is the summation of each season's firewood revenue and is shown in Table 1.6.

Table 1.6. The annual value of firewood in Paulshoek for the 138 households and 28 stockposts which use firewood. Prices are shown in $US for the Household Income Approach (HIA) and the Natural Habitat Value (NHV) valuation methods.

Item	HIA	NHV
Total Revenue	41 899	41 899
Total Cost	24 032	24 032
PROFIT	17 867	17 867
Per household	108	108
Per ha	0.9	0.9

The only significant cost associated with firewood is labour. Solomon (2000) reports that on average, households spend 151.9 days per year collecting firewood. Since stock posts are included in the firewood calculations and household firewood is generally collected by women and children, the herders daily wage of $0.96 was used to estimate labour costs. The per kg collection cost was therefore $0.068 and was multiplied by the total amount of wood used to obtain total costs. Although it is thought that households provide the bulk of the labour input used, it was impossible to distinguish between paid and household labour. Therefore, no distinction between the HIA and NHV methods is made. Furthermore, the quantity of sold firewood was unavailable. Thus, the average household value of $108 ignores differences between households.

Total value, per household value and per ha value

This study estimates that Paulshoek, as a single productive unit of approximately 20 000 ha, is worth $29178 and $23443 per year according to the HIA and NHV methods respectively (Table 1.7). This amounts to between $390 and $225 per household per year or $1.46 and $1.18 per ha per year depending on the valuation method used. The HIA value represents the benefit or contribution natural resources make towards sustaining household livelihoods. The total NHV value which is 20% lower describes the value of the resources themselves and is a useful indicator of the areas' productive value. Firewood is the most valuable product. Livestock and medicinal plants also contribute significantly to the value of the natural resources used but crop production and the use of donkeys contribute negligibly or reduce total values. Feral donkeys are a significant cost to livestock farmers amounting to 15% and 19% of the total value of all natural resources used for the HIA and NHV evaluation methods respectively.

Table 1.7. The contribution of different natural resource use sectors to the total value, value per household and value per ha of the Paulshoek communal area using the Household Income Approach (HIA) and Natural Habitat Value (NHV) valuation methods. Values are in $US and those in parentheses indicate a negative value.

Resource use sector	Total value		Per household value		Per ha value	
	HIA	NHV	HIA	NHV	HIA	NHV
Crop production	195	(580)	33	(97)	0.01	(0.03)
Livestock production	11813	6728	164	93	0.59	0.34
Domestic donkeys	451	576	113	149	0.02	0.03
Feral donkeys	(4508)	(4508)	(63)	(63)	(0.23)	(0.23)
Medicinal plants	3360	3360	35	35	0.17	0.17
Firewood	17867	17867	108	108	0.90	0.90
TOTAL	29178	23443	390	225	1.46	1.18

DISCUSSION

Comparisons with other studies and ecosystems

The highest values for natural resource production systems are for those found in tropical rainforests. The range of values reported extends from nearly $13 to $422 per ha (Peters *et al.* 1989; Godoy *et al.*, 2002). Godoy *et al.* (1993) evaluated more than 20 studies and calculated a median value of $50 per ha for tropical rainforests. Non-timber forest products in tropical deciduous forests were found to have a per ha value between $220 and $357 (Chopra, 1993). Campbell *et al.* (1993 and1997) conducted three studies on plant resources from miombo woodland in the communal areas of Zimbabwe and estimated annual per ha values for these studies of $5.50, $6.50 and $17. These values included costs of production and are therefore most similar to our NHV values. Even if the higher HIA value for Paulshoek is used, $1.46 per ha is far less than the values mentioned from other ecosystems with considerably higher rainfall and primary productivity. Furthermore, the values reported for Paulshoek include livestock that were not included in most of the above studies. Costanza *et al.* (1997) evaluated the world's food production and raw material values. Values estimated ranged from $6 to $75 for food production and $43 to $1014 for raw materials, and a combined food production and raw material average ha value of $347 was suggested. Paulshoek is far below the world average but the values above included non-use values that were not included in our analysis.

However, if the HIA household values for Paulshoek are compared with the household values obtained from studies conducted in other ecosystems, a different picture emerges. Shackleton *et al.* (2001) evaluated seven studies of non-animal husbandry resources from woodland regions of Southern Africa. Annual medicinal plant values ranged from $2.3 to $32 per household per year compared to values for Paulshoek of $35 for both the HIA and NHV evaluation methods. However, Shackleton *et al.* (2001) reduced their gross medicinal plant values by 39% to obtain NHV estimates. If the Paulshoek medicinal plant value is reduced by the same amount a value of $21 per household per year is obtained, which falls within the median of medicinal plant values reported by Shackleton *et al.* (2001). The most recent household income and expenditure survey for rural households in the Northern Cape reports an annual household expenditure of $28.70 on medical services (StatsSA, 2002). Although this represents a value 17% lower than the one obtained for Paulshoek the latter value is close to those reported in other studies.

Ntshona (2002) valued firewood in a woodland region of Southern Africa using the replacement cost of paraffin and estimated its value at $237 per household per year. Shackleton *et al.* (2001) obtained firewood values from $31 to $108 per household per year. Paulshoek value of $108 per household per year is comparable with these values. The recent provision of electricity to the village, however, is likely to change this value considerably.

Shackleton et al. (2001) obtained annual values per household for all woodland resources of between $442 and $124 which are similar to the values of $390 and $225 obtained for Paulshoek for the HIA and NHV evaluation methods respectively. However, when Shackleton *et al.* (2001) included livestock values in their analysis, the range of annual household values increased from $124 for non-livestock owning households to $707 for livestock owning households with a median value of $282. Average household livestock values in the studies they reviewed were $649 and $326 for the HIA and NHV methods respectively. Therefore, livestock can more than double the median HIA estimate for the resource value in woodland savanna settings. In Paulshoek, annual HIA household values range from $226 for non-livestock owning households to $390 for livestock owning households and livestock contributed on average $164 per household per year. Paulshoek values, therefore, are within the range reported by Shackleton *et al.* (2001). Furthermore, livestock farming in the savanna woodland regions is cattle farming (which provides higher yields) and not sheep and goat farming.

In summary, ha values are significantly higher for most other ecosystems, including savanna woodlands, but households values appear to be similar. The reason for this is that population density in Paulshoek is roughly 4 persons km^2 compared with a range of 38-71 persons per km^2 for woodland regions. Hence a hectare in Paulshoek produces less than a hectare in a woodland region but households can access enough hectares to satisfy their needs.

Private farm comparison

Communal production systems have often been considered unproductive in the past. In an attempt to disprove this many papers have provided detailed values of rural land based production systems and compared these against standard gross margin estimates for private farms (usually supplied by a state department) in similar or surrounding areas. For example, Scoones (1992) examined communal goat and cattle production and found that per ha values in communal areas were roughly ten times those for private farms in surrounding areas. Similarly, Shackleton and Mander (2000) evaluated a series of papers on woodland resources and found that average hectare values compared "favourably with financial returns from commercial farming in adjacent land use areas". This study confirms these findings as the average hectare values of $1.46 (HIA) and $1.18 (NHV) are similar to the $1.50 per ha value recognised for private farms (Northern Cape Department of Agriculture).

There are, however, problems with this comparison. Firstly, the full suite of resource products in the communal area has been examined whilst the private farm value is a standard value for sheep farming. Hence, no other resources used by farmers are valued and inter-farm variations in productivity and profit are ignored. Secondly, even though both values are reported in $US the values reported are distinct from one another in that private farm values are cash values whilst communal farm values are a combination of cash and transfer values. Cash values represent income which has been generated and which can be used to buy a good or service. Transfer values are values that do not require money to change hands since they are usually generated through own consumption, bartering, gifts and other non-cash transactions. Their value is generally locked into the local economy and can only be transferred outside of the communal production system with difficulty. Cash and transfer values have different implications for household livelihoods, react differently to policy decisions and have different relative utilities ($1 in cash has a higher utility than $1 of transfer value and this divergence will increase as cash becomes scarcer). Notwithstanding these problems Paulshoek's production system cannot be viewed as less productive than surrounding farming enterprises. In addition, the region supports at least twenty-five times the number of people that are supported on private farms and has done so for more than 100 years.

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REPORT 2

The value of flower tourism at the Namaqua National Park, South Africa

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INTRODUCTION

Resources are scarce and any decision relating to the use of resources will entail a trade-off between benefits, costs and forgone opportunities for individuals and society (Gren *et al.*, 2002). Economics as a discipline is largely concerned with determining how best to allocate scarce resources. Understanding the economic value of these resources plays a critical part in determining an optimal allocation (Scoones, 1992). Problematically, many of the goods and services provided by the environment have no prices. Heal (1997) argues that without the ability to compare market and non-market values it is impossible to determine appropriate policy decisions with regard to resource allocation.

Over the last two decades there has been an increasing focus on valuing non-market (non-priced) environmental goods and services. There are now a vast array of techniques for estimating the value of these goods and services. These methods place monetary values on the benefit or welfare individuals obtain from these goods and services. Welfare is estimated by analysing individuals' behaviour when changes in the price, quantity or characteristics of the goods or services occur (Boxall and Beckley, 2002). This can be done by observing people's behaviour in real world settings or by constructing hypothetical markets and evaluating individuals' preferences to hypothetical price, quantity or quality changes. The former method observes individuals revealing their preferences while the latter requires individuals to state their preferences. They are known as revealed and stated preference methods, respectively.

This study uses a revealed preference method, namely, the travel cost method (TCM) to estimate the recreational value of flower viewing at a national park in South Africa. The report contains seven sections. Following the Introduction, the study site and reasons for the study are described. Then, a brief overview of the TCM and the assumptions that underpin it are outlined. The data collection method is described and a series of summary statistics obtained from the data are presented. The assumptions used in this TCM study are stated in the next section and the findings presented. An alternative approach to valuing the recreational value of flower viewing is then described and the findings of this study are discussed in the last section. The main conclusion from the study is that the value of the park to the region extends well beyond the revenue it generates.

STUDY SITE

The study site is located within the Succulent Karoo Biome, an arid (150-300 mm of rainfall per annum) winter rainfall region in South Africa (Fig. 2.1). Extending 116 000 km^2 the Succulent Karoo Biome contains 4 849 plant and 472 vertebrate species. The region is further characterised by high levels of endemism (30% and 10% for plant and vertebrate species, respectively) and for housing approximately one third of the world's succulent plant species (Cowling and Pierce, 1999). It is the only desert in the world to qualify as a biodiversity "hotspot" (Myers *et al*., 2000).

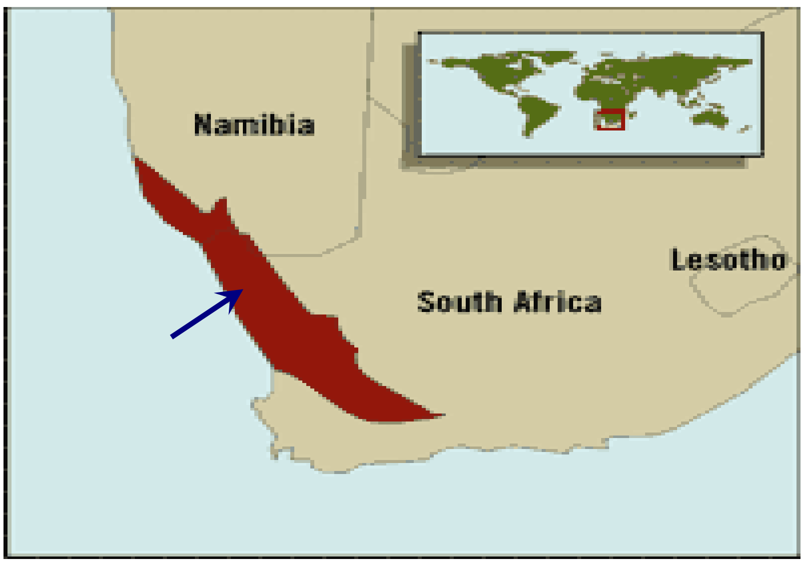

Figure 2.1. The broad location of the Succulent Karoo biome in the western part of southern Africa as outlined by Conservation International (2004) showing the approximate location of the Namaqua National Park..

The Namaqua National Park (NNP) is a 70 000 ha state-funded protected area located in western Namaqualand, a region of the Succulent Karoo Biome. As with the Succulent Karoo Biome, Namaqualand contains exceptional biodiversity but is most famous for the spectacular floral displays that occur in the region during late winter and spring. These floral displays draw large numbers of tourists and the NNP serves as one of the centres for this trade (Loubser, 2001). As many as 10 000 tourists visit the NNP from August to September but annual visitation varies in response to the quality of flowers. For the remainder of the year there are few visitors.

REASONS FOR THE STUDY

Despite the biological diversity and the regional revenue generated from flower tourism, awareness of these values in South Africa is low and before 1999 only 3.5% of the Succulent Karoo Biome was formally protected in conservation areas (Siegfried, 1999). Furthermore, the diversity and ecological systems that sustain it are under pressure from a range of factors that include: mining; agriculture (livestock and cereal production); alien plant invasions; unsustainable resource harvesting (particularly in the communal areas)); and the illegal trade of succulent plants (Cowling and Pierce, 1999 and Siegfried, 1999). Consequently, 936 of the biome's plant species are listed as threatened on the IUCN red data list (IUCN, 2004). Siegfried (1999) argues that effective policy regarding land use in Namaqualand will only be achieved once fundamental questions concerning the sustainability, value and efficiency of the region's land use sectors are answered. This is particularly true for those land use sectors whose production processes, or part thereof, fall outside formal market systems.

One such sector is conservation, which has been viewed as a financial sink since simple revenue (entrance fees) less running cost calculations are used to estimate its value. The NNP makes an average net loss of $US50 000 per annum and this is often cited as a reason to limit park funding or divert investment away from the park. This study attempts to demonstrate that the recreational value of flower viewing at the NNP is a significant overlooked value far larger than the park's annual net loss.

THE TRAVEL COST METHOD (TCM)

Introduction to TCM

The travel cost method is the most widely used non-market valuation technique for estimating the value of recreational sites. Its popularity stems from the fact that it mimics conventional economic techniques for estimating welfare based on market prices, is based on actual behaviour (revealed preference method), is inexpensive to apply and produces results that are easy to interpret and explain (Lesser *et al.*,1997).

The TCM is an application of demand functions to recreational trips since it estimates an empirical relationship between price (travel cost) and quantity (the number of trips). Implicit in this formulation is the assumption that travel costs can be used as a proxy for trip price, which is unobservable (Maille and Mendelsohn, 1993). The justification for this assumption is based on the observation that visitation declines as the distance visitors have to travel to the site increases. Furthermore, people incur costs when visiting sites and these costs increase with increasing distance from the site. Travel costs and distance are therefore weak compliments and by observing the change in the number of trips taken with changes in the cost of the private good (travel costs) a negatively sloped demand curve can be estimated (Boxall and Beckley, 2002).

Although these negatively sloped demand curves have been estimated in every TCM study, Randall (1995) argues that they are not representative of visitors reacting to changes in the trip price but are rather a product of the cost-accounting conventions adopted by researchers. He argues that individuals perceive travel costs as the opportunity cost of choosing one option over another where the subjective sacrifice determines choice. Crucially, this means that travel costs are subjective, not cardinally measurable, not third party observable and can therefore not be used as a proxy for the trip price. Furthermore, he states that it is for this reason that a series of longstanding theoretical problems with the TCM have not and can not be solved.

Although plausible this argument dismisses the fact that people do spend money on visiting recreational sites, that the amount of money spent does increase with increased trip distance and even if this value is not an accurate representation of the nature of the costs individuals face it can be used as an indicator of an individuals' willingness to pay (WTP) for the recreational site. Although the problems Randall (1995) describes have not been solved, conventions have been adopted by TCM practitioners to ensure the relative uniformity and comparability of results studies obtain. The remainder of this section briefly describes the TCM, the main problems with the method and the conventions adopted by researchers to deal with them.

TCM explained

The TCM is a survey technique whereby visitors to a site are questioned in order to obtain data pertaining to their: place of residence; travel expenditure; demographic and socio-economic characteristics; preferences towards the site and substitute sites; frequency of visits to the site and other sites; and trip information regarding the purpose, length and other pecuniary expenditures (Bateman, 1993). This information is then used to obtain an empirical relationship describing the frequency of visits to the site as a function of the calculated visit costs, socio-economic variables characterising the population and indices accounting for substitutes and other prices (English and Bowker, 1996). Following Bateman (1993) this study names the resulting empirical relationship the trip generating function (TGF) which takes the following general form:

$$V = f(TC, X) \qquad (1)$$

Where, V is the number of visits, TC is the travel cost and X is a vector of the socio-economic, substitute and other price variables. The coefficient on the travel cost variable is then used to estimate a marshallian demand curve that is integrated to yield the consumer surplus (CS). This represents the benefit or value of the recreational experience to visitors, which is used as a proxy for the site's value (Bateman, 1993).

Deciding on the correct TCM

There are three basic variants of the TCM which researchers can use. First, the zonal travel cost method (ZTCM), which groups visitors to a site into zones of increasing distance from the site and estimates the TGF by regressing the visitation rate from each zone against zonal average variables. This method implicitly assumes that individuals in each zone have identical demand parameters and does therefore not reflect utility maximising behaviour (Brown and Nawas, 1973).

Second, the individual travel cost method (ITCM), which uses individual level data and predicts the number of visits an individual makes to a site over a given period of time. It can therefore control for differences in preferences and socio-economic variables within the sample (Fletcher *et al*, 1990). However, this method cannot be used when large portions of the sample take one or less trips to the site per year (Anex, 1995).

Third, the random utility model (RUM), which explains the choice to visit a site as a function of the travel cost to the site, socio-economic characteristics of individuals, site characteristics and the characteristics of substitute sites. These observations of individual choices are then used to estimate an indirect utility function the parameters of which are then used to calculate the welfare associated with a change in the site's quality (HARC, 2003). RUM's are favoured when changes in site characteristics or quality are to be valued but cannot be used to determine the total value of a site (Freeman, 1993).

The remainder of this section discusses issues with the TCM from the ZTCM perspective since this is the method employed by this study.

Defining the visitor zones

When the ZTCM is used, the first step is to create zones of increasing visitor origins. This is a critical step since not only are the visitation rates based on the zones but so too is the estimation of travel distance which is often used to calculate travel time and expenditure. Problematically, there is little theoretical guidance regarding the optimal allocation of zones and most studies delimit zones in an arbitrary way (English and Bowker, 1997).

There are two issues of importance for the demarcation of zones. First, in order to calculate visitation rates, population data for that zone is required. This is generally obtained from census data, and the spatial distribution of these data therefore, also needs to be considered. Second, when distances from zones to study sites are used to estimate travel time and expenditure the network and quality of the roads in the zones must be take into account.

The first ZTCM studies established zones by delimiting concentric rings of increasing distance around the site. The size of rings was based on the location of the site and on the format of the available census data. Distances were then estimated as straight lines from the zone to the site. This approach takes no cognisance of the road quality and network and it makes simplistic assumptions for the calculation of the distances (Brainard *et al*., 1999). However, due to census data constraints many studies still use the concentric rings approach but incorporate more precise estimates of visitor origins and the routes taken to the site (Loomis *et al.* 1995).

Brainard *et al.* (1997) use Geographic Information System (GIS) techniques to derive accurate travel line surfaces which reflect the quality of the roads and the road networks. They call these surfaces isochrone surfaces, since they are composed of areas within a set range of travel times from origin to the site. This method accurately estimates distances and travel times but is very data and skill intensive and requires that census data be available in GIS format.

Once the zones have been defined the next step is to decide which variables to include in the TGF. The following four sub-sections describe some of the problems and conventions associated with this stage.

Substitute Sites

Single independent recreational sites are rare, in most cases sites will have substitutes and in some cases even compliments (Caulkins *et al.*, 1985). Ignoring alternative site prices biases consumer surplus (CS) estimates if these prices are correlated with the study site's price (Anex, 1995). The direction of bias depends on the nature of the dependence between the two sites, the correlation between the travel costs of the two sites and the mean and variance of the travel cost to the study site (Caulkins *et al.*, 1985 and McKean and Rivier, 1990).

Most studies ask respondents to list possible substitute sites and then include the travel costs to these sites as variables in the trip generating function (TGF) (Bockstael, 1995). The problem is that there may be many substitute sites and no guidance about which to include (HARC, 2003). One approach is to estimate the travel cost from a visitor's origin to the next most likely substitute site and include this in the TGF (Hesseln *et al.*, 2003).

Brainard *et al* (1999) used GIS to estimate the distances (travel costs) from a regular grid of points covering the UK to the location of all potential substitute sites. For each grid point the distance to a given substitute site is weighted with close substitutes given more weight than those further away. These weighted substitute site measures are then summed to give a substitute availability index for each grid point. This index was then incorporated into the TGF.

Site Quality and Characteristics

Traditional TCM studies estimate the welfare obtained from a site for a given set of site characteristics or level of quality. However, the change in welfare associated with a change in site quality can be determined using the TCM. This is usually done by using random utility models (RUM – see above) (Hesseln *et al.*, 2003). However, the individual travel cost method (ITCM) or zonal travel cost method (ZTCM) can be used when visitor's Willingness To Pay (WTP) for changes in site quality, obtained through contingent valuation (CVM) type questions, are included in the TGF (Park *et al.*, 2002 and Bhat, 2003).

Travel Costs

The proper specification of travel costs is fundamental to using the TCM since visit price (travel cost) is a prime determinant of visitor behaviour and different price specifications result in different consumer surplus (CS) estimates (Liston-Heyes and Heyes, 1999). There is a general consensus that both direct (petrol and other pecuniary expenses) and indirect (the opportunity cost of time) costs should be included in the travel cost variable but there is a great deal of contention regarding which pecuniary costs to include, how to calculate these costs and how to value the opportunity cost of time. Ward and Loomis (1986) suggest that a key determinant of whether to include a cost depends on whether visitors react to a change in this cost in the same manner they would react to a change in entrance fees.

According to Bateman (1993) there are three ways of estimating travel expenditures.

- Multiplying the roundtrip distance from each zone to the study site by a fuel cost per kilometre rate;

- Multiplying the roundtrip distance from each zone to the study site by a per kilometre full car cost which includes petrol, maintenance, tyres and insurance;
- Ask respondents how much it cost to get to the site.

Early studies used stated travel and time expenses to describe travel costs. This method evades the numerical difficulties that are encountered when round trip distances and per kilometre costs are used to estimate travel costs (Hof and King, 1992). However, these stated costs are distrusted since respondents may not know these costs, may specify the costs incorrectly or may not understand which cost (petrol or full car) to state (Brainard *et al.*, 1999 and van Zyl *et al.*, 2000). Notwithstanding, many studies still use this method (see: Menkhaus and Lober, 1996). Of the remaining two price specifications the petrol per kilometre rate is least popular since as Bateman (1993) argues one should include all variable costs of roundtrip travel since these affect decisions to travel further and are therefore in line with the weak complimentary assumption.

Another aspect of trip costs which must be considered is the on-site expenditure. Douglas and Taylor (1998) argue that these expenditures are perceived to be part of the trip cost by visitors and are therefore important in estimating the CS. Most studies deal with on-site expenses by adding them to the travel and time costs. English and Bowker (1996) state that there is little theoretical guidance regarding which on-site costs to include. They argue that any expenditure essential to the trip should be included since visitors will respond to changes in these prices in the same way they would respond to changes in the entrance fees.

Recreationists cite time (on-site and travel time) rather than income as the main constraining element in their recreational consumption. Time is therefore scarce and will be an important determinant of the demand for recreation (Bockstael, 1995). The vast majority of TCM studies treat time in one of three ways.

First, the opportunity cost of time is valued at some fraction of the wage rate and added to travel expenditure. The justification for doing this is based on an adaptation of the household production model (HHP) which states that households maximise utility subject to income and time constraints. By treating trips as a commodity and assuming that all commodities produced by the household have constant marginal costs the income and time constraints can be collapsed into one. Consequently, the solution to the household's maximisation problem implies that the cost of producing a commodity equals the constant marginal cost plus the time spent producing the commodity valued at some fraction of the wage rate (Bockstael, 1995). Although used extensively there is little guidance regarding which fraction of the wage rate to use. Shaw (1992) states it is often best to use sensitivity analysis to determine the appropriate fraction.

The second method was developed by Bockstael *et al.* (1987) as a critique of the former method. They argue that it is only possible to transform time into money costs and thereby collapse the time and income constraints into one when individuals can freely substitute between work and leisure time. Bockstael *et al.* (1987) develop a HHP model which reflects more realistic labour-leisure opportunities. The model argues that if an individual can alter the number of hours worked at the margin then the opportunity cost of time is valued at the wage rate and added to travel expenditure.

However, if individuals cannot freely substitute leisure and work time, time cannot be traded at the margin and the opportunity cost of time can no longer be related to the wage rate. For these individuals the travel expenditure and time variables must be separate arguments in the TGF. Although this model realistically depicts individual's labour-leisure decisions it increases the data demands and is prone to multicollinearity since, travel costs and time are usually highly correlated (McConnell, 1999).

Third, Creel and Loomis (1990) treat travel time as a constraint rather than as part of the travel cost. That is, the decision of an individual to take a recreational trip is one in which they minimise expenditure subject to taking a trip of a given length of time. Hence, time is entered into the TGF as a separate argument. This approach simplifies the calculation of travel costs and ensures that the coefficient on the travel cost variable describes only the change in visits for a change in direct costs. However, it assumes that all visitors have the same marginal value of time and is likely to cause multicollinearity (Bateman, 1993).

Shaw (1992), however, argues that there are no incorrect or correct methods for valuing time but rather that each study will be correct if the assumptions made realistically reflect the activity and sample under investigation.

Multiple Purpose and Destination Visitors

Visitors to a site must be defined as pure (only visit the study site), multiple destination trip (MDT), multi-purpose (visit a site for more than one reason) or meanderers (enjoy the journey). Pure visitors entire travel cost can be attributed to the site but not so for MDT or multi-purpose visitors since the estimated demand would overestimate the benefit derived from that site. For meanders the opportunity cost of time must be adjusted to reflect the fact that travel time yields utility (Bateman, 1993).

Most of the visitors to the Namaqua National Park were MDT visitors and as Loomis *et al.* (2000) argue, the most popular way of dealing with them is to portion the total trip costs to different sites. There are numerous ways of doing this but the most preferred method is to take visitors ordinal preferences for sites and convert them into cardinal cost shares (Morey *et al.*, 1995). One method of doing so is Kmietowicz and Pearman's (1981) extreme value approach (EVA) given by:

$$\min_{\gamma}\left\{\gamma_j \middle| \gamma_1 \geq \gamma_2 \geq \gamma_3 \geq \ldots \geq \gamma_n, \sum_{i=1}^{n}\gamma_i = 1\right\} = \begin{cases} \frac{1}{n}\, j = 1 \\ 0, otherwise \end{cases} \qquad (2)$$

And

$$\max_{\gamma}\left\{\gamma_j \middle| \gamma_1 \geq \gamma_2 \geq \gamma_3 \geq \ldots \geq \gamma_n, \sum_{i=1}^{n}\gamma_i = 1\right\} = \left\{ \frac{1}{j} \right. \qquad (3)$$

Where, γ is the rank of site j given that all sites must be ranked and that the sum of these ranks must equal one. The EVA calculates a lower and upper value for the site where only the most preferred site gets a minimum value larger than zero. If differences between the upper and lower bounds are insignificant the CS estimate is robust, if there is significant variation the lower band should be used and if there is massive variation further structural assumptions should be imposed upon the model (Kousmanen *et al* 2003).

Another approach is to calculate the total trip consumer surplus (CS) and allocate a share of this to the study site. Navrud and Mungatana (1994) use the fraction of the total trip time visitors spend at a site to determine the site's CS share. This approach was, however, criticised for its implicit assumption that the marginal utility of trip time is constant (van Zyl *et al.*, 2000).

Choosing the correct functional form and estimating the consumer surplus.

Once the variables to be included in the trip generating function (TGF) have been calculated or corrected the functional form of the TGF must be chosen. Hanley *et al.* (1989) argue that it is up to the analyst to make an 'expert judgement' with regard to the functional form. Willis and Garrod (1990) prescribe that a model must contain significant variables, have coefficients of the expected sign, have a reasonable R^2 and produce CS estimates that are not an order of magnitude different from other studies estimates for similar sites. Thus, there is little theoretical guidance regarding the choice of functional form.

However, the ZTCM and the ITCM are count data processes, where the former has to be converted into one. Hence, when sample size permits the poisson or negative binomial count data models should be used (Bockstael, 1995). Furthermore, when data is collected by on-site surveys no information on non-visitors is obtained. These samples are likely to truncated at the zero level and the above models can correct for this (see: Creel and Loomis, 1990). Furthermore, when the ZTCM is used if one or more zones report zero visitors then the sample is censored and the tobit model should be used (see: Hellerstein, 1992). Finally, certain functional forms (notably the log-log functional form) can produce excessive consumer surplus (CS) estimates since prices approach infinity as quantities approach zero (Carr and Mendelsohn, 2001) Models prone to this should be avoided or the CS estimates obtained should be corrected.

INVESTIGATING VISITOR BEHAVIOUR: SURVEY DESIGN, DATA AND PRELIMINARY STATISTICS

Data collection

A random sample of visitors to the NNP was undertaken over the 2002 flower season. A total of 204 visitors were interviewed about the following:

- Demographic information: age, sex, martial status, home language, home location, profession and income;
- Time information: trip length, travel time, amount of time spent in Namaqualand and whether the respondent was on paid leave or a week-end break;
- Expenditure information: car engine capacity; number of people in the car; and daily per person transportation, accommodation, food and other expenditure estimates;
- Preference information: respondents were asked to state the number of visits made to the NNP per year; whether they had visited the NNP before; how their

visit to the NNP fitted in with their trip; the main activity they wished to pursue or reason for visiting Namaqualand and the NNP; and to describe as a percentage the contribution that the prospect of visiting the NNP made towards their decision to take the trip;

- Route information: respondents were given maps of South Africa and Namaqualand onto which they traced their round trip route indicating the places they visited or planned to visit and the amount of time spent and relative rank of each visited site.

Results of the visitor survey

Visitor numbers and origins

During the 2002 flower season NNP received 9 707 visitors. Of these, 1 258 were foreigners and 8 449 were SA nationals. Of the latter group 7 257 travelled in 2 419 cars and 1 192 travelled in 85 busses. A total of 204 visitors were interviewed (2.1% of the total number of visitors) of which 31 were foreigners, 33 were locals in buses and 160 were locals in their own cars. Due to the low sample sizes only the local own-car visitors were analysed.

More than 90% of the visitors originate from the highly developed urban areas in South Africa. Visitors from Gauteng and Cape Town account for 43% and 25% of the visitors respectively. The remaining visitors originate from the urban areas of the east coast and the far north eastern regions as well as the central and central-north regions of South Africa.

Demographic Characteristics

The average age of the visitors was 56 years (Table 2.1). However, 73% of the sample was older than 55 years and 65% were pensioners. The majority (n > 95%) of the sample belonged to the same racial group (white) and spoke Afrikaans (60%) or English (40%) as home languages. Furthermore, 85% were married and the male to female ratio of visitors was 1.04. The lowest reported income was higher than the South African average and the average income was more than double the South African average.

Table 2.1. The age and income of 160 local visitors who visited the Namaqua National Park in their own car in the spring of 2002. Income data are presented in $US where $US1 = R10

Variable	Mean	Median	Maximum	Minimum
Age	56	61	>65	<18
Income ($US)	17 831	20 500	<35 000	7 500

Preferences and Reasons for Taking the Trip

Almost all of the visitors (98.6%) stated that flower viewing was their main reason for coming to Namaqualand. Furthermore, 64% of the sample stated that their visit to the Namaqua National Park (NNP) played a significant or central role in their decision to take the trip and the average contribution (as a percentage) that the prospect of visiting the NNP made to visitors' decisions to take the trip was 36% (Table 2.2). More than 70% of the respondents were visiting the park for the first time and less than 1% visited the park more than once a year. With regard to site preferences, the average number of sites visited was 3.6 and 95% of respondents gave NNP the highest rank.

Table 2.2. The contribution of the Namaqua National Park (NNP) towards the decision to make the trip to Namaqualand for 160 local visitors in their own car and the number of sites visited in the region.

Variable	Mean	Median	Maximum	Minimum
% contribution of the NNP towards the trip decision	36	30	85	0
Number of sites visited in Namaqualand	3.6	4	6	2

Trip Length and Expenditures

The average round trip distance of 1 844 km made by visitors to the Namaqua National Park (NNP) in 2002 (Table 2.3) reflects the relative remoteness of Namaqualand. Unsurprisingly, there were no day-trippers to Namaqualand and the average trip length to the region was 7.4 days. However, all visitors to the NNP itself are in a sense day-visitors since no accommodation is offered at the park. On-site time for 95% of the respondents to the NNP was less than 5 hours. Thus, although nearly all visitors come to Namaqualand to view flowers, and the prospect of visiting the NNP contributes significantly towards their trip decision (see above), they spend a relatively small proportion of their trip time at the park. Instead, more than 95% of the visitors undertake day trips from their base in one of the NNP surrounding towns and spend an average of 4.7 nights in the region. The range in the total stated transport and accommodation expenditures for the trip to Namaqualand suggests that some people taking shorter, cheaper trips while others taking longer, more expensive trips.

Table 2.3. Summary statistics for the length of the journey made by 160 local visitors to the Namaqua National Park (NNP)) in the spring of 2002 as well as their expenditure on transport and accommodation (in $US where $US1 = R10).

Variable	Mean	Median	Maximum	Minimum
Trip length (days)	7.4	7	14	2
Number of days spent in Namaqualand	4.7	4	13	1
Round trip distance (km)	1 844	2 352	3 320	360
Average km travelled in Namaqualand per day	179	202	250	100
Total transportation costs ($US)	108	132	315	29
Total accommodation costs ($US)	84	92	150	15

The relationships between trip description variables

Table 2.4 is a correlation matrix describing the strength (x) of the linear association between different trip description variables (where, $-1 \leq x \leq 1$). The round trip distance variable is positively correlated with daily transport costs, daily accommodation costs and the length of time spent in Namaqualand. Thus, as distance increases it costs more to get to the site, individuals spend more on accommodation (per day) and the length of time spent in Namaqualand increases. For the remaining variables it is important to note that: individuals who spend more on travel expenditure spend more on accommodation and spend longer in Namaqualand; daily accommodation expenditures are higher for older people but decline when trip length increases; and older people take shorter trips than younger people and place more emphasis on the NNP in their trip decision process.

Table 2.4. Correlation matrix for a number of trip description variables derived from a survey of 160 local visitors to the Namaqua National Park in the spring of 2002.

	A	**B**	**C**	**D**	**E**	**F**
A. Round trip distance to Namaqualand	1					
B. Daily travel costs	0.45	1				
C. Daily accommodation costs	0.12	0.41	1			
D. Days in Namaqualand	0.47	0.24	-0.14	1		
E. Age	-0.07	0.22	0.12	-0.35	1	
F. Percentage of reason for taking the trip attributable to the NNP	-0.59	-0.14	0.05	-0.46	0.38	1

The influence of rainfall on visitor number: An analysis from Goegap Nature Reserve

There are few visitors to the NNP except during the flower season which reaches its peak in August and September. Furthermore, the annual number of visitors during the flower season varies dramatically depending on the quality of the floral displays. Since, the quality of the floral displays is largely governed by rainfall there should be some relationship between rainfall and visitor numbers.

This hypothesis was tested by examining the monthly rainfall and visitation data for Goegap Nature Reserve (GNP) about 70 km north of the Namaqua National Park (NNP). The two areas experience similar climates and the more than 95% of the visitors to the NNP also visited GNR. The data from GNR is therefore a proxy for the NNP and Namaqualand in general.

Monthly rainfall and visitation data was available for 1995-2001. Many different lags of rainfall, current rainfall, numerous dummy specifications to capture seasonal effects and different functional forms were tested. The final model chosen was:

$$V_i = \beta_0 + \beta_1 RF_{L2} + \beta_3 Dummy + e_i \qquad (4)$$

Where V is the number of visitors in month i, β_0 is the constant term, β_1 is the parameter on rainfall lagged by two months (RF_{l2}), β_2 is a vector of parameters for a vector of dummy variables controlling for seasonal effects and e_i is the random error term.

All variables are significant at the 95% confidence level; the R^2 and adjusted R^2 are 0.8 and 0.783, respectively; and the model does not suffer from autocorrelation as the Durbin-H test statistic lead to the non-rejection of the null hypothesis of no serial autocorrelation. The model suggests that an increase of 1 mm of rainfall will result in an increase of nearly 17 visitors two months later (see the value for the coefficient of rainfall in the previous two months). The dummy variables capture the seasonal effect of rainfall on visitation. That is, for the same given rainfall two months previously (100 mm) the total visitation associated with the winter base group dummy (August and September) was 5224. If this rain fell during the months associated with the summer (January, February, March and December), spring (October and November) or autumn (April, May, June, July) dummies then the winter total is reduced by 3599.638, 3785.195 and 3644.507, respectively.

This model suggests that it takes two months for visitor numbers to respond to the first major winter rainfall episode (which stimulates annual germination). Visiting the NNP therefore requires considerable flexibility with regard to recreation time since visitors can at a maximum decide only two months in advance whether to visit the park or not.

Table 2.5. The rainfall-visitor number model derived from monthly rainfall and visitation data for the Goegap Nature Reserve for the period 1995-2001.

Variable	Coefficient	Standard Error	T Value
Rainfall in the previous two months	16.91741	4.034	4.19
Summer dummy variable	-3599.638	313.757	-11.47
Spring dummy variable	-3785.195	297.363	-12.73
Autumn dummy variable	-3644.507	341.18	-10.68
Constant	3532.818	281.2	12.56

THE TRAVEL COST MODEL

Methods and assumptions

Defining the zones

Having decided on using the zonal travel cost method (ZTC M) for the reasons outlined earlier, the next step was to delimit the zones of increasing origin. In this study this process follows what Brainard *et al.* (1997) describe as 'letting the data speak'. That is, the created zones of origin coincide with the description of visitor origins discussed above. Recall that 90% of the visitors came from densely and semi-densely populated and developed urban areas and that the remaining visitors were relatively evenly spread amongst the low density regions of the country. Separate zones were therefore defined for each of these densely and semi-densely developed urban areas. Distances from respondents' residences to the town in Namaqualand where they based themselves were estimated using the routes indicated by respondents in the mapping exercise. Zonal averages were then obtained and zones were amalgamated if their average one-way distances differed by less than 100 km. Using this method, nine zones were described; one for every province in South Africa. The remainder of the sample were identified according to their provincial location and amalgamated into the respective zones. Nine broad zones of increasing distance were obtained (see Table 2.7).

Calculating visitation rates
Zonal visitation rates were estimated using:

$$\text{Visitation Rate} = \frac{Vis_P}{Pop_P} \times 1000 \qquad (5)$$

Where Vis_p is the number of visitors from zone p (calculated from the NNP's gate record) and Pop_p is the provincial population of white people with household incomes above $6 000 per annum (the South African average). Data was obtained from the 2001 census and the visitation rate is expressed as the number of visitors per thousand. According to Maille and Mendelsohn (1993) the population used to estimate the visitation rate must reflect those individuals with the potential to visit the site. Since, the majority of visitors were relatively well-off white South Africans the sub-sample used is appropriate.

The trip generating function (TGF)
There are two features to consider when estimating the TGF. First, one needs to decide on the variables to include as explanatory variables and how to estimate them (specification). Second, one needs to decide on which regression techniques best capture the effects of these variables on the participation rate (functional form). Table 2.6 describes the variables that were initially included in the TGF. Both a top-down and bottom-up approach for including variables in regressions were attempted and only those variables which were significant were retained.

Substitute sites
Table 2.6 does not contain a variable dealing with the effect of substitute sites. However, such a variable is not needed since Namaqualand is an independent site. There are two reasons for this. First, the site itself is unique. It is the only region in South Africa that produces floral displays of the quantity and quality it is famous for and 98.6% of the visitors came to Namaqualand to view flowers. Second, the timing of the floral display ensures that only those individuals with flexible time constraints can take the trip. This, in conjunction with the peak flower season being outside of school holidays, means that most people do not book their annual leave during this period. Namaqualand is also too far away to represent a realistic weekend break for most visitors. This argument is supported by the fact that 86% of the visitors to NNP were pensioners or on unpaid leave. Thus, the visit to Namaqualand does not coincide with a set period of time (leave or week-ends) in which a trip must be taken and does therefore not have substitutes by default. Furthermore, 70% of the visitors were visiting for their first time and considering the average age (56) the argument can be made that visiting Namaqualand is a "once in a lifetime trip" for most people. Finally, there are no other sites in South Africa which receive the same influx of visitors over the same time period nearly (10 000 people over 6 weeks in 2002). Hence, people do not take alternative trips and Namaqualand can therefore be considered an independent site.

Table 2.6. A description of the model variables used in developing the trip generating function (TGF) for the zonal travel cost model.

Variable	Description
Visitation Rate	Dependent variable, visits per 1 000 people.
ln (Visitation Rate)	Dependent variable, natural log of Visitation Rate.
Gender	Dummy variables for male to female ratios of between 0.4 - 0.6, >0.4 and <0.4.
Income	Zonal average annual income.
Age	Average zonal age.
Age^2	Average zonal age squared.
Home language	Dummy variable indicating the dominant language of visitors from each zone.
Marital Status	Dummy variable taking a value of 1 if more than 80% of the zones sample were married and 0 otherwise.
Retired	Dummy variable taking a value of 1 if more than 60% of the zones population was retired and 0 otherwise.
Trip length	Average trip length for each zone in days.
Nights	Average number of nights spent.
Travel Cost	Numerous travel cost specifications were employed, these are discussed below.

The travel costs

The estimation of travel costs includes both travel expenditure and time. Four definitions of trip expenditure and four methods of dealing with time were employed to examine the sensitivity of consumer surplus estimates to changes in assumptions and cost accounting practices. The choice of which pecuniary trip expenditures to include was based on Ward and Loomis's (1986) proclamation that travel costs should serve as an adequate proxy for entrance fees, Bateman's (1993) argument that only those expenses that vary with distance should be included as transportation costs and English and Bowker's (1996) contention that only those costs that are essential to the visit should be included as on-site costs.

Two methods of calculating the travel expenditure were used. First, respondents were asked to state the daily per person travel expenditure. This was multiplied by the trip length to obtain a total transportation cost per person. Second, an estimated cost was obtained by multiplying a constant per km running cost estimate by the respondents' roundtrip distance. This estimate was then divided by the number of people in the car to obtain a per person estimate. The constant per km running cost estimate included repairs, tyres and fuel costs and ranged between $US0.0602 -

$US0.1052 (R0.60-R1.05) depending on the engine capacity of the respondents car. Added to this estimate were the respondent's transportation costs in Namaqualand. This was calculated by multiplying the same per km rate by the number of km travelled in Namaqualand (estimated from the mapping exercise in the survey) divided by the number of people in the car. These two travel expenditure measures were then averaged and used as the first two travel expenditure specifications.

The remaining two travel expenditure specifications were obtained by adding on-site expenditure to the above specifications. The only on-site expenditure essential to taking a trip was accommodation. Thus, the average total per person accommodation expenditure was added to both price specifications above.

Four methods of dealing with time were attempted. First, the opportunity cost of time was valued at zero. Although it is unlikely that visitors to the NNP valued their time at zero, 80% of the sample were either pensioners, on annual vacation or on week-end breaks. It is therefore unlikely that there would be any forgone income associated with their visit and valuing time at zero may be valid.

Second, time was valued at 100% of an individuals' after tax income. Since pensioners, who do not work but receive income, dominate the sample it can be argued that their opportunity cost of time is constant for every day of the year. Hence, the pensioners after tax income was divided by 365 and multiplied by the stated trip length. Of the remainder of the sample, 70% were individuals on unpaid leave. These individuals are at interior solutions in the labour-leisure supply model and their opportunity cost of time can be valued at their wage rate (Bockstael *et al.*, 1987). Thus, their after tax incomes were divided by 241 (average number of work days in South Africa) and multiplied by the trip length.

Third, time was treated as a constraint and the total trip time in days was therefore entered into the TGF as a separate variable. Since, 80% of the sample contains people who cannot freely substitute income for leisure (pensioners and people on paid leave or weekend breaks) it can be argued that they are outside or at corner solutions in the leisure-labour supply model. Hence, the opportunity cost of time cannot be estimated at the wage rate and time (days) should be entered as a separate argument in the TGF (Bockstael *et al.*, 1987).

Fourth, some relationship between the wage rate and the opportunity cost of time was assumed to exist and sensitivity analysis was used to find this fraction. Thus, time was valued at numerous fractions of the wage rate (where the second specification was followed to estimate the wage rate) and that fraction which fitted the data best was presented.

Most studies estimate the total amount of time spent in recreation as the on-site time plus the travelling time. When on-site time is constant over the sample, is negligible relative to travelling time and is not correlated to other explanatory variables in the model, its exclusion is harmless (Bockstael, 1995). Furthermore, most studies use some government travelling time estimate or employ advanced road engineering or GIS software packages to estimate travelling time (Brainard *et al.* 1997). In this study, on-site time in Namaqualand was not constant across the sample and was correlated with distance (see Table 2.4). Thus, for the first, second and fourth specifications above the trip length stated by respondents was multiplied by the per day opportunity cost of time. These were then added to the four travel expenditure specifications to obtain travel cost estimates.

Site quality variables
This study does not include any site quality variables and therefore produces a static welfare estimate with regard to site quality. However, the exclusion of site quality variables does not detract from the study's ability to reach its objective of demonstrating the current benefit visitors derive from the NNP

The functional form of the TGF
The use of the ZTCM negates the possibility that the sample is truncated and the broad categorisation of zones removes the possibility of censoring since no zones have zero visitors. Hence, the following log-linear (equation 6) and polynomial (equation 7) functional forms were estimated:

$$\text{Log (V)} = \beta_0 + \beta_1 TC + \sum \beta_j X_j + e \qquad (6)$$

And

$$\text{V} = \beta_0 + \beta_1 TC + \beta_1 TC^2 + \sum \beta_j X_j + e \qquad (7)$$

Where V is the visitation rate; β_0 is the constant term; β_1 and β_2 are the parameters on the travel cost variable (TC) and its square, respectively; $\sum \beta_j X_j$ represents all the socio-economic shift variables included; and e is the random error term. All variables were tested in both functional forms and insignificant variables were dropped. Final models were selected on the basis of coefficients having the expected signs, the significance of the variables, the R^2, and the absence of heteroskedasticity and multicollinearity (were, the presence of heteroskedasticity was tested for using both the White and Breusch-Pagan test). The latter method is applicable when there is prior knowledge of the variable causing the heteroskedasticity (population size).

Multiple purpose and destination visitors.
The travel costs need not be corrected for multiple purpose visitors since, 98.6% of all visitors came to Namaqualand to view flowers. Nor are meanderers a problem since this study follows the general trend of assuming that travel time yields no utility (see among others Liston-Heyes and Heyes, 1999). However, the travel cost variable should be corrected for multiple destination trip (MDT) visitors since, 100% of the sample visited more than one site. This was initially done using the extreme value approach (EVA), however, once the travel costs were corrected the minimum value models yielded poor R^2 values and none of the variables were significant. Hence, the EVA approach was adapted by taking each zone's average minimum and maximum cost share values and multiplying them by the consumer surplus (CS) estimated when full travel costs were used. This approach follows that of Navrud and Mungatana (1994) but instead of time being used to portion the total CS the preferences of the visitors are used. Another measure of preference, the average zonal stated percentage

that the prospect of visiting the NNP contributed to the decision to take the trip, was also used to estimate the NNPs CS share.

Estimating the consumer surplus (CS)
CS for the log-linear model was obtained using the formula:

$$\text{CS} = \frac{1}{-\beta_{TC}} \tag{8}$$

Where, β_{TC} is the coefficient on the travel cost variable (Creel and Loomis, 1990 and English and Bowker, 1996). This estimate was then multiplied by the average zonal minimum, stated and maximum CS shares and by the number of visitors from each zone. Summing across the zones yielded the total CS. Following Carr and Mendelsohn (2001) the polynomial model's CS was estimated using:

$$\text{CS}_i = \Bigg[\beta_0 TC + \frac{\beta_1 TC^2}{2} + \frac{\beta_1 TC^3}{3} + TC \sum \beta_j X_j + e \Bigg]_{TC_0}^{TC_{\max}} \tag{9}$$

Where CS_i is the consumer surplus for zone i, TC_o is the observed travel cost for that zone and TC_{max} is the travel cost at which this quadratic functional form begins to bends backwards (see Fig. 2.2). If the observed travel cost (TC_o) is larger than TC_{max} the CS for that zone is reported as zero.

Each zones CS estimate is then divided by the visitation rate for that zone to obtain a per person CS that was multiplied by the total number of visitors from that zone. The resulting total CS for that zone was then multiplied by the average zonal minimum, maximum and stated CS shares and the total site CS value was obtained by summing the respective share categories across all zones.

Results
The zones, round trip distances and visitor information
The zones presented in Table 2.7 are in order of ascending distance from the site. If the TCM assumption holds then visitation rates should by default be in ascending order. This is largely the case but the visitation rates for the Limpopo, Free State and North West provinces are slightly higher than is expected. This may be due to the small populations in these regions.

Table 2.7. The zones from which visitors to the Namaqua National Park (NNP) originate, the average round trip distance and the visitation rates. Data are derived from a survey of 160 local visitors to the NNP in the spring of 2002.

Zone	Average round trip distance (km)	Fraction of total visitors	Visitation rate (visits per 1000 people)
Northern Cape	600	0.07	21.0
Western Cape	1160	0.25	7.5
North West	1765	0.06	7.8
Free State	2220	0.06	8.1
Gauteng	2380	0.43	5.0
Eastern Cape	2555	0.03	2.3
Limpopo	2970	0.02	5.3
Mpumalanga	3120	0.02	3.2
KwaZulu-Natal	3320	0.06	3.0

The log-linear models

None of the log-linear models suffered from heteroskedasticity. Both the White and Bruesch-Pagan tests yielded test statistics that lead to the non-rejection of the null hypothesis of homoskedasticity at the 95% confidence level. In all models the only variable other than travel cost that was significant was income.

Table 2.8 describes the log-linear models obtained when the opportunity cost of time was valued at zero. For all travel cost definitions the signs on the travel cost and income variables are negative and positive, respectively. Thus, higher travel costs and lower incomes reduce the visitation rate for all models. Furthermore, all the variables are significant at the 95% level except income in the two stated cost models which is significant at the 90% level. The best model is the estimated travel expenditure plus accommodation model since it has the highest R^2 and highly significant variables.

Furthermore, stated travel costs are between 5-10% larger than the estimated travel costs (Table 2.8). Hence, the coefficients on the stated travel cost variables are smaller than those on their estimated travel cost counterparts. This is reflected in the consumer surplus (CS) per person estimates where the stated travel cost CS estimates are higher than those obtained when the estimated travel costs are used. When accommodation is included into the travel cost definition the CS estimates almost double, regardless of whether stated or estimated travel costs are used. Maximum CS estimates are more than three times the minimum estimates and the stated CS estimates are larger than the minimum estimates but are at least 50% lower than the maximum estimates.

*Table 2.8. Results of the regressions ($\pm$standard error) when the opportunity cost of time is valued at zero (dependent variable = log visitation per 1000 people, N=9). *=p<0.10; **=p<0.05.*

Variable	Stated travel cost	Stated travel cost plus accommodation	Estimated travel cost	Estimated travel cost plus accommodation
Travel cost	-0.001483**	-0.0008258**	-0.0017088**	-0.0009356**
	(0.0002457)	(0.0001141)	(0.0003386)	(0.0001143)
Income	3.11e-06*	2.79e-06*	7.15e-06**	4.91e-06**
	(1.97×10^{-6})	(1.68×10^{-6})	(2.35×10^{-6})	(1.50×10^{-6})
Constant	2.457547**	2.671976**	1.751084**	2.393542
	(0.5031487)	(0.4427193)	(0.5268508)	(0.3760704)
R^2	0.8722	0.9071	0.8276	0.9258
Adjusted R^2	0.8296	0.8761	0.7702	0.901
CS per person ($US)	67.431	122	58.5	107
Max total CS ($US)	489 346.8	878 784	424 684	775 6 2
Stated total CS ($US)	178 228.03	320 068	154 677	282 506
Min total CS ($US)	122 336.48	219 696	106 171	193 913

Table 2.9 and 2.10 describe the regression results when time is valued at 100% and 43% of the wage rate, respectively. The later fraction is the British Department of Transport's opportunity cost of time estimate and has been used extensively in studies in the UK (see Willis and Garrod, 1990). Although many models with different fractions of the wage were generated the results obtained follow a general pattern that is revealed when only one estimate is presented.

For both models the results follow the same pattern as those in the previous model. That is, all coefficients are significant at the 95% level, have the expected signs (negative for travel cost and positive for income), are larger for both the estimated specifications and are smaller when accommodation is included. The R^2 and adjusted R^2 are very high but highest for the estimated travel cost plus accommodation definition. Again the CS estimates per person are smallest for the estimated specifications, larger when accommodation costs are included and the stated consumer surplus value is closer to the minimum CS value than to the maximum CS value, which is more than double the stated value.

*Table 2.9. Results of the regressions (±standard error) when the opportunity cost of time is valued at 100% of the wage rate (dependent variable = log visitation per 1000 people, N=9). **=p<0.05.*

Variable	Stated travel cost plus opportunity cost of time	Stated travel cost plus accommodation plus opportunity cost of time	Estimated travel cost plus opportunity cost of time	Estimated travel cost plus accommodation plus opportunity cost of time
Travel cost	-0.0006079** (0.0000536)	-0.0004553** (0.0000441)	-0.000646** (0.0000623)	-0.0004818** (0.0000447)
Income	8.95×10^{-6}** (1.18×10^{-6})	7.32×10^{-6}** (1.24×10^{-6})	(0.0000108)** (1.36×10^{-6})	8.68×10^{-6}** (1.23×10^{-6})
Constant	1.546032** (0.247378)	1.88234** (0.2805478)	1.230049** (0.2632537)	1.674145** (0.2628914)
R^2	0.93	0.9518	0.9523	0.9556
Adjusted R^2	0.921	0.9357	0.9362	0.9408
CS per person ($US)	164.5	219.6	154.8	207.5
Max total CS ($US)	1 193 782	1 593 894	1 123 375	1 506 227
Stated total CS ($US)	434 796	580 523	409 152	548 593
Min total CS ($US)	298 846	398 473	280 843	376 557

*Table 2.10. Results of the regressions (±standard error) when the opportunity cost of time is given a valued at 43% of the wage rate (dependent variable = log visitation per 1000 people, N=9). **=p<0.05.*

Variable	Stated travel cost	Stated travel cost plus accommodation	Estimated travel cost	Estimated travel cost accommodation
Travel cost	-0.0009317** (0.0000985)	-0.0006155 (0.0000682)	-0.0010241 ** (0.0001215)	-0.000669** ((0.0000679)
Income	6.94×10^{-6}** (1.34×10^{-6})	5.42×10^{-6}** (1.37×10^{-6})	9.73×10^{-6}** (1.60×10^{-6})	7.17×10^{-6}** (1.30×10^{-6})
Constant	1.884422** (0.3049481)	2.224095** (0 .3340613)	1.416925** (0.3238198)	1.971147** (0.2965327)
R^2	0.943	0.938	0.9296	0.9474
Adjusted R^2	0.924	0.917	0.9061	0.929
CS per person ($US)	107	162.5	97.6	162
Max total CS ($US)	778 899	1 179 041	708 622	1 179 041
Stated total CS ($US)	283 688	429 427	258 092	429 427
Min total CS ($US)	194 725	294 760	177 156	294 760

Table 2.11 describes the model when time was included as an explanatory variable and the estimated travel cost (the price definition that yielded the strongest models) was used as the price definition.

Table 2.11. Results of the regression when time was included as a separate argument in the trip generating function (TGF) (dependent variable = log visitation per 1000 people, N=9)

Variable	Coefficient	Standard error	t value	Probability
Travel cost	-0.0006176	0.0005611	-1.1	0.32
Income	3.55×10^{-6}	2.69×10^{-6}	-0.38	0.72
Time	-0.068	0.179	1.32	0.245
Constant	2.036762	0.4953	5.29	0.003

The results obtained above were replicated for every price specification and functional form in which time was included as a separate argument in the trip generating function (TGF). That is, the R^2 and adjusted R^2 are very high (0.92 and 0.89, respectively) but none of the variables are significant. According to Gudjarati (1997) this is symptomatic of models suffering from multicollinearity. Hence, the opportunity cost of time was not endogenously modelled in this study.

The above results highlight the sensitivity of the consumer surplus (CS) estimates toward the travel expenditure and opportunity cost assumptions used. Maximum per person CS estimates ranged from $US58.5 - $US207.5 depending on whether stated or estimated travel costs are used, accommodation costs are included and the manner in which time is dealt with. Using stated travel cost estimates increases the CS by 5-10%, including accommodation increases the consumer surplus by approximately 80% and the opportunity cost of time assumption causes the consumer surplus to increase by between 0%-100% with increasing fractions of the wage resulting in higher estimates.

The results also describe the bias that results when no correction for multiple destination trip (MDT) visitors is made. The maximum values ranged between $US424 684 and $US1 193 782 per annum and were more than four times the minimum values (which ranged between $US 106 171 and $US 298 846 per annum) and more than double the stated values which ranged between $US154 677 and $US434 796 per annum. Although there is a significant difference between the minimum and maximum values the lowest minimum value is still larger than the NNP's average annual net loss of $US50 000.

The polynomial models

The polynomial models fitted the data poorly. In all cases income was insignificant and in most cases the travel cost variables were also insignificant. The general pattern was that as the travel cost variables increased in size the model fit the data better. Consequently, the models presented define travel costs as travel expenditure plus accommodation plus time valued at 100% of the wage rate.

In both models all variables are significant at the 95% level, the coefficient on travel cost is negative, the R^2 and adjusted R^2 are relatively high (higher for the stated model), there is no heteroskedasticity and the stated consumer surplus (CS) estimate is slightly larger than the minimum CS estimate but far lower than the maximum CS estimate. Interestingly, the estimated travel cost model's CS estimates are slightly higher than those for the stated travel cost model. However, this may be attributable to the poorer fit of this model. The most important finding from the polynomial models is that the CS estimates are less than half of those in the semi-log models. Using the same price specification as above the maximum CS estimates for the log-linear models were $US1 593 894 and $US1 506 227 for the stated and estimated versions, respectively.

*Table 2.12. Regression results ($\pm$standard error) for the polynomial models (dependent variable = visitation rate, n=9). **=$p<0.05$.*

Variable	Stated travel cost plus accommodation plus time (valued at 100% of the wage rate)	Estimated travel cost plus accommodation plus time (valued at 100% of the wage rate)
Travel Cost	-0.0141272**	-0.0132929**
	(0.0032)	(0.003834)
Travel $Cost^2$	1.43E-06**	1.35×10^{-6}**
	(4.2×10^{-7})	(5.04×10^{-7})
Constant	37.26866**	35.46352**
	(5.83)	(6.828225)
R^2	0.873	0.8135
Adjusted R^2	0.8307	0.7514
Max total CS ($US)	$US 722 986	$US754 254
Stated total CS ($US)	$US 266 980	$US277 729
Min total CS ($US)	$US 232 102	$US241 522

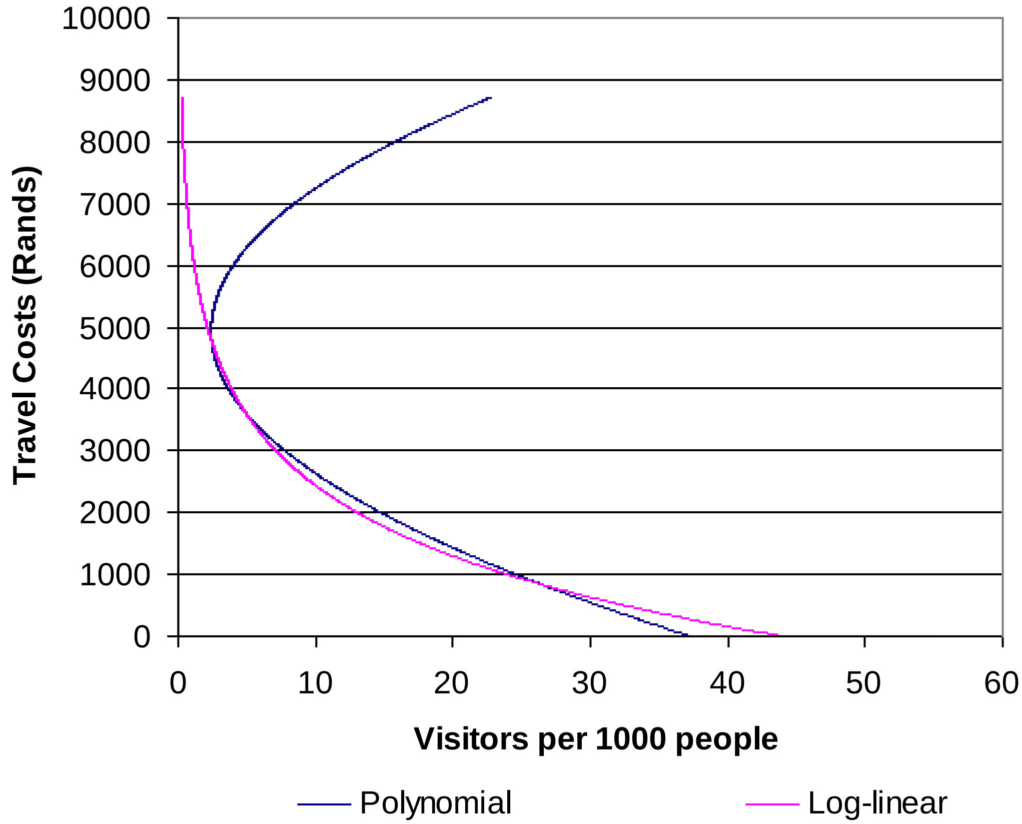

Figure 2.2. The log-linear and polynomial models.

Fig. 2.2 describes the log-linear and polynomial models using the stated version of travel cost specified in Table 2.12 and the average income for the log-linear model. The reasons for the difference in consumer surplus (CS) estimates are evident in the Fig. 2.2. That is, the polynomial model bends backwards when travel cost approaches R5 000 ($US500) and has lower visitation for lower travel cost values. It therefore excludes from each zone's CS estimate the surplus generated at the extremes. Furthermore, two of the nine zones' observed travel costs were higher than the R5 000 'choke price' and were therefore reported as having no CS. It is therefore not surprising that the polynomial model's CS estimates are low. The difference between these two functional forms' CS estimates may be further compounded by the log-linear model overestimating the CS since price approaches infinity as visitation approaches zero. However, the use of point estimates of consumer's surplus such as the one used here are widely recognised within the literature (see Creel and Loomis, 1990 and English and Bowker, 1996).

AN ALTERNATIVE METHOD

Motivation and method

The differences in the consumer surplus (CS) estimates obtained in the models above and the small sample size that was used to fit these models created the need for an alternative approach. Thus, the method prescribed by Menkhaus and Lober (1996) was used whereby, the demand curve is constructed by evaluating the aggregate number of tourists (expressed as a percentage) who demonstrate through their travel costs that they are willing to pay travel expenditures of at least this amount to visit the park. The benefit of this approach is that the sample size extends from 9 to 160 and it provides a simple method of estimating the demand curve. However, it treats all visitors as if they were from a single origin and assumes that all visitors face the same range of expenditures to visit the park. That is, people who live closer to the park face the same range of expenditures to get to the park than people living further away do. This assumption is clearly false since, Table 2.4 describes the positive correlation between distance and stated travel costs. Notwithstanding this issue the approach is still technically valid and should produce usable CS estimates.

The above relationship was estimated using numerous functional forms and all price and time definitions. The only model that produced good R^2 values and significant coefficients was a polynomial functional form that used the stated travel cost definition which excluded accommodation and valued time at zero. Hence, the only model was:

$$Y = \beta_0 + \beta_1 TC + \beta_2 TC^2 + \beta_3 TC^3 + e \qquad (10)$$

Where Y is the percentage of the population demonstrating their willingness to pay a given amount, TC is the travel cost, β_0 is the constant term and e is the random error term.

The CS for equation 10 was obtained using:

$$CS = 100 * P_{min} \left[\beta_0 TC + \frac{\beta_{11} TC^2}{2} + \frac{\beta_2 TC^3}{3} + \frac{\beta_3 TC^4}{4} \right]_{P\,min}^{P\,max} \qquad (11)$$

Where P_{max} is the price when Y = 0% and P_{min} is the price when y=100%. This total was divided by the sample size to obtain a per person CS estimate that was multiplied by 7257 (number of own-car visitors) to obtain the site's CS.

Results

The model produced significant coefficients of the expected sign (negative coefficient on travel cost), an R^2 of 0.7945, an adjusted R^2 of 0.7863, a per visitor consumer surplus (CS) value of $US 62.7 and a total CS estimate of $US454 986 (Table 2.13). Although the assumptions underlying this model may not hold the results obtained support the log-linear zonal travel cost method (ZTCM) models. That is, the log-linear

ZTCM estimated the maximum CS per person, using the same price specification, at $US 67.41.

Table 2.13. The alternative method regression results when a polynomial equation is estimated (dependent variable = percentage of visitors, n=160).

Variable	Coefficient	Standard error	t value	Probability
Travel cost	-0.161	0.0238	-6.76	<0.01
Travel cost squared	-7.16×10^{-5}	2.12×10^{-5}	3.37	<0.01
Travel cost cubed	1.05×10^{-8}	4.95×10^{-9}	-2.13	<0.01
Constant	123	7.15	17.22	<0.01

DISCUSSION

Using Willis and Garrod's (1990) caveat that the chosen model must contain significant variables, have coefficients of the expected sign, have a reasonable R^2 and produce CS estimates that are not an order of magnitude different from estimates obtained by other studies for similar sites, the following discussion describes the reasons why the log-linear models should be used to estimate the recreational value of flower viewing at the NNP. Furthermore, the most appropriate price and time specifications are discussed and a most preferred value is presented.

The log-linear models produced significant variables, coefficients of the expected sign, and high R^2 values. Although high the R^2 values are in line with those from other ZTCM studies. Willis and Garrod (1990) evaluated a series of studies on forest recreation sites in the UK and found that ZTCM studies had R^2 values that ranged between 0.8 and 0.96. Furthermore, the log-linear models are preferred to the polynomial models since the latter models produced lower CS estimates that are not due to the polynomial models being better but are rather a product of the method employed to calculate the CS. As Carr and Mendelsohn (1992) argue this method provides a conservative CS estimate. This finding is supported by English and Bowker (1996) and Liston-Heyes and Heyes (1999) who found that log-linear models provided CS estimates that were higher than those obtained from polynomial models. Another reason for trusting the results from the log-linear models is the fact that the alternative method provided CS estimates that were remarkably close to those from the log-linear model. Problematically, the behavioural assumptions underpinning this model are flawed and therefore render it useless as a tool to describe visitor behaviour. However, the similarity between the CS estimates indicates that the low sample size used in the log-linear models may not be as problematic as was expected. In order to compare the log-linear models' results with those from other studies per person per trip CS estimates were required.

Table 2.14. The weighted average per person per trip consumer surplus (CS) estimates for the log-linear models, where weights correspond to the zonal CS share values.

Time Preference Share	**Price Definition** (In US$ where $US1= R10)			
	Stated travel cost	Stated travel cost plus accommodation	Estimated travel cost	Estimated travel cost plus accommodation
<u>Time valued at Zero</u>				
Minimum	21.22	38.5	18.4	33.7
Stated	33.3	60.1	28.9	52.8
Maximum	67.4	122	58.5	107
<u>Time valued at 43%</u>				
Minimum	33.7	51.2	30.7	51
Stated	52.8	80.2	48.2	80
Maximum	107	162.5	97.6	162
<u>Time valued at 100%</u>				
Minimum	51.8	69.13	48.7	65.3
Stated	80	108.4	76.4	102.3
Maximum	164.5	219.6	154.8	207.5

The per person per trip CS (hereafter referred to as the per person CS) estimates range between $US18.4 and $US219.6. However, this includes the maximum CS share value which is 100% of the total CS value since the Namaqua National Park (NNP) was given the highest rank by more than 95% of the visitors. As Kousmanen *et al.* (2003) argue if multiple destination trip (MDT) visitors are not corrected for the CS can be over estimated by as much as 50%. In this study, ignoring the effects of MDT visitors overstates the CS by more than 50% because the whole sample are in reality

MDT visitors. The maximum values should therefore be excluded. If this is done, the per person CS estimates range from $US18.4 to $US108.4.

Furthermore, when the site is the most preferred site the minimum value equals one divided by the number of sites. This infers that if the remaining CS is divided equally among the remaining sites then all sites yield equal utility. However, if the remaining CS is not divided equally amongst the remaining sites then at least once site yields more utility than the NNP. Since, the NNP was given the highest rank no other site can yield an amount of utility greater than or equal to the utility the NNP yields. Hence, the minimum CS value underestimates the benefit derived from the NNP. The true CS therefore lies between the minimum and maximum values but is more likely to be closer to the minimum than the maximum value since many utility yielding sites were visited. The stated share values fulfil both these criteria. Thus, the preferred per person CS estimates now range from $US28.9 to $US108.4.

This range of CS estimates is dependent on the price definition and the cost of time measure employed with higher travel expenditure and travel cost specifications resulting in higher per person CS estimates. This finding is supported by a large number of studies (see Liston-Heyes and Heyes, 1999, amongst others). English and Bowker (1996) argue that changing the functional form can lead to an 80% difference in the CS but changing the price specification can cause CS estimates to change by over 1000%. Most studies therefore estimate a range of values that are supported by different assumptions.

There are a number of other studies for which per person CS estimates are available. For example, Liston-Heyes and Heyes (1999) valued a national park in England at between $US35 -$US97. Maille and Mendelsohn (1993) found the that value of ecotourism in Madagascar ranged from $US276 to $US360. Shrethsa *et al.* (2002) found that the value of recreational fishing in a region of Brazil was between $US540-$US869. Creel and Loomis (1990) estimated the value of hunting in California at between $US74-$US163 and Navrud and Mungatana (1994) estimated the value of wildlife viewing at a Kenyan National Park for local visitors at between $US68 - $US85.

The range of stated share CS values most preferred by this study is lower than the CS values for the Madagascan and Brazilian studies but the Madagascan study included air fares and the Brazilian study contained an average roundtrip distance of 2870 km. These results are therefore bound to be higher. The values estimated by the remaining studies are remarkably similar to the stated share CS values. Thus, the log-linear models that use the stated share to partition the CS fulfil all of Willis and Garrod's (1990) criteria.

The stated travel expenditures are only 5-10% larger than the estimated values. Both Willis and Garrod (1990) and English and Bowker (1996) observed similar discrepancies between stated and estimated values, when estimated values were approximated using full car costs. Thus, the stated values in this study should be a fair approximation of the costs visitors face. However, in keeping with the general trend in the literature, this study considers the estimated costs to be a better proxy for trip price. Accommodation expenditure should be included since visitors view this as part of the trip price. With regard to time both the zero and 100% value of time definitions are plausible. However, the 43% specification has no theoretical backing since if we assume that people can freely substitute income for leisure (an implicit assumption of this formulation) then we should value their time at 100% of the wage and not some fraction thereof (Bockstael *et al.*(1987).

Hence, the most theoretically correct estimates are the stated CS shares for the estimated travel expenditure that includes accommodation and values time at either zero or 100 percent of the wage rate. The site's CS values are therefore between \$US282 506 and \$US548 593. These values are 5 to 11 times larger than the Namaqua National Park's annual net loss of \$US50 000. Furthermore, for every CS share, functional form and price specification presented the estimated site CS was larger than the park's net loss. Indeed, even the lowest CS estimate of \$US122 337 is more than double this amount. In addition, the values presented here exclude foreign tourists and locals who visited in buses. These values are therefore an underestimate of the recreational value of flower viewing at the NNP.

CONCLUSION

This paper shows that the recreational value of flower viewing at the NNP is far larger than the annual net loss the park makes. The values presented here underestimate the NNP's value since the social services it renders and its contribution to the local economy have been ignored. Nonetheless, even a fraction of the parks value (the recreational value) is greater than the costs of running the park.

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REPORT 3

The sustainability and valuation of three land use production sectors in Namaqualand, South Africa.

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INTRODUCTION

Covering some 50 000 km^2 of the arid and semi-arid western part of South Africa, Namaqualand is a region of extraordinary biotic diversity (Cowling and Pierce, 1999) and is the only desert in the world to qualify as an internationally recognised biodiversity "hotspot" (Myers *et al.*, 2000). This diversity is under pressure, however, from a range of different land use practices including livestock farming under communal and private land tenure regimes, agriculture, mining, the spread of alien plants, unsustainable resource harvesting and the illegal trade in succulent plants (Cowling and Pierce, 1999; Siegfried, 1999). Conservation initiatives within the region have aimed at prioritising those areas with high diversity and endemism (Hilton-Taylor, 1996; Cowling and Hilton-Taylor, 1999; Lombard *et al.*, 1999) but no research has yet been done on valuing the different land use sectors in the region. This exercise is important since tradeoffs in land use options will become increasingly important as government (local, provincial and national) and mining private sector and conservation agencies all seek to extend their influence in the area. Fundamental questions concerning primary and secondary production, the sustainable use of natural resources and the value and efficiency of different land use practices in the region still need to be answered (Siegfried, 1999).

Under traditional economic analyses these questions could be addressed for those land use sectors whose benefit was captured by formal markets. Applying traditional methods to production processes located outside formal market systems has led to these systems being viewed as unproductive and low in value (Scoones, 1992). However, by using ecological-economic methods non-market production processes have been evaluated and compared against formal economic activities (Peters *et al.*, 1989; Shackleton, 1990; Scoones, 1992; Godoy *et al.*, 1993; Chopra, 1993; Campbell, *et al.*, 1993; Shackleton, 1996; Campbell *et al.*, 1997; Shackleton *et al.*, 2001; Ntshona, 2002 and James *et al.*, 2004). The examination and comparisons between land based production systems has been further improved by the development of ecological economic models that allow for questions of sustainability, productivity and value to be examined over time (Higgins, *et al.,* 1997a, 1997b; Luckert, *et al.,* 2000; Grundy *et al.,* 2000; Campbell *et al.,* 2000a, 2000b; Gambiza *et al.,* 2000; Binder *et al.,* 2001; Sankhayan and Holfstad, 2001)**.**

In this article we develop an ecological-economic model to address questions of sustainability, productivity and value for the private farming sector (sheep farming), the communal area sector (plant resource use and sheep and goat farming) and the conservation sector (tourism) in Namaqualand. We specifically address the following key questions:

- How sustainable are the private, communal and conservation sectors in Namaqualand in terms of their ability to maintain plant and animal production over time under current land use practices?
- How do the three different land use sectors compare in terms of their per ha value and net present value over a thirty year time frame?

STUDY AREA

Namaqualand is located in the Northern Cape Province of South Africa and is comprised of several diverse landscapes and vegetation types. This work focused on land use practices evident in the Upland Succulent Karoo vegetation (Low and Rebelo, 1996) of the Kamiesberg mountains in the central part of Namaqualand. Rainfall in the area falls in the winter months (May-September) and is between 150 to 300 mm per annum depending on elevation and proximity to coastal influence. The vegetation on the granite and gneiss-derived soils is a succulent shrubland and is dominated by leaf succulents in the family Aizoaceae, stem succulents in the family Euphorbiaceae, perennial and deciduous shrubs in the families Asteraceae, Solanaceae and Scrophulariaceae and numerous bulbs (Iridaceae, Hyacinthaceae) and annual asteraceous species. Occasional trees also dot the landscape, particularly in rocky, upland environments. Steep elevation gradients characterise the region that is comprised of a mixture of privately owned farms, communal areas and formally protected areas set aside for conservation purposes.

CURRENT LAND USE SECTORS

Private Farming

Farming in Namaqualand on land held under private tenure is today dominated by the commercial farming of sheep for meat. Relatively large farms of upwards of 5 000 ha are owned by a single family who often own more than one farm with herds exceeding 500 animals (Hoffman *et al.,* 1999). The production year begins in late autumn when the herd, with a recommended ewe to ram ratio of 0.97, starts to lamb before the winter rains. Once the lambs are weaned at about six months all male weaners and selected female weaners are sold. Breeding ewes are kept for approximately six years and sold thereafter. In seasons with poor rainfall farmers allow the condition of their animals to fall but will sell animals if conditions deteriorate to critical levels. Limited purchase of fodder does occur but this is not a common practice in the region although many land owners cultivate a portion of their land for fodder production purposes. Stocking rates are generally within those recommended by the Department of Agriculture and livestock are rotated within fenced paddocks every few months depending on the particular grazing system being used. As a result, plant cover is relatively high with an agriculturally acceptable mix of adult palatable plants (Todd and Hoffman, 1999).

Communal areas

The communal areas included in this model are the two discrete reserves of Leliefontein and Kommagas and the settlement of Soebatsfontein. Land is not owned privately but by a local or national government authority. Resource use in this sector includes livestock farming and plant resource harvesting. Firewood accounts for the bulk of the plant materials used directly by people but medicinal plants and construction materials are also used in relatively small quantities. The dominant activity with regard to income and land use intensity is goat and sheep farming. Animals are herded on a daily basis and corralled every night to escape predators. Farmers within the communal areas keep animals primarily for local consumption and as a store of capital and rarely sell their animals at formal markets. Animal numbers are generally twice as high as those recommended by the Department of Agriculture. Vegetation, particularly on the flat, low-lying areas is generally comprised of annual plants and unpalatable shrubs such as *Galenia africana* (Todd and Hoffman, 1999). This model assumes that communal farmers follow an ecological tracking farming system whereby the maximum number of animals the vegetation can support are kept subject to the removal of a base number of animals to meet production costs. A large number donkeys are kept on the commons and provide transport, ploughing and firewood delivery services. These animals incur no individual costs for the owner but have a significant impact on the supply of grazing. Many are not used by the inhabitants of the communal areas and may be considered feral.

Conservation sector

The conservation sector in the region includes the Goegap Nature Reserve and the Namaqua National Park. The areas draw visitors primarily during the late winter and spring months when the annual plants flower in spectacular profusion. For the remainder of the year there are few visitors. Furthermore, the annual number of visitors fluctuates depending on the quality of the floral displays with few visitors during poor years. Three general categories of tourists visit the areas, namely, tour groups in busses, local visitors in their own cars and foreign visitors in hired cars. Limited accommodation is offered by the sector and most visitors spend their days in the conservation areas and overnight in surrounding towns. The conservation sectors revenue therefore accrues over a short time period and largely from gate takings. The only other source of revenue obtained is funding from state and international development agencies.

MODEL DESCRIPTION

A dynamic ecological-economic model was built to demonstrate differences in productivity, sustainability and economic value between three land-based production sectors in the Upland Succulent Karoo region of Namaqualand. These sectors are private farming (covering 705 655 ha), communal area farming and resource use (648 400 ha) and the conservation sector (75 000 ha). The model was developed in STELLA (High

Performance Systems, 2000), a high-level programming language that allows for model development in a collaborative workshop environment. Data pertaining to each of these sectors exists across a range of study sites and sources. A generic, average or hypothetical model was created for each sector that allowed for the integration of the data. Model dynamics occur on a per hectare basis and with an annual time step. Total area values were obtained by aggregating the dynamics in each generic hectare. The model is therefore spatially aggregated and homogenous. We chose to present 30 years of model output since this reflects reasonable long-term planning horizons for the region.

The three production sectors are evaluated through a series of sub-models, namely, rainfall, plant, grazing, animal production, resource use and valuation (Fig. 3.1). For each of the three land use sectors the same series of interactive sub-models are used but the initial conditions, rules and assumptions differ. The rainfall sub-model predicts rainfall ($mm.yr^{-1}$), which in turn predicts potential plant growth and mortality (plant sub-model). The actual or realised above ground plant biomass ($kgDM.ha^{-1}.yr^{-1}$) is determined by the limits that plant mortality (plant sub-model), existing plant biomass (plant sub-model), competition (plant sub-model), grazing (grazing sub-model) and plant resource harvesting (resource use sub-model) place on potential growth. The impact of grazing on above ground biomass is directly related to the number of goats and sheep in the animal production model and the number of goats and sheep are regulated by birth rates, mortality rates and off take rules governed by the amount of food available (plant sub-model). This feedback between the plant and animal sub-models is expressed in the grazing sub-model. Resource demand for communal areas (construction materials, medicinal plants, firewood, donkey services and crop production) and the conservation sector (tourism and funding) are simulated in the resource use sub-model. Values for each production sector are estimated in the valuation sub-model and amalgamated according to the balance sheet requirements of each sector.

Rainfall sub-model

The rainfall within in the region modelled is characterised by high winter rainfall (mean of 97.6 mm), lower rainfall in autumn (mean of 59.7 mm) and spring (mean of 40.3 mm) and very little rainfall in summer (mean of 17.7 mm). Variation in each seasons rainfall is relatively low with the co-efficient of variation being 0.33, 0.35, 0.60 and 0.30 for winter, spring, summer and autumn respectively. The distribution of rainfall over time is best explained by a general parabolic shaped curve (Desmet and Cowling, 1999) and can be simulated using the Gamma density distribution, which provides a flexible class for modelling non-negative random variables and is often used in modelling rainfall regimes (Rice 1995). The gamma density function is calculated using two parameters α and λ where mean rainfall = $\alpha \lambda$ and the coefficient of variation = $\alpha \lambda^2$. The rainfall sub-model simulated each season's rainfall (RF_{SEASON}) using the mean and coefficient of variation for that season to estimate the gamma distribution. Seasonal rainfall was randomly selected from the gamma-distributed values and total rainfall (RF_{TOTAL}) was obtained by summing the four RF_{SEASON} values.

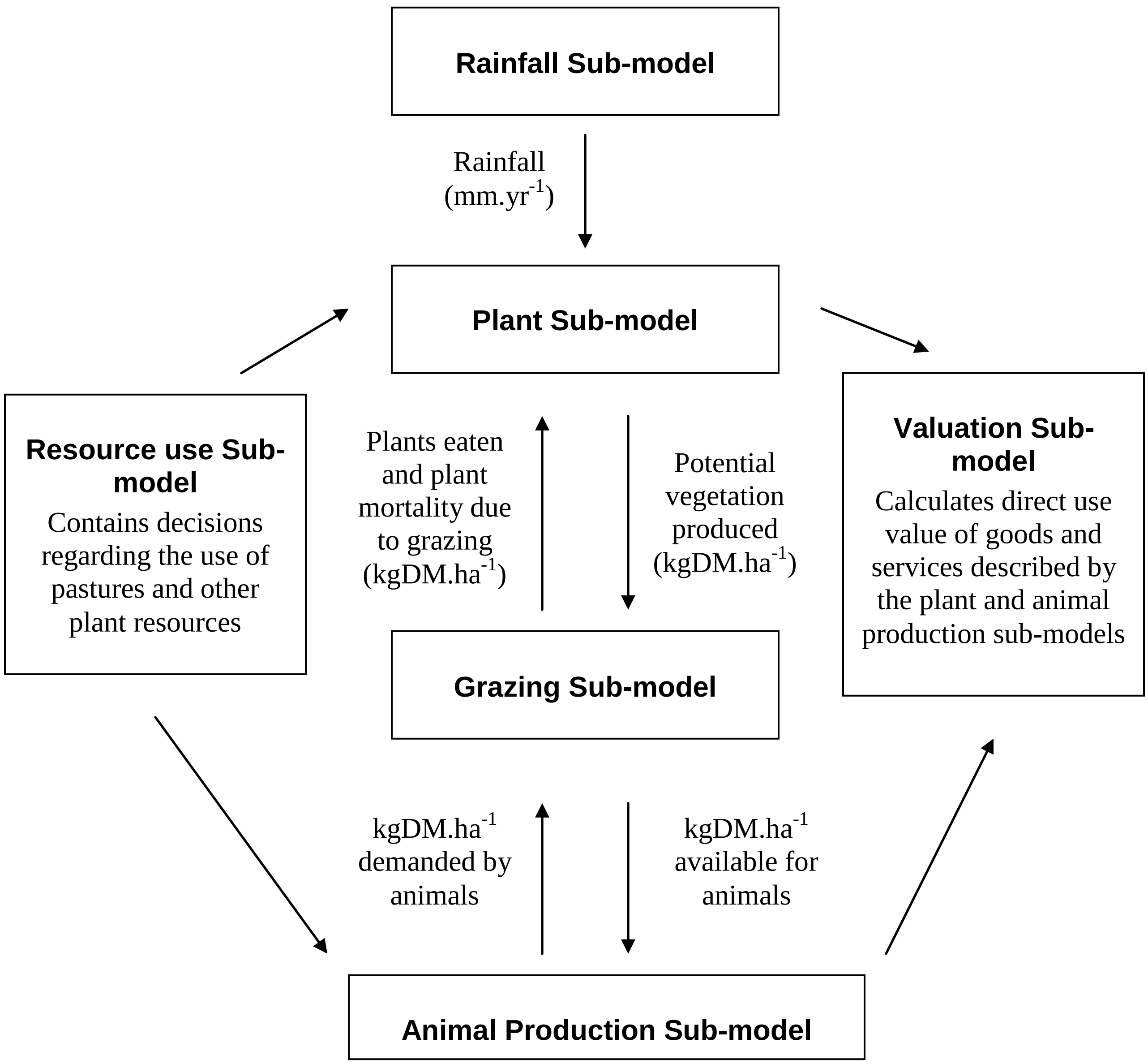

Figure 3.1. Flow diagram for the six sub-models used in the analysis of the three production sectors (communal, commercial, conservation) in Namaqualand.

Plant sub-model

The plant sub-model simulates the quantity of above ground plant biomass in one generic hectare for each land use sector ($kgDM.ha^{-1}.yr^{-1}$). It is identical for all land use sectors except with regard to the initial biomass (PBI_{TOT}) and the harvesting and grazing rules. The initial biomass for each sector is divided into seven plant functional groups (PBI_{PFG}): trees (PBI_{T}), long-lived succulent shrubs (PB_{LL}), short-lived succulent shrubs (PBI_{SL}), non-succulent palatable shrubs (PBI_{PAL}), non-succulent unpalatable shrubs (PBI_{UNPAL}), bulbs (PBI_{B}) and annuals (PBI_{A}). Each functional group was modelled separately and initial biomass increased through growth and decreased through mortality, harvesting and grazing. For all plant functional groups, except annuals and bulbs, growth is given by:

$$Growth_{PFG} = (GR_{PFG} \times PBI_{PFG}) \times [1- (SA_{PFG} \div K)] \qquad (1)$$

where GR_{PFG} is the growth rate of each plant functional group and is estimated by a linear relationship between the effective rainfall ($RF_{EFFECTIVE}$), the fraction of total rainfall that plants can use for growth, and the minimum (GR_{MIN}) and maximum (GR_{MAX}) growth rates for each functional group. The remaining variables SA_{PFG} and K define the space available for each plant functional group (see equation 3) and the carrying capacity of one hectare of land respectively. Annuals and bulbs differ in that the quantity of above ground biomass after one time period is zero. Hence, their growth was expressed as:

$$Growth_{PFG} = (RF_{EFFECTIVE} \times RUE_{PFG}) \times [1- (SA_{PFG} \div K)] \qquad (2)$$

where RUE is the rain use efficiency for each plant functional group expressed as $kgDM.ha^{-1}.yr^{-1}$. For both equation (1) and (2) the first expression defines how much plants are able to grow for a given amount rainfall. The second expression defines how much of that potential growth is realised due to constraints exerted by the existing biomass of the functional group in question, the existing biomass of the other functional groups and the competition between these groups. The SA_{PFG} variable summarises the effects of these variables as:

$$SA_{PFG} = \Sigma (PB_{PFG} \times COMP_{PFG}) \qquad (3)$$

where the space available (SA_{PFG}) for each plant functional group is determined by the amount of biomass potentially available in one hectare and the amount of biomass potentially available depends on the amount of biomass in each functional group (PB_{PFG}) and the competitive ability of each functional group relative to another. The matrix in Table 3.1 describes the competitive ability ($COMP_{PFG}$) of each functional group relative to the other groups. For example, assume that all PB_{PFG} comprises 100 $kgDM.ha^{-1}$. For trees, the total biomass in the hectare is 580 $kgDM.ha^{-1}$ while for annuals the biomass is 1550 $kgDM.ha^{-1}$. Hence, for annuals there is more biomass and less space and subsequently by equations (1) and (3) they will have less growth than trees. Three variables therefore determine how much each functional group can grow, namely, the effective rainfall, the initial biomass of the functional group, and the amount of space available for that functional group.

Table 3.1. The weights of each plant functional group which reflect its competitive ability relative to other functional groups when competing for space.

	Trees	Unpalatable shrubs	Palatable shrubs	Long-lived succulent shrubs	Short-lived succulent shrubs	Bulbs	Annuals
Trees	1	0.8	0.8	0.8	0.8	0.8	0
Unpalatable shrub	0.75	1.0	0.75	0.75	0.75	0.75	0
Palatable shrub	1.0	1.0	1.0	1.0	1.0	1.0	0
Long-lived succulent shrub	0.8	0.8	0.8	1.5	0.8	0.8	0
Short-lived succulent shrub	0.8	0.8	0.8	0.8	0.8	0.8	0
Bulbs	1.0	1.0	1.0	1.0	1.0	2.0	0
Annuals	1.5	1.5	1.5	1.5	1.5	1.5	5

Cases arise where the total amount of growth (Σ Growth $_{PFG}$) cannot be realised, as K will be exceeded and the total potential growth is greater than the total amount of space available, with the amount of space estimated by:

$$\text{Space Available} = K - \sum PB_{PFG} \quad (4)$$

If there is sufficient space to accommodate all the potential growth the realised growth (RG) is given by equation (3) for bulbs and annuals and equation (1) for the remaining groups. However, when the potential growth cannot be attained the real growth for each functional group is defined by:

$$RG_{PFG} = \text{Growth}_{PFG} \times (\text{Space Available} \div \text{Growth}_{TOTAL}) \quad (5)$$

Hence, the available space is proportioned according to the group's potential growth. The total amount of plant biomass (PB_{TOTAL}) after one time-step depends on realised growth, the existing biomass from the previous time-step and the biomass lost through the harvesting of live plants, grazing and mortality. The reduction of biomass through the harvesting of live plants and grazing is described later. However, the linear relationship between total rainfall (RF_{TOTAL}) and the maximum (MR_{MAX}) and minimum (MR_{MIN}) mortality rate defines plant mortality (kgdm/ha). Dead plant matter forms part of a stock of standing dead plants that increases through the annual mortality of live plants and is reduced through harvesting and decay, with the quantity of decay dependent on a group specific decay rate (DR_{PFG}) and the amount of standing dead.

$$DECAY_{PFG} = DR_{PFG} \times \text{Quantity of Standing Dead}_{PFG} \qquad (6)$$

Grazing sub-model

The grazing sub-model links the plant and animal production sub-models by equating the supply and demand for food thus creating a food per animal ratio that is used as a proxy for animal condition and determines the loss of vegetation. The supply of vegetation for grazing arises from new growth and old existing vegetation. The quantity of old palatable vegetation (OV_{PFG}) for each functional group is a fraction (OVP_{PFG}) of the total stock of old vegetation. Similarly, the new palatable vegetation (NV_{PFG}) for each functional group is a proportion (NPP_{PFG}) of the total amount of new growth (RG_{PFG}) for each functional group. The total amount of palatable vegetation was estimated as the summation of old and new vegetation for all functional groups.

Total biomass ($kgDM.ha^{-1}$) demanded for grazing (DEM_{TOTAL}) stems from donkeys (DEM_{DONKEY}), sheep (DEM_{SHEEP}) and goats (DEM_{GOATS}), where the demand for each species is estimated as the product of the equivalent number of adult animals ($ADN_{SPECIES}$) and the quantity of vegetation an adult of that species requires for maintenance needs ($REQ_{SPECIES}$). Maintenance needs, according to the private farming sector, are defined as a sufficient quantity of food such that animals produce offspring, milk and meat in average quantities. The grazing sub-model equates the supply of vegetation against the demand for vegetation (FPA) and uses this proportion to determine the quantity of food each animal eats and therefore the loss of vegetation and animal condition. If supply is bigger than demand (FPA >1) animals have more food than they need. If food supply is less than demand (FPA <1) animals are not obtaining enough food for maintenance needs and lose condition. Total vegetation eaten (VEGEAT) is estimated as the product of the FPA and the $REQ_{SPECIES}$. However, an upper limit of 1.5 was set on the FPA since animals can consume more than $REQ_{SPECIES}$. The total loss of biomass is larger than the amount animals eat as plants are damaged. Since each functional group responds differently to grazing damage (DAM_{PFG}) the quantity of each functional group lost ($PBLOSS_{PFG}$) was estimated as:

$$PBLOSS_{PFG} = [(NV_{PFG} + OV_{PFG}) \times (VEGEAT \div TOV_{TOTAL})] \times (1 + DAM_{PFG}) \qquad (7)$$

The first term describes the amount of food available from each plant functional group. Multiplying this by the fraction of total vegetation eaten to total vegetation available for eating calculates a proportional amount of vegetation eaten for each plant functional group. This assumes that animals have equal preferences with regard to the palatable vegetation provided by each functional. The damage function determines grazing mortality and final vegetation loss for each functional group ($PBLOSS_{PFG}$) is subtracted from PB_{PFG}.

Animal production sub-model

The animal production sub-model simulates the births, deaths and removal of livestock in the communal and private farming sectors. It uses the FPA ratio (grazing model) as a proxy for animal condition that informs birth rates, mortality rates and off take decisions. Although the sub-model framework is identical for both the communal and private farming systems, the off take rules and variable parameters differ.

Simulation begins with a stock of adult sheep and goats ($ANI_{species}$) which produce offspring according to the equation:

$$Births_{species} = ANI_{species} \times EWEP_{species} \times BR_{species} \qquad (8)$$

where $EWEP_{species}$ is the proportion of ewes in $ANI_{species}$ and $BR_{species}$ is the birth rate for each species in each land use sector. The birth rate is defined by the relationship between maximum and minimum birth rates under different FPA conditions. That is, when enough food is available to meet maintenance needs (FPA>1) the birth rate is at the maximum. When FPA < 0.6, only 60% of the animals maintenance needs are met and a 2% birth rate is assumed. When food is above the minimum (60% of maintenance) but below the maintenance requirements (FPA =1) the birth rates are estimated by a linear relationship between the FPA and the maximum (BR_{SPMAX}) and minimum birth rates. The offspring are classified as juveniles for a period of six months until they are weaned. During this period the total number of offspring ($Births_{species}$) are reduced through mortality and off take. As with the birth function the mortality function describes the mortality with reference to the FPA. Minimum mortality occurs when maintenance needs are met but when food is below the maintenance requirements the mortality rate is defined by a linear relationship between the minimum mortality rate and the FPA. At the end of the six-month period (half a time-step) the farmers remove a certain number of the male weaned animals. The off take of weaners differs for the private and communal farmers but both follow the formulation below:

$$OFFTAKE_{JUVSP} = JUVSTOCK_{SP} \times SEXR_{SP} \times JUVP_{SP} \qquad (9)$$

where $SEXR_{SP}$ is the percentage of males in the stock of surviving juveniles ($JUVSTOCK_{SP}$) and $JUVP_{SP}$ is the percentage of the males removed. The remaining weaned animals are left to mature for a 12-month period. During this time the only reduction in their numbers occurs through mortality. As with offspring mortality the mortality of weaned animals is a function of the FPA. If food requirements are met, animal mortality is at its minimum level (AMR_{MIN}). If the food supplied is only enough to meet the minimum animal condition allowing for survival (AC_{MIN}) then animal mortality is at its maximum level (AMR_{MAX}). However, if the FPA is between the maintenance and minimum conditions the mortality rate is defined by a linear relationship between the FPA and minimum mortality.

The remaining population of weaned animals matures after 12-months and joins the other animals in the adult class. These animals are reduced through mortality (identical to the mortality function for weaned animals) and off take. As with the other variables defining animal production, off take decisions are governed by the FPA. Private farming was modelled using the recommended stocking rates suggested by the Department of Agriculture. Hence, when conditions are favourable ($FPA \geq 1$) farmers will remove animals such that the recommended stocking rate (RSR) is maintained. However, if the supply of food is slightly below the amount required to meet maintenance needs farmers allow the condition of their animals to fall below FPA =1 but not below a minimum condition (MINCOND). Thus, when FPA is less than maintenance but larger than the minimum condition, farmers remove animals as if maintenance requirements were met.

Therefore, recommended stocking rates are maintained when maintenance and minimum condition requirements are met. However, the animal condition is lower for the latter situation and prices reflect this. In cases where livestock numbers have been reduced below the recommended level, farmers will reduce off take during good years to allow for stock numbers to reach recommended levels. When the FPA is below the amount needed to keep animals at the minimum condition, farmers remove all animals such that a maximum number of animals can be maintained at the minimum condition.

Communal farmers produce animals with the objective of maximising herd size. Thus, herd management follows an ecological tracking system whereby the maximum number of animals the vegetation can support are kept. Farmers do, however, remove animals to meet costs and some subsistence needs. Hence, a base off take ($OFFBASE_{SP}$) is subtracted from the adult population (AN_{SP}) annually. Communal farmers use the milk produced by goats. The production of milk for human consumption was simulated by assuming that the demand for milk by the inhabitants of the area (population x annual quantity demanded per person) would only be met when the goat population was at least 50% of the initial population (ANI_{GOAT}) and when birth rates were at least 45%. If these conditions were not met the production of milk for human consumption was assumed to be zero.

Resource use sub-model

The resource use sub-model simulates the demand for resources in the communal and conservation sector. For communal areas the demand for medicinal plants, firewood, crop production, construction materials, livestock numbers, and donkey services are described (see also James *et al.*, 2004). The demand is expressed per person and extended to the entire communal area by multiplying it by the total user population. Table 3.2 lists the resources, their uses, the units of demand and the method of obtaining total demand where the total population in the communal area (POP_{COM}) is assumed to be growing by 2% per annum (Central Statistical Services, 1996).

Crop production differs from the other communal area resources in that the level of production is not a function of the population size but rather a function of winter rainfall, which farmers use as a cue for production. Hence, crop production is determined by the relationship between the maximum number of hectares sown (HS_{MAX}), minimum number of hectares sown (HS_{MIN}) and the amount of rain falling in winter. Thus, when winter rainfall is high (RF_{WINTER} >150mm) the maximum number of hectares is sown. When it is low (RF_{WINTER} <35mm) the minimum number of hectares is sown and if rainfall is between the minimum and maximum levels the number of hectares sown is determined by a linear relationship between the three variables. The total number of hectares sown is divided between the four crops (wheat, oats, barley and rye) according to a fixed proportion ($CROP_{TYPE}$) which represents the average contribution each crop made in the area over a six year period.

For the conservation sector, the only user group included are tourists, whose numbers are a function of the quantity of flowers (annuals) on display. If a poor flower season occurs ($PB_{ANNUALS}$ < 150) a minimum number of tourists visit ($VISIT_{MIN}$) the area. However, if an excellent flower season occurs ($PB_{ANNUALS}$ >350) a maximum number of tourists visit ($VISIT_{MAX}$) the area. For flower seasons between the minimum and maximum quality the number of tourists is estimated from a linear function with number of visits dependent on the quality of the annual displays.

Table 3.2. Resources used, their units and total demand in the communal areas of Namaqualand. Plant resources are expressed for each plant functional group. POP_{COM} is the number of people living in the communal areas.

Resource	Use	Units	Total demand
Plants	Medicinal plants	$kgDM.person^{-1}.yr^{-1}$	Units x POP_{COM}
	Firewood	$kgDM.person^{-1}.yr^{-1}$	Units x POP_{COM}
	Construction materials	$kgDM.person^{-1}.yr^{-1}$	Units x No. farmers
Grazing	Sheep and Goats	$No.\ animals.person^{-1}$	Units x POP_{COM}
	Donkeys for transport and collecting firewood	$km.person^{-1}.yr^{-1}$	Units x POP_{COM}
	Donkeys for ploughing	$ha.yr^{-1}$	Total for all crops
Croplands	Wheat, oats, barley and rye production	$ha.yr^{-1}$	Total production is determined by the area of each crop sown and the amount of winter rain (see text)

Valuation sub-model

The valuation sub-model calculates the revenue and costs for each land use sector. All values calculated are direct use values and are reported in 2001 $US prices where $US1 = ZAR10. Final values are obtained using a simple revenue (quantity x unit price) less running costs formula. Thus, three types of information are required for each resource: quantity, price and cost. Quantity is expressed at the hectare level; price at the unit level and cost at the person, unit or animal level. Hence, cost varies in accordance with the level of use. In reality, prices and costs vary over time in response to changes in supply, demand and quality. Furthermore, rural, land-based production systems function under conditions where prices vary dramatically (Campbell *et al.*, 1997). However, there are no data for the region describing the movement of prices over time. Inflation indices that correspond to the three production sectors are also unavailable and the demand for the resources is low relative to the supply. All prices reported are constant real 2001 prices. This is true for all resources except firewood and livestock where declining supplies of firewood and variations in meat prices in response to quality are too significant to ignore.

The private farming sector value is derived solely from the production of sheep for meat sales. The animal production model supplies the number of adults ($OFFTAKE_{ADSHEEP}$) and weaned animals ($OFFTAKE_{JUVSP}$). These animals are assigned an average off-the-bone meat weight ($KGMEAT_{AGECLASS}$) that fluctuates in accordance with the animal’s condition (FPA). That is, the FPA is multiplied by the $KGMEAT_{AGECLASS}$ to obtain a real number of kg per animal. Upper (1.4) and lower (0.4) limits are, however, placed on the affect of FPA on animal weight and meat quality. Similarly, the average kg price for adults and juveniles ($PKGP_{AGECLASS}$) decreases by 20% when the FPA < 0.80, increases by 20% when the FPA >1.1 but < 1.3 and falls by 5% when the FPA > 1.3 as the meat contains too much fat. For FPA between 0.80 and 1.3 the price for adults and juveniles is given by equations 10 and 11 respectively.

- $PKGP_{ADULT} = 9.77 \times FPA + 3.9$ (10)
- $PKGP_{JUV} = 11.803 \times FPA + 4.27$ (11)

Both capital ($CAP_{PRIVATE}$) and running ($RUN_{PRIVATE}$) costs are estimated at the animal level and subtracted from the total revenue according to the formulation above. The values obtained for the communal area are derived from a suite of resources. Some of these resources are used as inputs into the production of other resource products and services. For example, crops are produced as fodder for livestock. In order to avoid double-counting the benefits from resources used as inputs, no revenue is calculated for these products. For example, when considering crops, the value they create is captured by increased livestock production. If their value were to be calculated separately, the benefit from crop production would be captured twice. Thus, for these products (construction materials, crop production, donkeys used for firewood collection and ploughing,) no revenue is estimated but the production costs are calculated and subtracted from the relevant production process. The remaining resources (livestock, milk, firewood, medicinal plants and donkeys used for transport) have separate values calculated using the standard formulation above.

For all products, unit costs and where applicable prices, are obtained from James *et al.* (2004). Firewood prices are assumed to vary with the supply of firewood. If the biomass of firewood (PB_{TREE}) is above 500 $kgDM.ha^{-1}.yr^{-1}$ the average value of firewood (FWP_{AVE}) decreases by a fixed proportion (FPP), and yields a minimum firewood price (FWP_{MIN}). However, if the supply is below 100 $kgDM.ha^{-1}.yr^{-1}$ the average value of firewood (FWP_{AVE}) increases by a fixed proportion (FPP) and yields a maximum price (FWP_{MAX}). For PB_{TREE} values between 100 and 500 $kgDM.ha^{-1}.yr^{-1}$ the price is estimated by a linear relationship that expresses the maximum and minimum prices against biomass. The fixed proportion variable (FPP) allows for the investigation of different price fluctuations.

The method for obtaining communal livestock values is similar to that used for the private sector. That is, costs are expressed at the animal level and prices vary with animal condition. However, communal farmers own goats and sheep and sell whole animals and not kg of meat, although in some cases buyers do calculate the selling price on an average per kg value. An average price per animal ($PPA_{SPAGECLASS}$) was obtained and varied in accordance with the FPA. When the FPA > 1 the price increased. If the FPA < 0.7 the price decreased and when the FPA was between 0.7 and 1 the average price per animal was received. As with the firewood price, no data is available to calculate the magnitude of the price fluctuations and a range of price variations was therefore simulated.

The conservation sector value is obtained from tourist expenditure and funding derived from state and foreign donor agencies. The revenue accruing to this sector is apportioned according to the money spent in the conservation area by tourists, the expenditure of tourists during their entire holiday in Namaqualand and funding revenue. For the former two values the average expenditure per tourist in the conservation areas (EXPCONS) and the average expenditure per tourist per holiday (EXHOL) were multiplied by the number of visitors. The annual value of funding was determined by linearly depreciating the total amount provided by the duration of the project. The running costs of the conservation areas for the 2001/2002 financial year were subtracted from total revenue to obtain an annual value, which was divided by the number of hectares under conservation to yield a per ha value.

The comparison of the value of each production sector was based on the Net Present Value (NPV). The NPV is defined as the difference between discounted benefits and costs over time. It was chosen to compare the different sectors over the benefit/cost ratio and internal rate of return methods, since the former is a relative measure most effective for evaluating projects of different sizes and the latter measure is problematic when benefits and costs of a system vary over time (Campbell *et al.*, 2002; Veeman and Luckert, 2002). Because the values projected are used to assess the benefit that households obtain for one hectare and over time, the NPV approach was taken. A range of inflation free prices (real 2002 values) and discount rates were used.

RESULTS

Vegetation condition

Although the plant sub-model simulates the behaviour of each functional group, the quantity of edible vegetation is used to demonstrate the productivity and sustainability of each land use sector over time (Fig. 3.2). The quantity of edible vegetation is highest in the conservation sector. Inter-annual fluctuations occur in response to rainfall but these variations do not cause instability amongst the plant functional groups. The relatively high production and quality of vegetation in the conservation sector draws visitors to the area and is sustained over 30 years. The vegetation in the private farming sector follows what would be expected if the Department of Agriculture's recommended stocking rate were applied. A sufficient quantity of edible vegetation exists and increases over 30 years. Recommended stocking rates ensure that the palatable plant guild remains dominant in the landscape and enables this guild to out compete the unpalatable guild, thus increasing the quantity of edible vegetation over time. In contrast, the communal areas in the model are heavily stocked at roughly twice the recommended rate. Under these conditions, the quantity of edible vegetation is low and decreases slightly over time since unpalatable plants are dominant and increase over 30 years. However, the decrease in the quantity of edible vegetation is relatively slight and is sustained over the time period investigated.

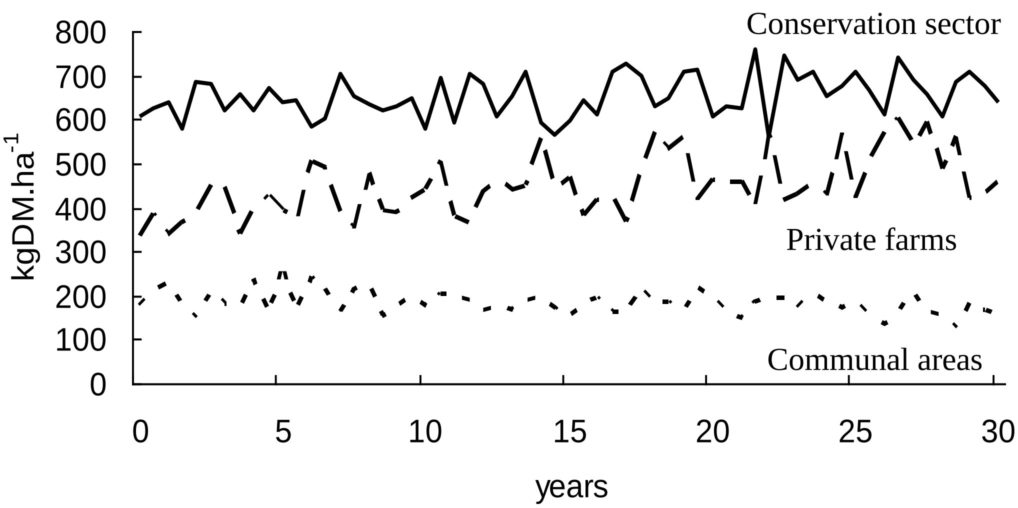

Figure 3.2. The quantity of edible vegetation (kgDM ha^{-1}) in each land use sector over 30 years.

Adult animal numbers and condition

Although herds are comprised of different animal age classes, the adult ewe population constitutes the productive capacity of these herds. Since ewes dominate adult populations in both the communal and private farming areas, the number of adults is used to discuss the productivity and sustainability of livestock production in these two sectors.

Animal numbers are controlled by the amount of edible vegetation available and the farmer's management systems. Hence, for communal farmers, the maximum number of animals the vegetation can support is maintained, regardless of animal condition. Both sheep and goats are farmed and although numbers fluctuate above and below a mean number no decreasing or increasing trends are evident (Fig. 3.3). However, for a more complete understanding of changes over time, the condition of these animals needs to be investigated. The FPA (ratio of supply vs. demand) is used as a proxy for animal condition where an FPA of one describes an animal at maintenance condition. Fig. 3.4 indicates that animal conditions in communal areas fluctuate wildly between 95% and 80% of maintenance. For all time periods animal condition is lower than ideal and fluctuates in response to the condition of the vegetation although no declining trends are noticeable over the time period investigated with the model.

The private farming system differs from the communal system in the model in that animals are kept at the recommended stocking rate of 42300 sheep thus preserving the maintenance condition of their animals. Under this management system adult animal numbers and animal condition are easily maintained over the simulated period at this level. Furthermore, the good vegetation condition in this sector means that animals are better able to absorb exogenous shocks (e.g. severe drought, sudden cold weather) than animals in communal areas.

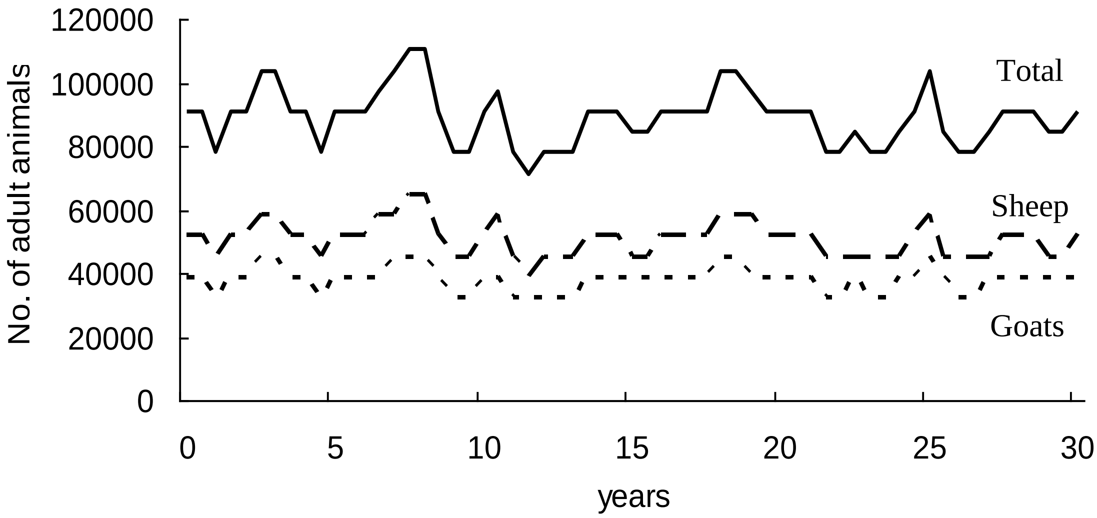

Figure 3.3. The number of adult sheep and goats as well as the total number of animals over 30 years in the communal area.

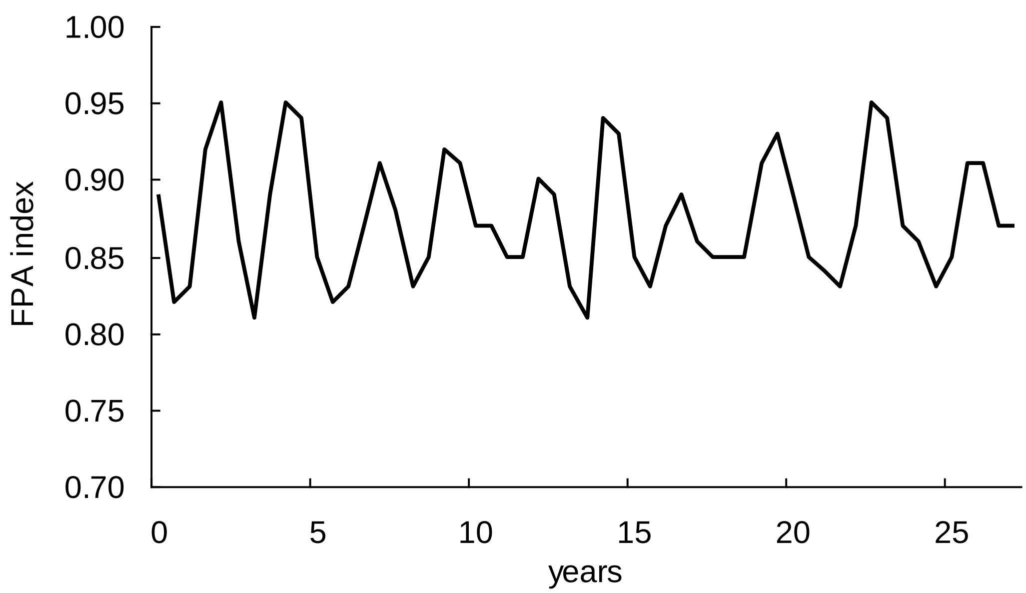

Figure 3.4. The ratio of food supply versus food demand (Food Per Animal (FPA) index) for animals in communal areas over 30 years.

Hectare values

Because the private farming sector improves the condition of the vegetation and maintains the number and condition of the sheep, the profits from this sector are constant under the constant real price system modelled. If running costs are subtracted from revenues, farmers make approximately \$1.5 ha^{-1} but when capital costs are included per hectare profits fall to approximately \$1 ha^{-1}. Comparisons with the other sectors are made with the former value.

The values reported for the communal area include those derived from livestock production as well as those from firewood, medicinal plants and the services of domestic donkeys (primarily for transport and ploughing) (Fig. 3.5). Livestock prices were allowed to vary by 50% above and below a mean price in response to animal condition. Livestock production generates values that vary from year to year but do not exceed \$0.5 $ha^{-1}.yr^{-1}$ or decrease below \$0 $ha^{-1}.yr^{-1}$. Furthermore, the initial value for firewood, medicinal plants and donkey services is roughly double that of livestock production. Firewood contributes more than 90% toward this value and the linear increase in value of these services is due to increased demand for firewood from a population that increases by 2% per annum. None of these services, including livestock production, show a declining trend and never decline below \$0 $ha^{-1}.yr^{-1}$. They can therefore be viewed as sustainable. Livestock values for communal areas are at best 30% of those generated by private farmers. However, when all resources used in the communal areas are combined their values are initially lower but increase over time and after about 20 years become larger than those for private areas.

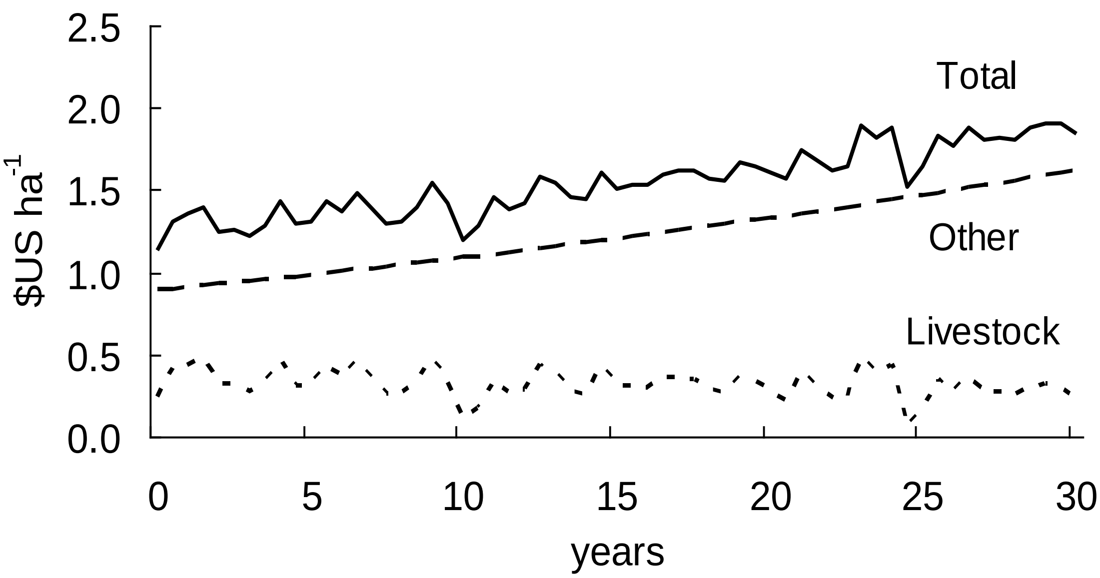

Figure 3.5. The profit (per ha) for the communal sector derived from livestock production and "other" services including firewood and medicinal plant use and the services of domestic donkeys.

Three values are presented for the conservation sector (Fig. 3.6). Firstly, a revenue less running cost value, defined as "profit", is described where revenue accrues from fees charged by the sector for any good or service delivered to tourists. The returns to the conservation sector are negative and profits range from -$1 $ha^{-1}.yr^{-1}$ to -$1.5 $ha^{-1}.yr^{-1}$. Therefore, if the conservation sector value is defined in a similar manner to the private farming sector the returns will always be negative. In a second analysis, this value was extended to include the contributions of foreign and state funding administered by the sector. Very high values are received at first, but as funding is only received for short periods of time, the value falls dramatically. If future funding is forthcoming, it is likely that hectare values will respond in a similar manner to the initial values in 3.6. However, it is difficult to predict or model the occurrence of future funding and this paper treats funding as an exogenous shock that is external to the productive value of the sector. The final value described for the conservation sector is the expenditure by tourists visiting the sector on goods and services outside of the sectors boundaries (e.g. accommodation, petrol, food and other goods and services). Under this analysis the hectare value for the conservation sector ranges from $2 $ha^{-1}.yr^{-1}$ - $4 $ha^{-1}.yr^{-1}$ depending on the number of tourists visiting the region. If this revenue is included the conservation sector will receive positive profits that are comparable with, and generally even higher than the other sectors.

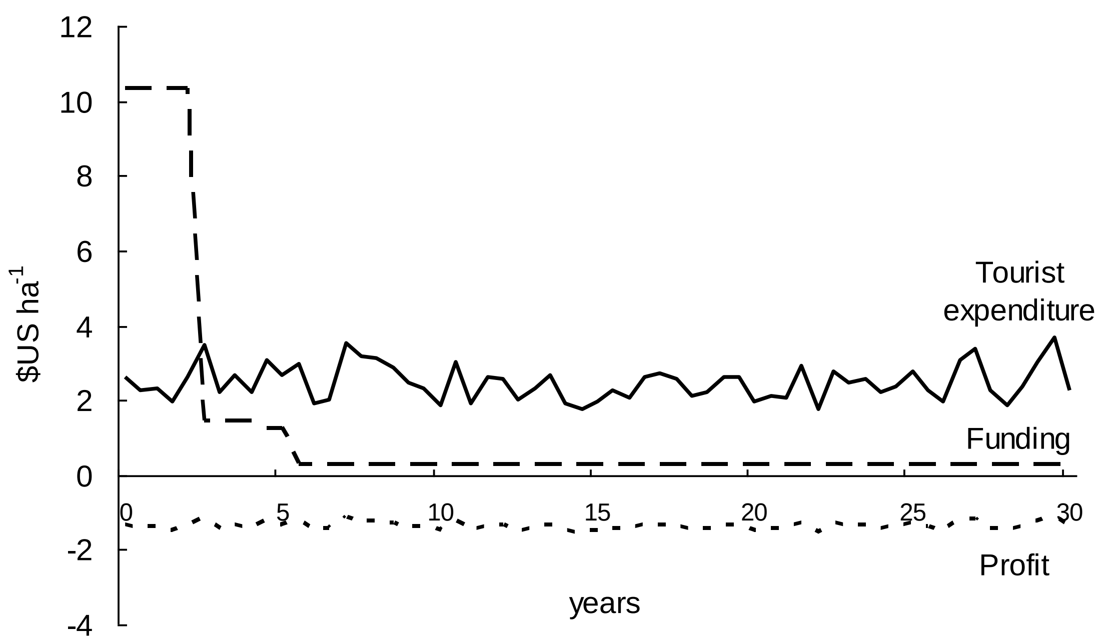

Figure 3.6. The values (per ha) generated for the conservation sector over the 30-year period. "Profit" is a revenue less running cost value, "funding" includes contributions from local and international conservation donor agencies and "tourist expenditure" includes money spent by tourists on goods and services outside of the formal conservation sector.

Net Present Values

The Net Present Values (NPV) of the communal, private and conservation sectors were determined using a 17%, 10% and 5% discount rate respectively. These discount rates reflect the preference participants in each sector place on future streams of income relative to present income. Fig. 3.7 shows how for each time period the NPV for the communal area is higher than that for the private sector. Even though the initial hectare values are higher for the private farming sector the result below is not surprising since communal area farmers will discount future earnings more than private farmers and demand for communal resources increases with population. The net value for the conservation sector includes the tourist expenditure value and profit but ignores funding. Future earnings are valued highly by the conservation sector and as a consequence NPV increase considerably over time and are far larger than those for the other sectors. This high value relies solely on the value of tourist expenditure and indicates the value and potential of this benefit to the region.

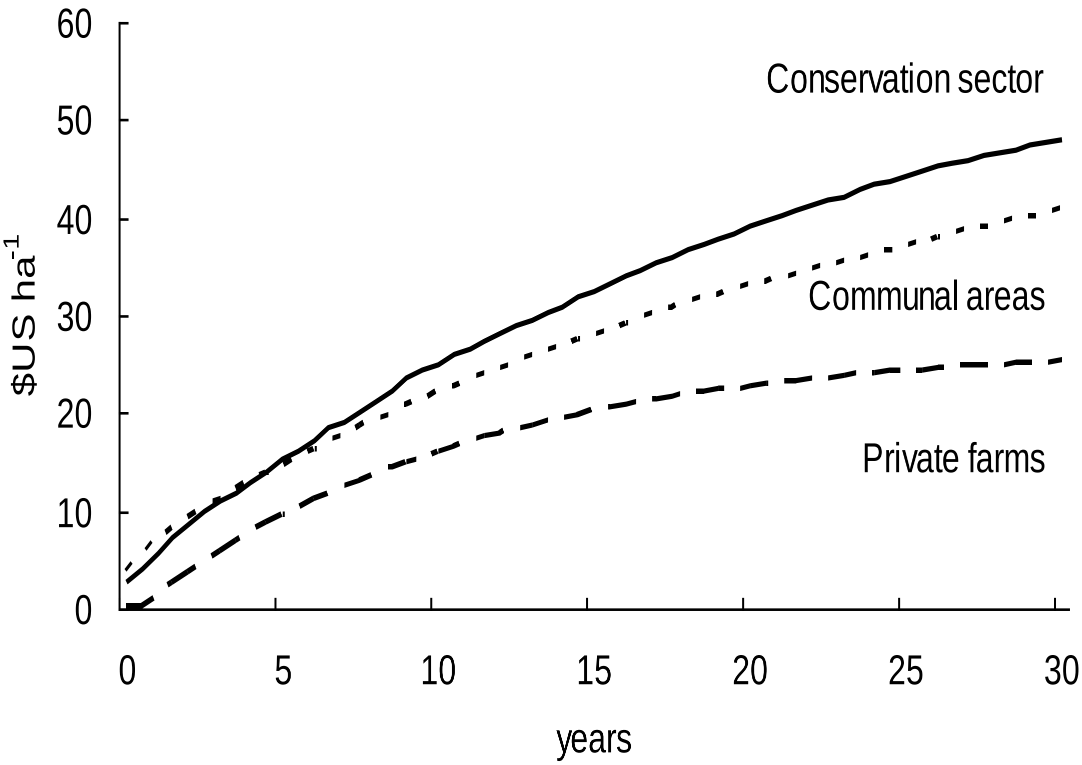

Figure 3.7. The Net Present Value (NPV) of each land use sector over 30 years.

DISCUSSION

Models represent a trade-off between realism, generality and precision (Higgins *et al.*, 1997). All models compromise some of these attributes in favour of others. Deciding which attributes to focus on is generally dictated by the availability of data and the objectives of the model. For this model the objectives for the three sectors simulated were the same but the quantity and quality of the data available for each sub-model and land use sector varied considerably. Although this is problematic, it is unavoidable when modelling a wide range of processes and we believe it did not impact severely on the findings of the model.

Sustainability and productivity

Combining the results yields insight into the sustainability and productivity of each land use sector. The productivity and sustainability of the private farming sector cannot be doubted. If farmers keep livestock numbers within the recommended stocking rates edible biomass will be maintained, animal populations will remain at a constant desired condition and profits will be maintained indefinitely. However, other factors, such as the influx large quantities of cheap foreign meat, could have a severe impact on this sectors' functioning but were not included in this model. Based on the current management system, vegetation condition, and the cost and price assumptions used in this model, the private farming sector will remain productive, profitable and sustainable over the long term.

The communal area sector is more complicated. Profits are positive and remain positive over the period modelled for livestock and other resource production processes. Although the number of adult animals is not constant it does not show a declining or increasing trend over time. However, the condition of the animals fluctuates in response to the fluctuation in vegetation conditions. Communal farmers attempt to maximise herd size and not meat production, hence fluctuations in animal condition and herd size are to be expected. Given their production objectives of many people in this sector and the maintenance of positive, albeit fluctuating profits over the period of the model, land use practices in the communal areas of Namaqualand can be considered sustainable. However, as with the private farming sector this statement is only valid given the management system, condition of the vegetation and cost and price assumptions used. As with the private farming sector no exogenous impacts (e.g. mine closure, climate change) were modelled. Clearly, the communal system will be far more vulnerable to such changes than the private farming sector since the quality of the vegetation is far worse, animal conditions fluctuate and the profits from livestock farming are not large enough to withstand any serious price or cost distortions. Given the rather weak potential of the vegetation to produce food it seems unlikely that communal areas are as productive as they could be but under the present circumstances it is unlikely that productivity will increase.

For the conservation sector the "profit" value is negative and will only increase if costs are reduced, tourists spend more time and money in the area or if more tourists visit the area. Thus, the productive value of one hectare of land in the conservation sector is negative if one follows a strict revenue less running cost scenario. This treats the conservation sector in the same way one would treat a business. However, the functioning of a conservation area and its employees goes beyond the running of a business and includes development initiatives and acts as a magnet that draws tourists into the region. The productive value of one hectare of conservation land could therefore include both the funding and wider expenditure revenues. Under this definition the benefits derived from conservation are large, sustainable and impact on a great number of people in a range of sectors (local communities, business and private farmers).

Comparisons

Although direct comparisons between the three different sectors are problematic, it is possible to make qualified comparisons. For example, the communal area per ha value and NPV is higher than that for the private farming sector. However, this comparison might be considered unfair since a detailed inventory of communal area resource use was obtained and compared against the benefits derived from livestock production only in the private farming sector. Since the values do not differ substantially it would be presumptuous to declare communal areas more valuable. Furthermore, less than 30% of the communal values are cash values (the remainder is generated through bartering, gifts and other non-cash transactions). Hence, the bulk of the communal area values are "locked" into the communal trade system and only 30% of the total value can leave this sector and enter into other economic sectors (for example, trading with local business). In contrast, all of the private farming value calculated is a cash value that has larger implications for the regional economy of Namaqualand. Cash and non-cash values have different utilities and respond differently to exogenous forces. Hence, comparing these sectors and making direct comparisons is problematic. Even though a hectare of communal land generates benefits that may even be higher than the benefits generated by a hectare of private farm land, on a regional scale, private farmers may contribute more to the economy, since the benefits they receive are paid in cash. However, communal areas support orders of magnitude more people than private farming areas and this should also be considered in comparative analyses.

Comparisons for the conservation sector are more complicated since it is not clear which values to include. Depending on the definition used, conservation areas confer benefits that value between \$1 $ha^{-1}.yr^{-1}$ -\$11 $ha^{-1}.yr^{-1}$ and represent the most valuable sector in the region. However, funding values are an exogenous income source and expenditure values are those that arise to individuals outside the sector. For a fair comparison with the other sectors any state funding or subsidies and any economic transactions outside of the boundaries of the private farm and communal area sectors would have to be incorporated as well. Hence, only the profit estimation is comparable but this results in a negative value for the conservation area and obscures the many benefits derived through the existence of this sector in the region.

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REPORT 4

The effect of three livestock management strategies within four planning scenarios on plant, animal and economic indicators in a communal area of Namaqualand, South Africa.

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INTRODUCTION

Land use practices are not static in time but change in response to environmental, social and economic circumstances. External shocks such as drought, political change or global currency exchange rates can have far-reaching implications for local people's livelihoods and the way in which they manage their resources (Ellis and Galvin, 1994). Understanding the influence of such events on local environments and local economies under a range of different management options is essential for sound planning purposes. It provides state and provincial departments and local municipalities, which hold responsibilities for agriculture, tourism, environment or labour, for example, with the ability to predict the outcome of certain events and to adjust their policies accordingly so as to mitigate their harmful effects on people's lives.

In Namaqualand, South Africa, 45% of the population live in six main communal areas comprising about 25% of the land area (Hoffman *et al.*, 1999). The region has experienced a high level of volatility in the last decade with severe droughts in 1998 and 2003, a significant increase (by 330,000 ha) in the size of the area available to livestock farmers in communal areas and a substantial downscaling of the mining sector, which has been the economic mainstay of Namaqualand for several decades. Several livestock management strategies have either been implemented or proposed to cope with these changing circumstances on both the former communal areas as well as the "new" land reform farms. In addition, there is considerable debate in the range science literature about the best option for managing both livestock and the environment in Africa's communal areas (see Morton and Barton, 2002). One view is that livestock numbers should closely track environmental conditions with farmers selling or moving just before a drought and rapidly increasing the herd immediately after a drought (Behnke and Kerven, 1994). In an analysis of a data set from Zimbabwe, however, Campbell *et al.*, (2000) have argued that this approach is inappropriate and less economical than a conservative stocking strategy which maintains animal numbers at a constant level significantly lower than that which can be supported by available biomass. We address some of these issues and investigate the effect of three management strategies on plant and animal production in the communal areas of Namaqualand as well as their economic viability over 30 years under four scenarios which appear likely for the region.

METHODS

Model description

The Upland Succulent Karoo Land Use Model (USKLUM, see Report 2) developed in STELLA (High Performance Systems, 2000) at a collaborative workshop was used. Model dynamics occur on a per hectare basis with an annual time step. Thirty years of model output were presented since this reflects reasonable long-term planning horizons for the region. Starting conditions for the vegetation reflect current annual biomass production estimates for communal areas in Namaqualand of about 200 $kgDM.ha^{-1}.yr^{-1}$.

Management strategies

USKLUM was run for Namaqualand’s communal areas under three livestock management strategies: Opportunistic Strategy (OS), Conservative Strategy (CS) and Tracking Strategy (TS). These conform broadly to the strategies outlined in Campbell *et al.*, (2000) and use the same terminology. The OS management system represents the current farming system or status quo, where communal farmers maximise herd size by stocking rangelands close to the ecological carrying capacity (the largest number of animals the vegetation can support (see Behnke and Scoones, 1993)). The only animals removed are for own-consumption and sales to meet production costs. Under the CS management system farmers reduce and maintain livestock at the level recommended by the Northern Cape Department of Agriculture. Herds are kept at the recommended level if the vegetation can support and maintain these animals at a maintenance condition which is the condition at which mortality is minimum, fecundity maximum and animals produce an optimal quantity of meat. Maintenance condition is achieved when the quantity of food supplied equals the quantity of food demanded, indicated in USKLUM when the food per animal ratio equals 1 (FPA=1). If the condition of the vegetation is such that the recommended number of animals cannot be maintained at FPA=1 then the maximum number of animals that can be farmed at the maintenance condition are kept. This represents a commercial farming system operational on most private farms in the region and aims to maximise the production of good quality meat for market sale. The TS management system (equivalent to Campbell et al., (2000) “Tight Tracking scenario” is a compromise between the OS and CS management systems. Farmers under TS attempt to maximise herd size subject to a minimum animal condition. The minimum condition is defined as 80% of maintenance condition (FPA=0.8). Thus, under the TS management system herds are not kept at the recommended level or at the ecological maximum but at some point between these two where large herds are at least in a condition which is 80% of the maintenance condition. A base number of animals for own-consumption and running costs are removed and when conditions deteriorate the maximum number of animals that can be maintained at 80% of maintenance are kept.

The proportion of ewes in a herd is 80% for the OS and TS management systems and 95% for the CS management system which reflects current ratios in communal areas and private farms. Juveniles were removed from the animal population according to the formulation below:

$$OFFTAKE_{JUVSP} = JUVSTOCK_{SP} \times SEXR_{SP} \times JUVP_{SP} \qquad (1)$$

where $SEXR_{SP}$ (assumed to be 50%) is the percentage of males in the stock of juveniles ($JUVSTOCK_{SP}$) and $JUVP_{SP}$ is the percentage of the male juveniles removed (40% for the OS and TS and 50% for the CS). The remaining population of weaned animals is left to mature for a 12 month period. During this time the only reduction in their numbers occurs through mortality. Adult animals are reduced through mortality and off-take. For the OS and TS management systems an annual constant number of adults are removed to meet own-consumption and cost needs. Under the TS management system any animals remaining after the base off-take that cannot be maintained at a minimum condition of 80% of maintenance are removed. Farmers sell animals when conditions deteriorate and herds are maintained at a condition equal to at least 80% of maintenance. Similarly, the off-take of adults under the CS management system requires that when conditions are favourable the recommended number of animals are kept at FPA=1. If it is not possible to maintain the recommended number of animals, farmers allow animal condition to decline by 10% (FPA=0.9) and maintain recommended herd sizes. If conditions deteriorate farmers sell all those animals that cannot be maintained at the condition of FPA=0.9.

Scenarios

Four scenarios are tested. The first investigates current conditions in the communal areas of Namaqualand (see Rohde *et al.*, 2003). The second explores the effects of a once-off, 20% increase in stock numbers that might occur, for example, if a significant number of retrenched mine workers invest their severance packages in livestock. A once-off reduction in stock numbers to recommended levels is addressed in the third scenario. This might occur if, for example, provincial or municipal governments insist on a reduction in stock numbers before drought aid or infrastructural investment is provided. Finally, the impact of a 20% reduction in annual rainfall combined with a 25% increase in the coefficient of variation (CV) of rainfall is explored in the final scenario. Such future climatic scenarios have been discussed by several authors (Midgley *et al.*, 2001; 2002)

Indicator variables used to test the efficacy of each management system

Three variables are used to explore differences between management systems under each scenario. Firstly, the quantity of edible vegetation ($kgDM.ha^{-1}.yr^{-1}$) is used as an indicator of the relative productivity of one management system to another as well as the sustainability of the farming system over 30 years. Second, the number of adult animals is also used as an indicator of productivity and sustainability. Adult animals are used instead of total animal numbers since ewes represent the productive capacity of a herd and comprise between 80%-95% of the adult population, depending on the management system. Adult animals are also used as an indicator of the quantity of capital savings each management system provides since communal farmers rely on livestock as a store of wealth or form of capital saving from which funds can be appropriated during times of need. This objective is an important reason for livestock farming amongst rural households (Shackleton *et al.*, 2000; Rohde *et al.*, 2003). Third, the net present value (NPV) of each management system discounted at 17% (Campbell *et al.*, 2000) is used to compare the economic viability of each system under each scenario. Livestock values used to generate the NPVs are productive values that include own-consumption, gifts, bartering and local and market sales. The NPVs for the CS management system excludes the initial sale of all animals that need to be sold such that recommended stocking rates can be adhered to. Including the sale of these animals would introduce a capital value into the NPV for the CS management system where no such value is included for the other management systems. All prices are constant real 2000 prices expressed in $US (where $US1=R10).

RESULTS

Vegetation condition

The quantity of edible vegetation produced on a hectare of land under each management system over 30 years is shown in Fig. 4.1. For all scenarios, except the decline in rainfall scenario (Fig. 4.1d), the amount of edible vegetation increases significantly in the CS management system to about 500 kgDM.ha^{-1}.yr^{-1} over the period of investigation. There is little difference between the OS and TS management systems in the amount of biomass produced with both dropping to about 80% of their initial starting conditions after 30 years. A reduction in rainfall amount and an increase in the CV of annual rainfall results in a significant drop in annual biomass production to about 80 kgDM.ha^{-1}.yr^{-1} after 30 years for all management systems investigated.

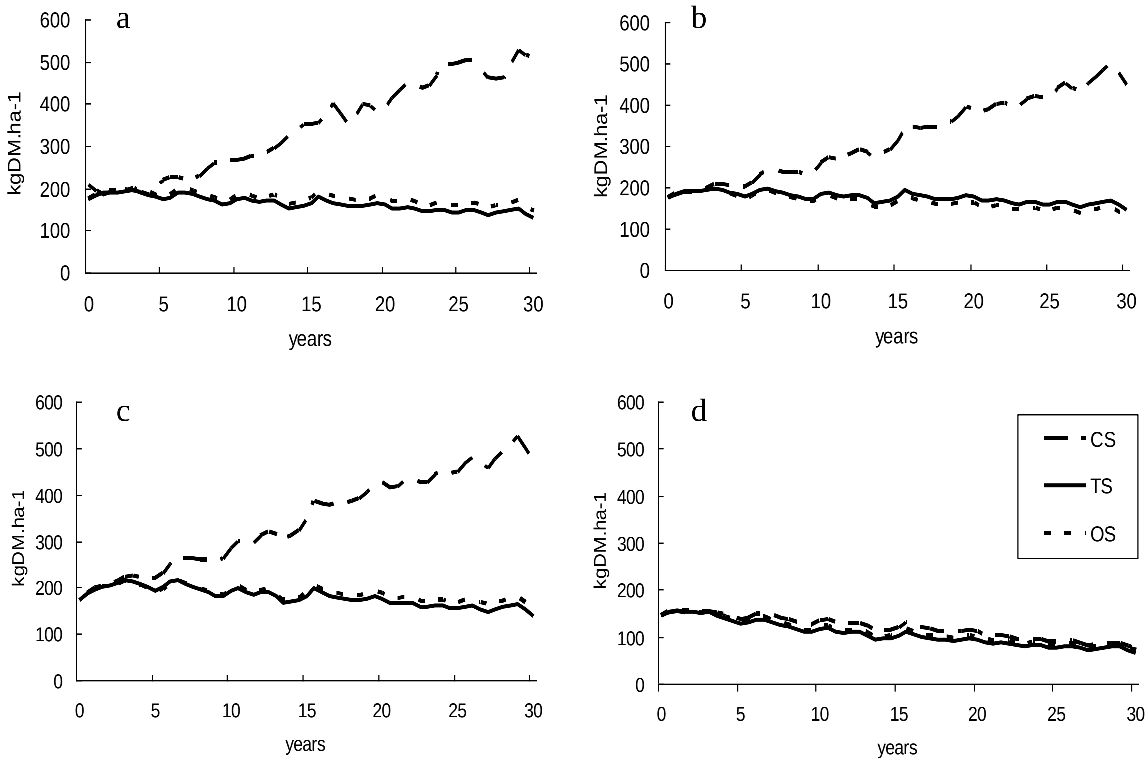

Figure 4.1. The quantity of edible vegetation in kgDM.ha^{-1} in Namaqualand's communal areas under three different management systems (CS = Conservative Strategy; TS = Tracking Strategy; OS = Opportunistic Strategy) for four different scenarios (a) Current conditions; (b) An initial 20% increase in livestock numbers; (c) A reduction in livestock numbers to levels recommended by the Department of Agriculture for commercial farms; (d) A decrease in total rainfall by 20% and an increase in the coefficient of rainfall (CV) by 25%.

Animal numbers

The number of animals over 30 years under each management system in Namaqualand's communal areas is shown in Fig. 4.2. Following an initial selling of animals under the CS management system the number and condition of adult animals are maintained at recommended levels (32 420) for all scenarios (Fig. 4.2a-c) except for climate change (Fig. 4.2d). Under the latter scenario, animals numbers in the required condition decrease by more than 60% to below 13 000 animals. The TS and OS management systems show animal numbers not significantly different from one another for all scenarios investigated. When animal numbers are either initially increased (Fig. 4.2b) or decreased (Fig. 4.2c) they return, after about 10 years, to numbers relatively similar to those where no intervention has occurred (Fig. 4.2a). For the first three scenarios, animal numbers show slight downward trends over the 30 years under both TS and OS management systems. Under the climate change scenario, however, animal numbers decline by more than 50% under both management systems to below 40 000 animals.

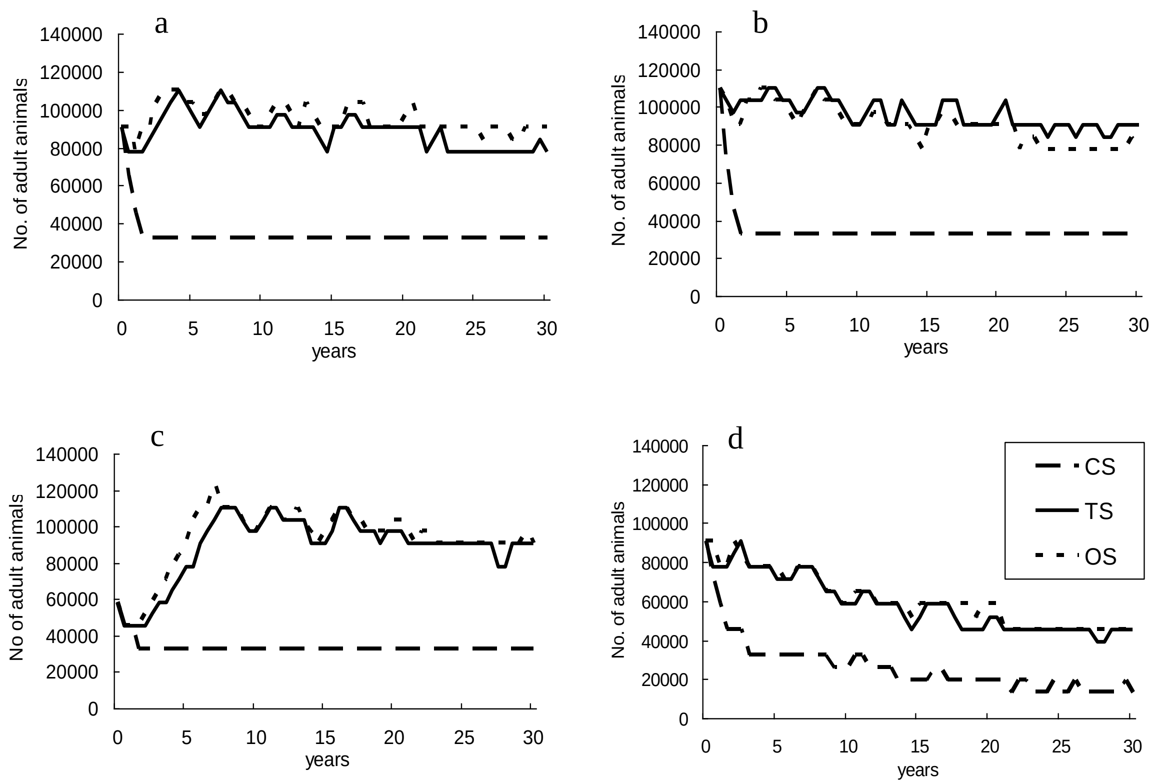

Figure 4.2. The number of adult animals (sheep and goats) kept on 648 400 ha of Namaqualand's communal areas under three different management systems (CS = Conservative Strategy; TS = Tracking Strategy; OS = Opportunistic Strategy) for four different scenarios (a) Current conditions; (b) An initial 20% increase in livestock numbers; (c) A reduction in livestock numbers to levels recommended by the Department of Agriculture for commercial farms; (d) A decrease in total rainfall by 20% and an increase in the coefficient of rainfall (CV) by 25%.

Net Present Value (NPV)

Fig. 4.3 describes the NPV of each management system for each scenario. All NPVs calculated were positive and increased or remained stable over the entire simulated period. Under all scenarios the NPV from the CS management system was highest, followed by TS and the OS management system. The lowest values for the TS and OS management systems occurred for the climate change scenario. Low values were also obtained for the TS management system when livestock numbers were reduced by an initial 20%. This scenario also resulted in the greatest divergence between management systems.

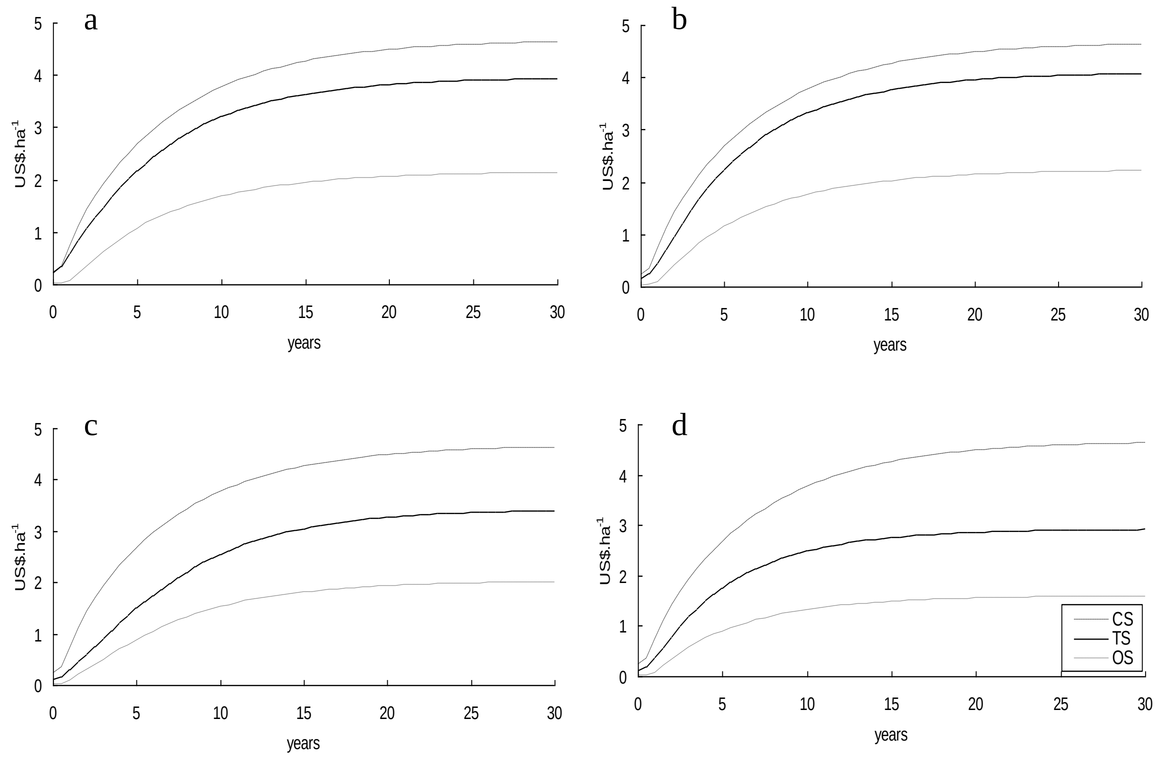

Figure 4.3. The Net Present Value in US$.ha^{-1} for Namaqualand's communal areas under three different management systems (CS = Conservative Strategy; TS = Tracking Strategy; OS = Opportunistic Strategy) for four different scenarios (a) Current conditions; (b) An initial 20% increase in livestock numbers; (c) A reduction in livestock numbers to levels recommended by the Department of Agriculture for commercial farms; (d) A decrease in total rainfall by 20% and an increase in the coefficient of rainfall (CV) by 25%.

DISCUSSION

Vegetation condition

The CS management system requires that animal numbers be maintained at the level recommended by the Northern Cape Department of Agriculture. This is approximately 50% of the current number of animals on Namaqualand's communal areas (Todd and Hoffman, 2000). Since the amount of edible vegetation is influenced by grazing pressure it increases significantly under relatively low stocking rates. However, this assumes that when animal numbers are reduced to recommended stocking rate levels that palatable adult plants are still present in the shrub matrix and when released from grazing pressure will grow to fill the available space. Long-term grazing impacts, however, can reduce the number of palatable shrubs left in a community (Todd and Hoffman, 1999), particularly around stock posts and watering points (Riginos and Hoffman, 2003). Recruitment of palatable plants into transformed landscapes characteristic of many communal areas may, therefore, delay vegetation recovery beyond the 30 years indicated in the model. This is particularly true for leaf succulent plants in the Mesembryanthemaceae. Seeds of plants in this sub-family typically disperse over relatively short distances (2 m or less).

Biomass production under the OS and TS management systems is not significantly different for the first three scenarios. When animal numbers are changed (such as under the 20% increase or decrease scenarios), farmers increase stock numbers or herds are reduced through sales (TS) or deaths (OS). Over a relatively short time of about 10 years, herd sizes return to current levels and the vegetation is maintained at approximately the current condition. For the first three scenarios at least, TS and OS management strategies appear broadly sustainable over 30 years with a relatively modest decline in edible plant production over this time period. In comparison with the CS management system, however, OS and TS keep available biomass production at levels far below the potential productive capacity of the vegetation.

When the total rainfall is reduced by 20% and the CV is increased by 25% biomass production deteriorates significantly under all management systems, even CS. Under such a scenario the management system employed will have little influence over the productive capacity of the vegetation. This result is alarming since long-term rainfall records for Springbok show a roughly 20% decline in annual rainfall between 1878 and 2003. Further deterioration in rainfall could have severe and lasting impacts on the vegetation of the region.

Animal numbers

For all scenarios, the CS management system maintains fewer animals than the TS and OS systems but these animals are in a better condition and able to be sold at commercial markets which price animals based on the quality of their meat. In reality, commercial markets prefer Dorper sheep, bred for their rapid growth and high quality meat production. This breed, however, is difficult to herd and is not as hardy as the hybrid animals comprising Afrikaner, Persian and Karakul breeds which are generally raised in the communal areas of Namaqualand today. Although this level of complexity was not covered by the model it is an important consideration for any policy intervention based on this analysis.

Livestock numbers are similar for the TS and OS management systems because both maximise herd size subject only to the minimum condition constraint set for TS or to the maximum carrying capacity value set under OS. However, because animal condition is better under OS, higher fecundity and lower mortality occurs in this management system. The massive livestock mortalities under a modelled opportunistic selling management system reported by Campbell et al. (2000) were not evident in this analysis for Namaqualand. In addition, under OS, increased animal production means that higher levels of juvenile and adult animal off-take are required to maintain animals at the minimum condition. The obvious increase in sales which becomes possible under TS provides a direct benefit to farmers.

When animal numbers are initially either increased or decreased farmers respond by allowing livestock numbers to either decrease or increase respectively to levels where the maximum number of animals at a minimum condition (OS) or at any condition (OS) can be maintained. Thus, over about 10 years, and without any further intervention, animal numbers return to levels similar to those where no intervention occurred. One important finding from this analysis, therefore, is that irrespective of whether an TS or OS management strategy is employed, livestock numbers are generally sustainable over 30 years under the first three scenarios investigated. There is little suggestion that either primary (vegetation) or secondary (livestock) production will collapse in the communal areas over the period under investigation.

In the climate change scenario explored in this analysis animal numbers decline to between 50% and 60% of their potential over the 30 years under all management systems with some indication that they might stabilise at these lower levels with time. Even when animal numbers are reduced to recommended levels such as under the CS approach, a decrease in the amount of annual rain and an increase in its variability makes it impossible for farmers to maintain animals in a marketable condition. To do this they need to reduce animal numbers even further to cope with the consequent reduction in vegetation production. Under the TS and OS approaches, climate change is equally devastating.

Net Present Value (NPV)

NPV is the difference between the discounted benefits and costs. Any NPV value that is >1 indicates that benefits exceed costs and that a certain approach or system is feasible. Higher NPVs indicate that an approach contains more value or that the benefits exceed the costs by a greater degree than an approach with a lower NPV. A particular management approach is considered more advantageous if the NPV increases or remains stable over time. Higher NPVs indicate a greater contribution towards livelihoods than lower NPVs (Veeman and Luckert, 2002).

In our analysis all NPVs were all positive and either increased or were stable suggesting that all management systems were economically feasible over the 30 year period. The lower values for the OS management system occur because farmers operating under this system remove only those animals that are either consumed or sold to meet the running costs of production. The TS management system not only enjoys increased NPVs through increased off-take but also fosters higher birth and lower mortality rates and improved animal condition. High NPVs for CS systems are due to the large numbers of livestock sold and slaughtered. The positive NPVs under the climate change scenario occur because of the large number of sales under the CS and TS systems and the OS system remains positive since there are enough animals to provide food and revenue.

If NPV is the only consideration with regard to choosing one livestock production management system over another then the CS system would be most preferable, followed by the TS and OS management systems respectively. However, herds represent a capital investment for communal farmers. Large herds are preferable as they allow farmers to access capital or finances during periods of financial stress. The CS management system requires that farmers sell excess animals resulting in far smaller herds. Even though CS animals are in a better condition the very small herds would require excessively high prices before the capital value of these herd became similar to those under the remaining management systems. The average condition and large herd sizes under the TS management system indicate that this system would provide the highest capital savings value under all scenarios except the change in rainfall scenario, where the CS management system would have the highest value.

Productivity, sustainability and value

Deciding on the best management system for the communal areas of Namaqualand requires choosing the management system which optimises all the variables discussed above. The system that maintains or improves the condition of the vegetation, the condition and number of adult animals (productive capacity and capital value) and provides an adequate NPV could be considered the best management system. Under current conditions, increased as well as decreased stock numbers scenarios, the best option would be the TS management system. Model output suggests that vegetation condition does not decline significantly under this approach and animal condition is kept above or at the accepted minimum level. In addition, animal numbers are high and maintained at this level and the NPV of the productive benefits from livestock are relatively high. Although the CS management system leads to improved vegetation condition and a higher NPV, animal numbers are relatively low. Even though animal condition is high the capital value of the herds will be substantially smaller than for the other two management approaches. Under the OS management system, animal conditions are low and capital value may be reduced to a point where reduced earnings (NPV) cannot be accounted for.

The key to a successful TS management strategy, however, is knowing when to sell animals. In the relatively predictable winter rainfall region of Namaqualand this is made a little easier since dry summers are expected each year. The period from October to March is the most crucial for livestock survival and if a poor spring (September to November) precedes the summer then it is probably advisable to sell animals at this time each year. This period also coincides with a high demand for livestock, particularly goats, over the Christmas festival period and Namaqualand areas are ideally placed to capitalise on this market.

Forecasting and scenario planning

Our analysis suggests that if the status quo (i.e. the OS approach) is maintained in Namaqualand, vegetation production will decline slightly over the next 30 years with an associated slight decline in animal numbers. Current levels of grazing will, therefore, not result in the ecological collapse of Namaqualand's rangelands. This supports Shackleton's (1993) view of communal rangelands elsewhere in South Africa. However, the recovery and restoration of these highly transformed and relatively unproductive rangelands is also unlikely in this scenario. In addition, the economic value of this approach is relatively low but by tracking environmental conditions under TS, profits can be boosted significantly while maintaining capital assets. Interventions in this regard could contribute significantly to people's livelihoods in the region. However, more sophisticated marketing strategies, infrastructural spending (e.g. to improve regional road and communication networks) and logistic support (e.g. transport to markets) will be needed to implement this approach.

A once-off increase in livestock numbers, which might occur if a significant number of people invest their severance packages in livestock holdings, does not result in a sustained increase in livestock numbers. After a period of less than a decade livestock numbers return to pre-increase levels. Other opportunities for capital investment should therefore be encouraged amongst retrenched workers who return to the communal areas with their cash payouts. However, there also appears to be little long-term impact on the productivity of the vegetation. Agricultural and natural resource conservation agencies, therefore, need not be alarmed at the long-term impact of a once-off increase in livestock in the region. The vegetation cannot sustain the high number of animals which will return to pre-increase levels with little further impact.

If communal area farmers were to reduce their animal numbers by 20% a significant reduction in profitability for more than 15 years will result. Such a once-off reduction, therefore, has important implications for people's livelihoods (Tapson, 1991). In addition, vegetation condition is not significantly improved and will only do so if this reduction were maintained over the long term such as in the CS approach.

Under the climate change scenario investigated, different management systems have little impact on primary production which declines over the 30 year period of investigation. Adult animal numbers and therefore capital savings also decline and even though the NPVs are positive, the values obtained in the latter years contribute negligibly to total values and in some cases fall slightly. Thus, the year to year viability of livestock production under all management approaches will be severely affected under the climate change scenario investigated in this analysis. This is particularly true if the real constant price assumptions are removed. If climatic conditions change the least vulnerable management system is the CS system but even under this system the long term viability of livestock production is questionable.

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