

**MODELLING THE EFFECT OF PROPERTY SIZE
ON THE OPPORTUNITY COST INCURRED BY
WILDLIFE PRODUCTION**

by

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Submitted in partial fulfilment of the requirements
of the degree of Master of Science
in the School of Environment and Development
University of Natal

Pietermaritzburg

1998

ABSTRACT

It is claimed that high returns can be achieved from hunting and ecotourism operations. As a result wildlife production is a rapidly growing form of land-use in South Africa. Lately, rural African communities have approached regional conservation agencies for aid to establish small game reserves so that they too may benefit from wildlife production. However wildlife operations have high input costs relative to domestic stock operations and no attempt has been made to determine the effect of property size on the costs and revenue generated by wildlife. It is thus necessary to conduct a Cost-Benefits Analysis to ascertain this effect by determining the opportunity cost incurred by choosing wildlife over other land-uses suitable in semi-arid savannas, namely communal subsistence production and commercial beef production.

This project attempts to quantify the revenue generated, and the variable costs and fixed costs incurred by wildlife production, subsistence production and commercial beef production in order to observe their behaviour against property size and by this means to establish the size ranges for which each of the three land-uses is most appropriate. Mathematical modelling is used to define each of the three land-uses and how their revenue and cost curves interact with property size. The resultant profit curves are able to assess only the financial benefits from each of the land-uses to the local community. An assessment of the full economic benefits to the local and broader community would require different criteria and apportionment of costs and revenue.

The effect of property size on fixed costs is the single most important factor which distinguishes the behaviour of the profit curves of the three land-use options: subsistence production has negligible fixed cost input and so is able to achieve greater profitability than either beef or wildlife at small property sizes. Beef has high input costs per hectare at small land sizes which diminish with each unit of additional land. Wildlife operations also have high input costs at small land-sizes which decrease per hectare with additional land added. However due to the service industry nature of wildlife operations, fixed costs increase per hectare after some point (in this case it is assumed to be 2000 ha). This is because the attractiveness of game reserves to tourists increases with size due to the inclusion of “many” species of game, which in turn

increases the number of people entering the park per hectare and as such the fixed cost input required to accommodate those extra people.

The specific results derived from the model indicate that the profit curve of wildlife rises far more steeply than those of either subsistence production or commercial beef production. However, due to the effect of input costs, both commercial beef and subsistence production are more profitable at land sizes of less than 3000 ha. This indicates that investing large sums of money into small game reserves of less than 3000 ha may not be justified on the basis of profits alone.

PREFACE

The work described in this dissertation was carried out in the School of Environment and Development at the University of Natal, Pietermaritzburg, from August 1997 to June 1998, under the supervision of Professor JW Hearne (Department of Mathematics and Applied Mathematics).

These studies present original work by the author and have not otherwise been submitted in any form for any degree or diploma to any other University. Where use has been made of the work of others, it is duly acknowledged in the text.

A handwritten signature in cursive script that reads "Kyle Tomlinson". The signature is written in a dark ink on a plain white background.

ACKNOWLEDGEMENTS

I wish to thank the following people and institutions for their major contributions in different ways to the work presented in this dissertation:

Professor John Hearne for supervision of this project;

The KwaZulu-Natal Nature Conservation Service for providing essential data for the analysis, and particularly the following people who provided assistance: Yvonne van Niekerk, Tanya Oellermann, Ivy Khumalo and Dr Peter Goodman;

The Foundation for Research and Development for providing financial assistance;

Mrs John Bride who has provided financial assistance for this degree and most of my University career and who has always encouraged me to greater achievement;

My Mother, Patricia Tomlinson, for language and grammatical editing to this thesis, and for giving me the room and encouragement to explore my diverse interests.

Finally, on completion of my thesis, to the examiners, Professor Michael Lyne and Dr Pete Goodman, who have given invaluable comments and indicated the weaknesses in my analysis procedure.

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LIST OF SYMBOLS

(Note: symbols are presented in order of their appearance in the text and also classed under specific models where they are particular to those models.)

$WTP(t)$	theoretical economic flow values for a national park at time t
$\Pi(t)$	theoretical economic flow values for cattle grazing at time t
t	instantaneous time (usually referring to a year in time)
i_x	discount rate
PV_T	present value at time $t = T$
α -diversity	number of species within a homogenous community
β -diversity	incorporates the species turnover along habitat gradients and among different communities
CC	carrying capacity
AU	animal unit
CC_{BG}	CC for bulk grazing
CC_{SG}	CC for selective grazing
CC_{Br}	CC for browsing
C_v	variable cost
C_f	annual average fixed cost
S	property size

a. Commercial beef model

P_c	profit generated from commercial beef production
R_b	revenue generated by beef

b. Subsistence production model

$R_{m,t}$	total revenue from milk in year t
SR_t	stocking rate in year t

u_c	average stock unit for weighted population distribution of a subsistence cattle herd
F_i	fraction of animal class i in the population
Y_m	yearly yield of milk per cow
cf	condition factor for animals
SR_d	desired stocking rate
$R_{s,t}$	revenue from sales
s_i	fraction of animal class i that are sold
ps_i	meat sales price for animal class i
ph_i	sales price for hides of animal class i
$R_{sl,t}$	revenue from dead animals
m_i	mortality fraction of animal class i
pc_i	carcass price of animal class i
$C_{p,t}$	cost of cattle purchases in year t
pr_i	purchase rate of animal class i
pp_i	purchase price of animal class i
$R_{a,t}$	revenue from an increase in livestock assets
c_i	number of animals in class i
ix	index representing the amount by which cattle prices increase in real terms
cr	calving rate
wr	weaning rate
cm	calf mortality
hm	herd mortality rate
$R_{d,t}$	potential revenue from cattle manure
Y_d	constant of collectable dry matter per AU per year
fr_{eq}	fertiliser equivalent per unit manure
frc	fertiliser cost per kilogram
$R_{w,t}$	revenue generated by cattle draft power
Y_w	work yield per animal per year
dp	draught price per day
$C_{s,t}$	total variable costs of subsistence cattle
c_{LU}	variable cost per cattle livestock unit

$R_{cr,t}$	revenue generated from cropping
M_s	specific maize production of dryland cropping
mp	maize price per tonne
cf_m	condition factor of maize
sdp	seed price per hectare
F_j	fraction of species j in the overall combined species population
P_s	profit generated by subsistence production

c. Wildlife harvesting model

$K_{t,j}$	total animal purchase cost of species j in year t
pc_j	purchase cost of species j
x_j	number of animals of species j
p_{PB}	payback period
ix	real interest rate
C_{fn}	total costs of fencing
C_{tr}	total cost of troughs
T_s	specific number of troughs per hectare
$h_{t,j}$	number of animals of species j harvested in year t
p_j	price index for species j
J	profit generated from animal harvesting by the chosen species mix
v_j	number of trophies per year
b_j	number of meat hunts per year
pv_j	price of trophy for species j
pb_j	price of meat hunt for species j
ps_j	sales price for live animals of species j
cs_j	costs associated with selling individual animals of species j
min_j	minimum population of species j allowed by the model
u_j	AU equivalent of species j
F_{fj}	fraction of total feed required by mixed feeder species j which is supplied by selective grazing
R_j	specific growth rate of the population of species j

r_j	intrinsic rate of increase of species j
z_j	available AUs in excess of the minimum population constraint
f_{\min}	factor of adjustment for the minimum population of a species
\max_j	maximum number of animals of species j
f_{\max}	factor of adjustment for the maximum population of a species

d. Ecotourist model

A	maximum value of sigmoidal data
Q	constant relating to the y-intercept of sigmoidal data
λ	gradient of the sigmoidal curve
x	independent variable
y	dependent variable

1. INTRODUCTION

1.1. HISTORY OF COMMUNITY-CENTRED CONSERVATION IN AFRICA

Originally, conservation areas were established with little or no regard for local people. The management strategy was preservationist and emphasized a planning role aimed at excluding local people (Wells *et al.* 1992). The theme of protecting natural phenomena from exploitation for public enjoyment served as the model for development of protected areas worldwide (Machlis & Tichnell 1985). Communities next to these “preserves” frequently bore substantial costs (loss of wildlife, vegetation and water sources - Cummings 1993) as a result of lost access for which they received little in return. Local communities tended to be poor and as such perceived the conservation area as restricting their ability to earn a living (Wells *et al.* 1992). As populations grew, the pressure of unsustainable land use practices led to increasing frequency of illegal and destructive encroachment.

In 1980, the “World Conservation Strategy” document produced by the International Union for Conservation of Nature and Natural Resources (IUCN 1980) emphasized the importance of linking protected area management with the economic activities of local communities. Conservationists at the 1982 World Congress on National Parks, in Bali, recognised the need to include local people in protected area planning and management. The congress called for increased support for communities next to parks through measures such as education, revenue sharing, participation in decisions, appropriate development schemes near protected areas, and - where compatible with the protected area’s objectives - access to resources (McNeely & Miller 1984).

Growing awareness of the complexity of links between poverty, development, and the environment, has led to a search for ways to link the three and make “sustainable development” work, and to make conservation people-orientated (Wells *et al.* 1992).

Recognition that successful long-term management of protected areas depends on the cooperation and support of local people is growing. It is neither politically feasible nor ethically justifiable to exclude the poor - who have limited access to resources - from parks and

reserves without providing them alternative means of livelihood (Wells *et al.* 1992). Increasingly, conservation bodies are seeking to obtain local community cooperation and to introduce Integrated conservation-development projects (ICDPs - Wells *et al.* 1992) that will bring tangible benefits to these communities.

In addition to the needs of local communities, conservationists have come to realise over the last decade that conserving certain high-profile species and scenic landscapes is not sufficient. In order for conservation to be successful, it must preserve biodiversity and the biological processes in nature (Western & Wright 1994). Clearly, small isolated patches of land have limited significance for conserving biodiversity, as established by Island Biogeography Theory (Soulé 1987). Much less so are they able to conserve large-scale ecological processes which have significance for global stability and resilience (Edwards & Abivardi 1998). Consequently, conservation bodies are directing their efforts to conservation in all forms of land-use (e.g. farming procedures), not only areas set aside purely for habitat conservation (parks, game reserves etc.)(McKenzie 1997).

Two examples of such community-based conservation projects in southern Africa are the Richtersveld National park in South Africa, and the Communal Area Management Programme for Indigenous Resources (Campfire) Project in Zimbabwe.

The Richtersveld National Park is significant to conservation because of its high species endemism. The park is managed jointly by the Nama community who own the land, and the National Parks Board, who pay the Nama for access to the park. The Nama community continue to live on the land and use the grazing resources for their livestock (sheep and goats) (Financial Mail 1994)

The Campfire project was established to allow local communities to manage the wildlife on their land and to benefit from its utilisation, usually in the form of hunting concessions. Originally these communities were prohibited from utilising game on their lands under the preservationist conservation regime of colonial Rhodesia. That system was not sustainable because it failed to recognise the needs of these people. Hill (1987) lists four reasons - primarily based on institutional structure and societal perceptions - why Campfire is likely to

succeed:

1. The government directing conservation is politically recognised and respected by local communities.
2. Since utilisation resembles pre-colonial methods of wildlife management, a measure of earned trust develops between the local resource cooperatives and the national authorities.
3. Economic reciprocity develops between local communities and the government, as the latter sell the hunts and return money to the local people.
4. Local conservation officers operating in the resource cooperatives are accountable to their members for the distribution of resources, and the members are accountable to each other for the provision of inputs into the cooperative.

Hill makes his argument on the basis of a comparison with another conservation project in Zimbabwe: Operation Stronghold aims to prevent Rhino poaching and has worldwide financial support, but has proved ineffective because it has no community support:

1. Rural farmers perceive the government as enforcing anti-poaching laws with a top-down approach, as was practised under colonial authorities.
2. There is no trust between local people and parks authorities. The only part that locals play is if they are arrested as poachers or possibly harassed by anti-poaching squads.
3. The reciprocity perspective indicates that rural farmers derive no economic benefits from Operation Stronghold.

1.2. GAME RANCHING - AN ALTERNATIVE, ECONOMIC LAND-USE?

While Hill (1987) is certainly correct that conservation projects in developing countries must take into account institutional and perceptual considerations, it would still appear that the primary driving force for community-based conservation is economic: ecotourism and hunting. The IUCN distinguished a number of types of protected area categories, based on their objective uses (Table 1.1.). Rural communities are now aiming to benefit from the multiple-use management area designation (category VIII), which aims to allow sustainable utilisation of a large number of resources in game reserves and national parks.

Table 1.1. Protected area categories and management objectives (IUCN 1985).

Category	Type	Objective
I	Scientific reserve / strict nature reserve	Protect nature and maintain natural processes in an undisturbed state. Emphasize scientific study, environmental monitoring and education, and maintenance of genetic resources in a dynamic and evolutionary state.
II	National park	Protect relatively large natural and scenic areas of national or international significance for scientific, educational, and recreational use.
III	Natural monument / natural landmark	Preserve nationally significant natural features and maintain their unique characteristics.
IV	Managed nature reserve / wildlife sanctuary	Protect nationally significant species, groups of species, biotic communities, or physical features of the environment when these require specific human manipulation for their perpetuation.
V	Protected landscapes	Maintain nationally significant natural landscapes characteristic of the harmonious interaction of people and the land while providing opportunities for public recreation and tourism within the normal lifestyle and economic activity of these areas.
VI	Resource reserve	Protect natural resources for future use and prevent or contain development that could affect resources pending the establishment of management objectives based on appropriate knowledge and planning.
VII	Natural biotic area / anthropological reserve	Allow societies to live in harmony with the environment, undisturbed by modern technology.
VIII	Multiple-use management area / managed resource area	Sustain production of water, timber, wildlife, pasture, and outdoor recreation. Conservation of nature orientated to supporting economic activities (although specific zones can also be designated within these areas to achieve specific conservation objectives).

Latterly, as ecotourism has caught on among rural communities, a number of these communities are themselves approaching regional conservation agencies to provide capital, scientific and managerial expertise in order to establish small game reserves on their own lands. Wildlife management has been described by Giles (1969) as:

"the science and art of changing the characteristics and interactions of habitats, wild animal populations and men in order to achieve specific human goals by means of the wildlife resource".

Clearly the objective of rural communities is to generate capital for use in development projects. This has been based on the claims that wildlife ranching and hunting initiatives can generate more money than domestic stock systems in marginally productive and highly variable environments, because wild animals are better adapted to coping with such conditions and use a wider range of the forage resource (multiple species utilisation, e.g. Dasmann 1964).

However, establishing these community reserves requires high input costs, which are usually incurred by the conservation agencies, which provide capital for their establishment (fencing, managerial assets, expertise and game), with very little return on their investment (except perhaps community sympathy for conservation). For all the input, are the financial gains from wildlife really that substantial when compared with improving the management of Nguni cattle herds which have been part of the variable African ecosystem for thousands of years and are as such adapted to it to some degree? Not only do cattle provide meat, but also dairy products, skins and draught power. These all have economic values for a rural community and need to be assessed to calculate the real costs and / or benefits of converting to a game system.

Bearing this in mind, it is clear that the primary motive for this study is to direct land utilisation decision-making on the basis of profit margins from a number of different land uses. There are two main land uses that usually come into conflict with wildlife in semi-arid environments, namely commercial beef ranching and communal subsistence production. To justify wildlife where there is no serious conservation imperative, the latter must be shown to be more profitable than either of the farming options. Certainly this method of decision-making ignores the ethical reasons for conservation and the conservation value of the site. The latter requires different criteria for decision making which are generally based on non-monetary values to society. However, this study focuses on semi-arid savanna, which is well conserved as a vegetation type in southern Africa, so it is reasonable to exclude these considerations from the decision-making process.

1.3. THE EFFECT OF SIZE ON PROFITABILITY

It is reasonable to assume that the three land uses being considered here must all prove the most profitable under different local and regional conditions since they are all practised in semi-arid

environments. While some might argue that subsistence systems have survived to the present time due to the ignorance of the rural communities to “advanced” commercial farming practices or (more plausible) as a response to the high risk for small stock owners if they did convert to modern commercial techniques in farming, this analysis will show that subsistence can be the most profitable (perhaps also the most appropriate) land use.

The factor that most clearly affects the differing profitability of the three land uses is size, and the related concept of “economies of size”. In agricultural systems, economies of size are generally determined by the fixed costs that are incurred regardless of the size of the enterprise. Costs are divided into fixed and variable costs, where variable costs are those inputs which change according to the level of output. Fixed costs are incurred regardless of the intensity and size of the enterprise and cannot be changed over the short term (Barnard & Nix 1973). Thus on a cost per unit output basis, the value of fixed costs decreases relatively per unit as output increases (Britton & Hill 1975). This is simple enough to show in commercial agricultural systems, especially when only one form of agriculture is being analysed. When comparing different land uses, it can be seen that the shape of the profit curves against size will depend both on the fixed costs and sale value of the product unit, assuming that the level of intensity is as constant as possible across size (as will be assumed here). Subsistence systems have very few (if any) fixed costs, so their net benefit curves (i.e. profit curves) are certainly greater than commercial beef production systems on very small land sizes, as will be established in the analysis.

Wildlife systems add a further dimension to the effect of size. This is because they are multi-species systems where the marketed “product”, wildlife, becomes progressively more complex with increasing property size. Thus the product per unit variable cost varies as property size increases. In addition, fixed costs vary with size because size also determines the options open to wildlife (e.g. ecotourist developments) which in turn determines the fixed costs.

There is much debate about what constitutes the best measure of size, however Britton & Hill (1975) suggest that it is very dependent on the purpose for which the measurement is intended to be used. Britton & Hill (1975) divide measure of business into those calculated on input and those calculated on output. Measurements of input include area, standard man days (the

theoretically required input of labour), and the value of all the inputs used in a year. Output is measured in terms of physical data, such as tonnes of sugarcane produced on a farm (Mbowe 1996), however this measurement cannot determine the effect of intensity. All the above-mentioned measures, except for area, are not suitable when comparing different land uses, because their amounts and types of input and output are very different. Thus area or property size is the easiest measurement by which to compare profits from the three different land uses to be analysed here.

1.4. COST-BENEFIT ANALYSIS: A DECISION PROCEDURE

To assess the viability of any project, economists use a tool called Cost-Benefit Analysis, which is summarised by the standard put forward in the US Flood Control Act:

“the benefits to whomsoever they may accrue (be) in excess of the estimated costs”
(Gramlich 1990).

Cost is often thought of as an opportunity cost (the benefits forgone from other use options by proceeding with a project - Ceballos-Lascuráin 1995) and benefits are measured by consumer surplus arising from the project (Sugden & Williams 1978 as cited by Ceballos-Lascuráin 1995) (Consumer surplus is the benefit experienced by the consumer over and above what he or she must pay). Cost-Benefit Analysis is thus one method of evaluating any particular land-use option against another.

Although Cost-Benefit Analysis might be applied to purely measurable economic values to assess capital gains and losses from some decision, this form of analysis is usually insufficient. A proper Cost-Benefit Analysis should take into account both economic and social gains and losses. Often social values are difficult to express in monetary values.

De Lacy & Lockwood (1992) have described a number of methods that can be used to value non-market costs and benefits. The contingent valuation method (CVM) involves creation of a hypothetical market to enable quantification of the communities' willingness to pay (WTP) for

specified benefits from a particular resource. WTP works on the premise that people are willing to pay a certain amount for access to any resource, including such factors as emotional satisfaction obtained from natural habitats (people obtain serenity and also feel a sense of place) (Walsh *et al.* 1984). The technique was developed by resource economists to measure non-market values, specifically those associated with public or semi-public goods. In essence, people are asked to place a financial value on an experience or object. WTP implies that conservation will have economic/monetary benefits for the conservers; lost landscapes and lost species will express themselves as lost tourism potential.

A second method which has been used is the travel cost method (TCM), which estimates demand curves for recreational experience on the basis of how much it costs to get to the site. This latter technique has less value for the present analysis being undertaken in this project, since the Cost-Benefit Analysis is here designed to test the profitability to the local rural community and not to society as a whole.

Shah (1995) notes that:

“...if we are not able to quantify national park value then that means that we are not able to compare it with alternative use value and therefore cannot make a credible case for or against a national park.”

Similarly, the aim of this project is to assess profitability from game ranching as opposed to subsistence stock ranching or improved commercial stock ranching, at different sizes of land. Barnes & de Jager (1996) distinguish between financial and economic profitability. Financial profitability determines whether there is a financial incentive for resource users to invest in the activity, as it determines their actual benefit from the activity. The economic value of an activity, by contrast, determines whether and how much the activity contributes to the overall welfare of society and the nation, and so reflects in the national income.

The full economic value of protected areas can be broken down into four components: direct value, indirect value, option value and existence value (Turpie & Siegfried 1996). Usually only the direct value, which includes consumptive and non-consumptive use values such as hunting and game-viewing, is reflected in market prices. Indirect values are derived from ecosystem

services such as nutrient cycling, soil production and water run-off, and are extremely difficult to quantify. Option value is more obscure as it represents the value of retaining environmental assets such as genetic diversity for the option of later use, and existence value is the value of knowing that something exists. The latter component is often calculated using contingent valuation, in which people are surveyed to determine their willingness to pay (WTP) to prevent environmental changes.

Since our interest is in financial benefit to land owners and communities who own reserves, we shall not consider economic value of the land use options to society. The latter three categories of economic value are all more important in terms of their value to society as a whole. Thus our focus on financial benefits to communities and land owners will concentrate on direct benefits. Benefit here is measured as a profit to the community arising from either of the three land-uses. While economists usually define profit as a return to management, which is the residual revenue after accounting for the cost of variable inputs and the opportunity cost of fixed resources, including land (Lyne 1998, personal communication). By contrast this analysis implicitly defines profit to both land and management, in order to focus on the effect of land property size.

Shah (1995) has produced a monograph on the economics of Third World National Parks in which he puts forward a highly theoretical Cost-Benefit Analysis comparing the use value of an area under two exclusive alternative land uses: as a subsistence economic activity area and as a pure national park. The aim of Shah's Cost-Benefit Analysis was to assess when either of the two land uses was more profitable than the other. This was under the assumption that the land already exists as a national park which might potentially revert to domestic stock grazing lands if the Cost-Benefit Analysis proved the latter option to be more profitable. Since the technique is similar to that which is intended to be used here, it is useful to discuss Shah's theoretical analysis further.

Shah (1995) gives economic flow values to both the national park (WTP) and grazing (II) options, where these flow values are the amalgam of non-consumptive use value, consumptive use value, existence value, option value etc. Since $WTP(t)$ is the flow value at time t , all such flows can be added up over time, from the present to infinity, to yield the discounted present

value of a national park,

$$\int_0^{\infty} e^{-it} WTP(t) dt \quad 1.4.1.$$

, where i is the discount rate.

Similarly, for maximising returns from grazing,

$$\max \int_0^{\infty} e^{-it} \Pi(t) dt \quad 1.4.2.$$

The discount rate is the social rate of time preference (S RTP), as the case is built on the basis that the flow of values from the two alternatives reflect consumption rather than investment (in which case, rate of return on investment would have been used). Since the method is time based, the Cost-Benefit Analysis is interested in changes in consumption between the present and future.

Assuming that at time $t = T$, steady-state grazing commences, then the present value of the flow of steady-state profits Π_T from grazing is,

$$\int_T^{\infty} \Pi_T e^{-it} dt = e^{-iT} \frac{\Pi_T}{i} \quad 1.4.3.$$

Similarly, if steady-state flow of national park use value is also reached at time $t = T$, then,

$$\int_T^{\infty} WTP_T e^{-it} dt = e^{-iT} \frac{WTP_T}{i} \quad 1.4.4.$$

The difference in present value (PV) at time T is thus:

$$PV_T = \frac{e^{-iT}}{i} [\Pi_T - WTP_T] \quad 1.4.5.$$

Consequently, the viability of the grazing project is determined by whether or not PV is

positive. Shah (1995) notes that for all values PV_T may be negative (i.e. $WTP_T > \Pi_T$) in which case the grazing project is never viable. The present study examines a site in a rural area where it is assumed that the land has no active use and is being assessed to determine which of the three land uses would be the most appropriate.

In contrast to Shah's analysis, the variables identified in this study will be quantified to provide practical reality. However, it needs to be made clear at this point that the results obtained from the analysis are of limited value in the real world, since the land area is totally theoretical. It is the thinking involved and the process by which the result is established that are critical for our understanding of the issues involved and how best to extrapolate to other real-world examples.

From here on in the text this analysis will proceed on the assumption that the use of land by the rural community is purely financial and has no social values (such as ancestral burial grounds) to them. Thus an assessment can be made of the opportunity cost incurred by wildlife against property size when it is chosen over the two alternative land-uses, commercial beef production and subsistence production. Where actual prices exist for various financial parameters these will be used, and others that do not have actual monetary values will be quantified. For example, the draught-power use of cattle in a subsistence system, though it cannot essentially be sold, could be estimated against the cost of a tractor and its plough power.

1.5. MATHEMATICAL LINEAR OPTIMISATION: A TOOL FOR ANALYSIS

Mathematical modelling has been used as a decision-support system in wildlife systems to optimise population breeding structures for various forms of off-take, including trophy hunting, meat hunting and rare animal breeding (e.g. Starfield and Bleloch 1986; Hearne, Goodman & Collinson 1996; McKenzie 1997).

In 1986, Hearne & Buchan used modelling to carry out a simple Cost-Benefits analysis on the Pongola Floodplain and Makatini Flats. The aim was to assess the gains and losses of changing from a subsistence pastoral system to irrigated commercial agriculture, and also the effect on the pastoral system if the natural annual flood release was not maintained by the Pongolapoort Dam, which had been built upstream for agriculture on the flood plain. Since it was anticipated that the change in system would have transient and steady-state effects, a dynamic mechanistic model was used. The model concentrated on the impact of system change on subsistence pastoralism and provided useful insights into considerations for assessing the economic values of pastoralism. However, it did not analyse or model the crop agricultural system and relies on values already estimated from empirical data.

The linear optimisation technique has been used by Hearne *et al.* (1996) to optimise the off-take of large herbivores from a multi-species community (see Davies 1994 for a description and critique of the technique). The objective was to maximise hunting profits while maintaining stable animal populations, and will be the technique used in this model to maximise profits from hunting on the game ranch.

Due to the complexity of the present Cost-Benefits Analysis, a number of techniques will be used to model the three different land-use systems and, where applicable, the different components of those systems. Wildlife can be broken into two components, namely ecotourism and wildlife harvesting (hunting and game sales). Thus the linear optimisation hunting model used by Hearne *et al.* (1996) will be adapted to optimise the species mix. The model used by Hearne *et al.* (1996) is site-specific, and as such does not consider property size which is the key variable for this Costs-Benefit Analysis. Therefore specific adaptations designed to account for the effect of size have been included in the optimisation model. Ecotourism is poorly understood and so the models used in the analysis are derived from multilinear statistical techniques. The domestic stock models, commercial beef and subsistence production are not optimisations since they do not combine a large number of species and are rather simple mechanistic models (similar to that used by Hearne & Buchan 1986) relating animal numbers to productive output.

In addition, the modelling exercise conducted here differs from the pastoral model of Hearne

& Buchan (1986) mentioned above, in that the three proposed land-uses for the Cost-Benefits Analysis will be treated as exclusive land-uses, whereas Hearne & Buchan's (1986) pastoral model was looking at a mixed system of commercial agriculture and subsistence pastoralism. In other words, each of the three land-uses has a separate model across which the independent variable, property size, will be varied. Results for each model will then be compared.

1.6. AIMS AND OBJECTIVES

The aim of this project is to conduct a Cost-Benefits Analysis that compares financial returns from wildlife production, communal subsistence production and commercial beef ranching for a given area of land to assess the opportunity cost incurred by choosing wildlife production over either of the two alternative land-uses. Mathematical modelling is seen as the most appropriate tool to handle the complexity of such a comparison. Property size will be varied in order to identify in what range of sizes each of the land uses are (if at all) the most profitable option. The product that is sought from this analysis is a graph showing profitability for wildlife production, subsistence production and commercial stock ranching against property size. By this means, points of intersection will indicate where game ranching proves more profitable than commercial or subsistence stocking. In establishing this result using modelling, the key advantage is that we shall be able to observe the behaviour of the cost and revenue curves (which are both needed to construct the net benefit or profit curve) for each of the land options in response to size.

To summarize, the objectives are:

- Construction of suitable mathematical models of the annual revenue and cost curves for each of the three land uses.
- Graphical interpretation of the revenue and cost curves of the different land uses.
- Graphical comparison of the derived profit curves to determine points of intersection between the different profit curves, thereby providing a decision-support tool for the most appropriate land use.

1.7. THE WAY FORWARD

As a first step in achieving the project's goals, before the linear optimisations can be conducted, variables involved and considerations relating to them need to be identified and discussed. Chapters 2 and 3 deal with identifying the variables and options for domestic stock enterprises (commercial stock ranching and subsistence production) and wildlife production respectively. Chapters 4 and 5 try to cost all these variables and give descriptions of the mathematical functions in each of the models while distinguishing between consumptive (commercial stock ranching, subsistence production and wildlife harvesting) and non-consumptive (ecotourism) uses respectively. Results of the analysis are discussed in Chapter 6 and the report ends with a discussion on the weaknesses in the model.

Before proceeding with the analysis, it must be stressed that the Cost-Benefit Analysis for this project has been designed to assess specifically the effect of size on the profitability of each of the three alternative land uses. As such, the analysis is simplistic and basically ignores the effect of location which can be critical both to game ranching (accessibility to tourists) and commercial stock ranching (proximity to markets).

In addition, as the number of possible situations is endless, the project will focus on land potential for a semi-arid savanna, which has limited potential for other forms of land use (such as crop production). Needless to say, high production agriculture, such as that obtained from sugarcane farming, will generally far out-compete any other form of primary land use on a profitability per hectare basis. If such a case were to be considered for conservation use, the argument would have to be made on the grounds of gains to society as a whole from maintaining the park amenity.

At this stage, a few assumptions can be made for the analysis:

- Since paying for the land is a constraint common to all three types of land use, it does not have a differential effect on the three operations. It can thus be ignored and all costs are related to the specific requirements of the three considered land uses.

- For simplicity, it will be assumed that the shape of the property is square. Thus the relationship of the area to perimeter remains constant as the area increases. This is important in order to calculate the costs of perimeter fencing as a simple function of the area, and any other factors that require a constant shape relationship for simple calculation of the results. In choosing a square for this relationship there is an inherent bias, as a square has the greatest area : perimeter ratio of any rectangle and is greater than that of a circle. As a result, fencing costs will be underestimated by the model. However this will prove useful as it will favour the profit curve of wildlife production, thereby further substantiating any results reached from the project which indicate that wildlife production is not the most profitable land-use at small property sizes.

2. OPTIONS FOR DOMESTIC STOCK PRODUCTION

In a semi-arid savanna with limited water availability, it is reasonable to assume that the restricted land potential lends itself only to different forms of stock ranching, domestic or wild, and a limited amount of dry land cropping. This is especially the case among rural African populations, who are largely subsistence farmers and lack the capital to develop crop production schemes that are marginally cost effective on low-potential soils. The latter fact also assumes that the community is fully market-orientated, which in most instances it is not, with a large amount of the produce being circulated and consumed within the community itself. For the present research, it shall be argued that any form of irrigated and/or commercial crop production is not viable, and that only small amounts of dry land agriculture are possible. On this basis there are two alternative agricultural systems that may be considered in the analysis, subsistence and commercial livestock production.

In the past, economic analysis exaggerated the advantages of commercial stock ranching which always showed the commercial option to be far more viable than subsistence stock ranching. However, the analyses were based on economic statistics such as market sales, and did not account for other forms of production (e.g. draught power, dairy products etc.) which have great significance for subsistence farmers. Economists simply measured pastoral output in terms of income per animal regardless of the stocking rates of the systems under consideration (Behnke 1985). As analysis techniques improved and started to cost these non-market priced values, the differences in productivity between the two systems began to diminish. Behnke (1985) notes that:

“The more closely and accurately the gap between subsistence and commercial production is quantified, it would appear, the more the two systems seem to achieve rough economic parity.”

This has brought into question the claimed superiority of commercial livestock production, and even whether it is in the economic interests of African livestock producers (Behnke 1985).

2.1. ECONOMIC AND ECOLOGICAL CARRYING CAPACITY IN SEMI-ARID SAVANNA

The key ecological difference between subsistence and commercial stock ranching is stocking rate (SR). SR is related to the carrying capacity (CC) of land, which can be divided into two types, economic and ecological CC. Figure 2.1. shows the relationship between SR and productivity as determined by Jones and Sandland (1974, cited by Edwards 1981).

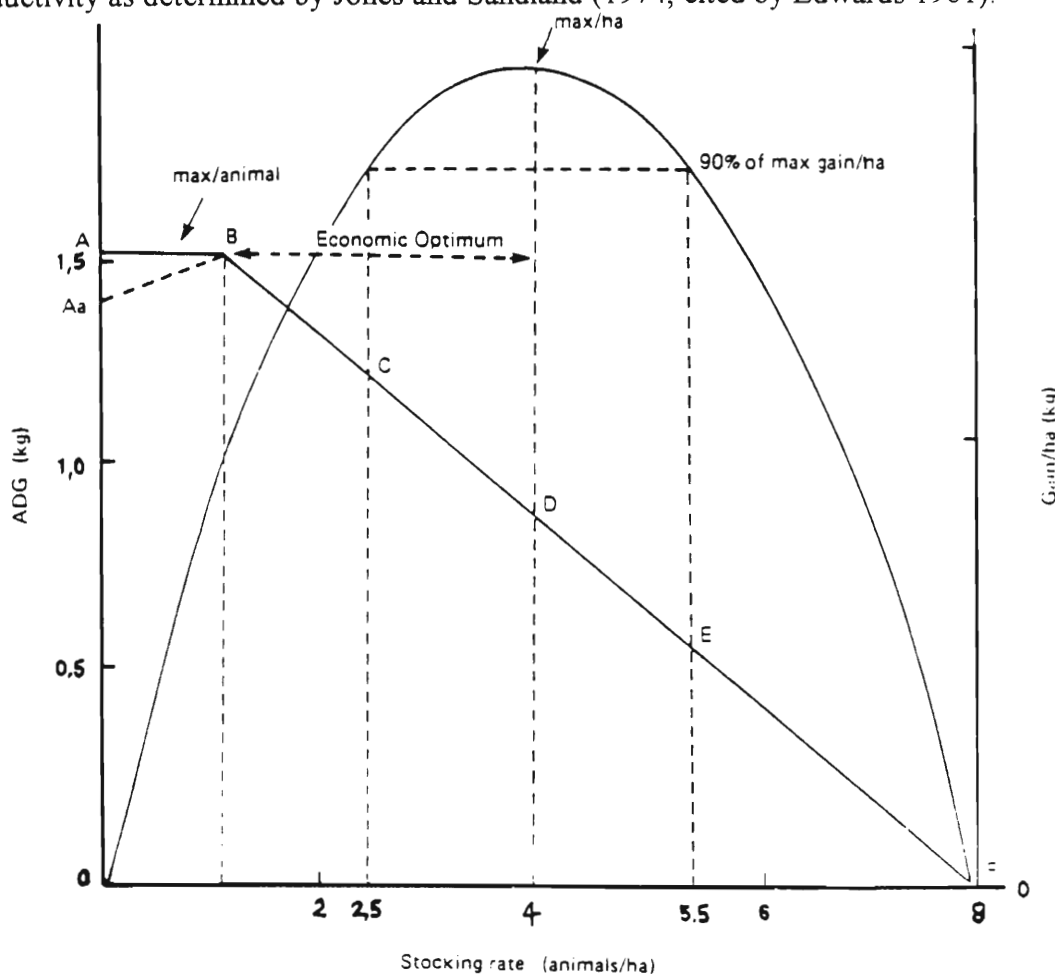


Figure 2.1. The relationship between stocking rate (SR) and animal production, both on a per animal (ADG) and per hectare (Gain/ha) basis (Jones & Sandland 1974 taken from Edwards 1981)

Ecological CC refers to the maximum number of animal units a piece of land can hold without being subject to density-dependent mortality and permanent environmental degradation, and is as such subject to environmental constraints (Caughley 1982). In other words, if another animal unit is added to the system the available forage determines that at least one animal unit must be

removed or die. Economic CC is the SR which provides the maximum economic returns and is determined by the economic objectives of the producers (Caughley 1982; Scoones 1993) while being subject to the environmental constraints. Generally, subsistence stock ranching schemes work very close to ecological CC, (game reserves may also approach ecological CC if poorly managed) whereas commercial schemes usually work at much lower SR's. This is because subsistence farmers aim to maximise stock numbers for draught power, dairy, wealth etc., whereas commercial ranchers try to balance individual animal performance with animal numbers to maximise meat production and quality for market sales. Trophy hunting also works at lower SR's to maximise individual performance of trophy animals.

A further complication which CC adds to the system is that in semi-arid savannas, CC is a dynamic value determined by highly variable rainfall. So although subsistence systems work closer to ecological CC, droughts and other episodic events regularly knock back population numbers to lower levels (Scoones 1993). Commercial farming schemes in semi-arid areas are of course also subject to the same fluctuations in primary productivity, and commercial farmers try to minimise losses by either buying supplementary feed to carry their stock through the drought years or by reducing stock numbers quickly in drought years and buying in supplementary stock in good rainfall years. The latter method is also adopted by subsistence farmers, but they are more conservative and therefore still lose a large number of animals to starvation during drought years.

2.2. COMMERCIAL STOCK RANCHING

2.2.1. The productive output of commercial ranching

The main difference between subsistence and commercial operations is that due to the market orientation of commercial enterprise, the emphasis of a beef production system is on that single product and not on the array of products that will be identified for subsistence operations. This analysis will similarly emphasize meat production as the product being sought by a commercial stocking venture in semi-arid savanna.

Van Zyl *et al.* (1993) state that the key objectives in setting up a beef production system are:

- a long-term production system suited to the environment
- sustained productivity
- a product as close to the optimal marketing stage (age and condition) as economically and environmentally feasible
- a high productive yield per unit area and not necessarily per animal

With these objectives in mind, one of the most important considerations is stock breed, which is based mainly on the breed's adaptability to the environmental conditions of the farming area. Breeds vary in their ability to tolerate parasites, disease, heat and poor quality forage (Van Zyl *et al.* 1993). Generally, in dry and subtropical regions, crosses of *Bos taurus* and *Bos indicus* and indigenous cattle breeds have proved the most successful. Indigenous breeds like Nguni have high reproductive rates, low incidence of dystocia (due to smaller calves at birth) and low maintenance requirements (Van Zyl *et al.* 1993) (see Table 2.1.). However at the other end of the scale, *B. taurus* breeds put on greater livemass in the long run than either *B. indicus* or indigenous Sanga breeds (see Table 2.2.). Regardless of this fact, Van Zyl *et al.* (1993) argue that calving rate is more important than weaning weight, as heavier weaning weights can never compensate for low calving rates.

Maintaining animal condition over winter when forage quality goes down can be easily achieved by supplying protein-rich licks, provided there is sufficient dry matter for cattle to eat. In semi-arid savannas, the grasses are usually sweet (they maintain their quality throughout the year) and the problem is insufficient dry matter over winter and more especially during drought years. To optimise profits under these variable situations requires careful management to adjust stock numbers to ensure that there is sufficient forage throughout the year.

Table 2.1. Fertility and comparative income from selected breeds in southern Africa on extensive range conditions without supplementation (after Barnard & Venter 1983 as used by Van Zyl *et al.* 1993).

Breed	Average Calving % (six years)	Average calving interval (days)	Net income (AFR*=100)
Afrikaner	74	460	100
Hereford	78	462	97
Sanga	92	372	141
Santa Gertruidis	78	420	103
Simmentaler	78	416	88

* Afrikaner (i.e. all species compared to the Afrikaner breed)

Table 2.2. Production characteristics of selected beef breeds in southern Africa (after Van Zyl *et al.* 1993).

Breed	ADG* (g)	FCE**	ADA***	400 days weight (kg)
Simmentaler	1749	7	1341	575
Hereford	1706	6.5	1247	535
Brahman	1210	7.1	1025	442
Afrikaner	1157	7.7	901	392
Nguni	1108	7.3	783	341

* Average daily gain

** Feed conversion efficiency

*** Average daily gain per day of age

2.2.2. The system of beef production

In South Africa, three main systems of extensive beef production can be recognised (Van Zyl *et al.* 1993):

2.2.2.1. Weaner production

Weaner production is the most commonly used form of beef production in South Africa, and involves the production and sale of weaners at six to nine months. Weaners are produced from a herd which consists primarily of breeding females, and may or may not be intensively finished before sale. Since beef prices are cyclic, profits from this form of production are variable. In addition, weaner production has limited elasticity and is as such susceptible to drought years when numbers must be reduced and demand prices are low. At such times, yearlings and steers fetch higher prices. Since breeding herds cannot be maintained in regions where rainfall is variable, this form of beef production is not suitable for arid and semi-arid savannas.

2.2.2.2. Production of steers

A herd designed to produce steers that are raised to the slaughtering stage, has less breeding females than that for weaner production, and is determined by the marketing age of the steers. Weaner calves that are brought into the system and finished off on the veld can also be classified under this system. Flexibility in herd composition becomes particularly important in areas with poor and erratic rainfall. In drought-susceptible regions, the female component of the herd needs to be reduced, as females need to maintain good condition to ensure high fertility and calving rates. Consequently, it may be necessary in very dry regions to do away with cow-calf herds altogether.

2.2.2.3. Speculative beef production

This is done either with steers bought in at various ages or speculation with cows and calves. The system is very flexible and allows a manager to exploit fluctuations in cattle prices and grazing quality or to build an efficient breeding herd. The system requires great skill to buy in animals when prices are low and then re-sell them when meat prices rise or when there is a demand for breeding cattle (especially pregnant females). In addition careful planning is required to provide sufficient forage whatever the strategy may be. This system will not be used here because there is limited room

for the number of speculators that a market can take and the degree of success achieved is largely dependent on the individual.

The beef farming system of choice for this analysis is thus steer production, since variable semi-arid environments do not lend themselves to weaner production and speculative beef production is highly variable and determined by individual human behaviour.

2.2.3. The costs associated with commercial stock ranching

In contrast to subsistence farming which has low external inputs, commercial farming systems require high input costs in order to recognise a reasonable level of profitability. This, incidentally, probably means that subsistence farming will be a better short-term investment due to low payback costs. In addition it is probable that relative investments per unit area will be higher for smaller farming enterprises, which is one of the key reasons for undertaking this Cost-Benefits Analysis. This project will not consider the effect of discount rate on the time required to pay back a commercial ranching enterprise, subsistence ranching or wildlife production, as there should not be a differential effect on the three options. In essence, recognising that time required to pay back investment costs will differ between the three options, as investment costs of commercial ranching and wildlife production can be substantial whereas subsistence ranching costs are small (even negligible), is key to this analysis.

Agricultural economists recognise two types of costs, fixed costs and variable costs. Fixed costs do not change when the level of output alters and have fixed quantities, whereas variable costs do change with output level (Barnard & Nix 1973). The terms refer to total costs, not the costs per unit of production. Fixed costs cannot be altered in the short term and include such factors as farm layout (fencing, buildings etc.) whereas variable costs are affected by decision making and include factors such as soil fertilisation rates in crop production systems. However, the costs of extensive beef production are fairly low when compared to intensive farming systems.

Since variable costs are determined by management decisions, the effect per animal unit (AU - see definition later) is the same, and thus the relationship between variable costs and size is

linear, assuming that there is a constant rate of input and thus production per hectare. Variable costs can be divided into the following categories:

1. Management costs
 - manager
 - farm labour
2. Health and veterinary costs
3. Transport and market-related costs

Fixed costs, by contrast, are costs that must be incurred in order to set up a farming system regardless of size. Fixed costs thus cause the effect of “economies of size” (Lyne & Ortmann 1996) whereby the costs of these inputs are cheaper for larger farms that can spread the costs over the greater volumes of output they produce compared to small farms. For example, one of the recognised fixed costs is the cost of obtaining new information on farming practices, which costs the same amount to small as to large farm owners. The result is a curvilinear cost curve for which at small farm sizes, the costs decrease dramatically with each extra unit of land added to the farm. The curve flattens off at large farm sizes, thus becoming quasilinear as the change in cost per AU with each extra unit of land added becomes very small.

2.3. COMMUNAL SUBSISTENCE PRODUCTION

As agricultural science has developed, few researchers will formulate policies on the basis of maximum yield or biological efficiency, but by some economic performance measure to assess benefits/returns over variable costs (Zandstra 1983). The fundamental economic problem which arises when one applies the technique to subsistence or semi-commercialised enterprises is that formal economic analysis is based on existing markets which assign empirical prices to goods and services (Behnke 1985). By its very nature, subsistence production never reaches a market, as most of the production is used “in-house” or “in-kind”. Since in-kind/in-house production is so important,

“the results of any calculation of economic costs will be highly sensitive to any changes in the way subsistence production is valued” (Behnke 1985).

The cash value assigned to subsistence production has long been debated and at least two different procedures have been used which lead to significantly different imputed values (Behnke 1985). The standard approach used by agricultural economists is the “farm gate” price, which is the price a farmer receives when he sells the product at the boundary of his farm (Gittinger 1972). Behnke (1985) argues that this method is inaccurate as in a semi-commercialised economy, local market demand for basic foodstuffs and consequently price, will be low precisely because food self-sufficiency is a primary objective of household economic activity.

The second method of costing subsistence production is based on the concept that rural farm households are dual-purpose institutions which both produce and consume. Thus the relevant market price to give home consumption/subsistence production is that price that producers would have to pay to replace home produce with purchased equivalents (Behnke 1985).

There are a number of practical problems which need to be dealt with when using the replacement cost technique, most notably (1) changing patterns of food consumption in the commercialisation process, (2) instability in pastoral/non-pastoral terms of trade, and (3) the issue of crop-livestock interactions in agro-pastoral production systems (Behnke 1985). The first issue is self-explanatory, but (2) relates to price fluctuations in good and bad years when crop prices will rise and meat prices will drop, thereby heavily impacting on subsistence livestock farmers. Point (3) relates to the fact that in mixed farming-livestock systems, many products generated by a family’s livestock enterprise are neither consumed nor sold but rather invested in the family’s cropping enterprise and *vice versa*. For example crop residues are used for animal fodder, manure used for fertiliser, animal strength used for draught power etc. In all cases, the appropriate value of the subsistence input or terminal product is the cash cost of purchasing its replacement e.g. buying fodder to replace crop residues, buying fertiliser to replace manure or buying a tractor for ploughing.

Having established the theory behind the technique being used here to assess the economic benefit from subsistence farming, all that remains is to identify the production outputs being obtained from a subsistence system and their associated values. Scoones (1992) identified these in his research on livestock populations and the household economy in Zimbabwe, and they are discussed in the sections that follow (see also Table 2.3. below). Scoones distinguishes between products derived from cattle and those derived from goats, which both formed part of

the pastoral system in the Zvishavane District in Zimbabwe. Generally, cattle were valued for their live use such as draught power and dairy, while goats were valued for their terminal products, meat and skins.

Table 2.3. Ranked economic value of cattle functions in the communal areas of Zvishavane District, Zimbabwe (after Scoones 1992).

Function	Economic value (per year/per adult (Z\$))	Farmer ranking
Draught	462	2
Milk	187	4
Transport	131	1
Manure	26	5
Sale	15	6
Slaughter	0	7
Bridewealth	0	3

2.3.1. The value of cattle and goats in subsistence production systems

2.3.1.1. Biological productivity

Biological productivity measures birth rates and mortality rates of stock animals. This indicates the reproductive and survivorship success of stock, and also their ability to build numbers after shock events such as droughts. Scoones (1992) distinguished between soil types as well as between rainfall years to assess their effect on primary production. He noted that adult mortality of cattle was greater on clay soils than sandy soils (by about ten percent) in both good and bad rainfall years, and similarly that calving rates were higher on sandy soils (78 percent) than clay soil savanna (68 percent). Mortality of calves was slightly higher than adults in all areas.

In contrast to this, 85 percent of all goat mortality (46 percent was the overall level) was of pre-weaned kids, and the highest mortality was on sandy soil savanna. Adult mortality was much lower, ranging between four percent and 20 percent, for clay and sandy savanna respectively.

2.3.1.2. Milk production

Milk from cattle had a variety of uses, but was most often consumed fresh or when soured. Other uses included the treatment of goat skins for mats, use as a skin cream, for medicine and as a cooking oil.

The average daily milk production from a cow over a year was 2.67 litres per day (including the dry period; the lactation period was six to eight months and averaged 6.2 months). Taking calf requirements into account, a household with twelve cows could expect 480.6 litres per year. By contrast Bembridge & Tapson (1993), working in the Transkei, found that a herd with three cows could provide two litres a day throughout the year for household consumption, which converts to about 243 litres per cow per year.

Goat's milk was produced in small quantities and was mostly used for tea. As the average lactation period is eight months and the birth interval is 8.4 months, there was potentially milk throughout the year. However, production decreased dramatically in the dry season, so milking would endanger kid survival. Thus milking was restricted to a four to five month period in the rainy season, with an average amount of 150 *ml* per day extractable.

2.3.1.3. Sales, slaughters and purchases

Sales of cattle and goats to commercial ranchers and at official sales did occur, but were restricted. Cattle slaughters were rare, being restricted to big occasions or when animals are about to die anyway. Sales were concentrated in drought years (0 - 7.8

percent; slaughter rates 0 - 4.2 percent) and were predominantly (82 percent) of oxen. After drought mainly heifers (55 percent) and cows (20 percent) were purchased to build up stock numbers, which was a 5.2 percent increase in total cattle stock numbers.

Sales were for animals near the end of their productive lives (oxen = 8 - 10 years, cows = 10 years). The only other time that cattle might be sold was if there was a serious need for cash, such as for schooling. Most sales were from larger herds, which relates to the reduced risk that owners of larger herds face when compared to owners of only a few cattle (the former were also likely to have surplus to agropastoral requirements).

Goats were an important source of cash income and slaughter for household consumption, so sales were higher at 14 percent. Sales were either breeding goats (young females) or slaughter animals. Goats were purchased for increasing the breeding flock (young females) or for slaughter.

2.3.1.4. Manure

Scoones (1992) identified that the main use of manure was as a fertiliser for agriculture. Other uses included floor preparation in buildings, lining of baskets and sometimes as a supplementary fuel, but he did not attempt to quantify these. Application rates were 1.2 to 1.4 tonnes of manure per household per year, where one tonne is equivalent to 200 kg fertilizer (39 percent of households did not apply manure, mostly in the clay veld areas which have high fertility). The amount of manure collectable per animal depended on foraging behaviour and kraaling practices. If animals were kraaled each night, then manure produced during the night could be collected whereas daytime manure would be deposited on grazing areas. Arable land grazing was concentrated in the dry season after the harvest thereby improving soil fertility for the following season, but the exact extent of this was not known. Scoones calculated that 879 kg of dry manure could be collected from 1 cattle unit per year.

Goat manure was used in vegetable gardens, but little went to fields, as this spread *Acacia* spp seeds.

2.3.1.5. Work power of cattle

Work spans of cattle consisted of two to four animals (average of 2.8 cattle) where the composition was 44 percent cows, 44 percent oxen and 12 percent donkeys. About 57 percent of the total adult cattle population was used regularly. Peak use is for ploughing in the agricultural season, but cattle were also used for transportation during other parts of the year (especially harvest collection in March to May). The average number of days each span spent working was 55.4 days.

Table 2.4. Values of cattle work activities per animal per year in the communal areas of Zvishavane District, Zimbabwe (after Scoones 1992).

Activity	Value (Z\$)
Ploughing	463
Threshing/harrowing	26
Agricultural transport	15
Transport	116

2.3.2. The costs of subsistence production

As subsistence stocking generally was free-ranging, the main cost to households was herding labour (Scoones 1992). Dipping and other veterinary costs were met by the government in the communal areas (see Table 2.5. below).

There were a number of different options for mobilising cattle herding labour in Zvishavane (Scoones 1992). The most popular (68 percent) were cooperative arrangements between households, where two to four (average = 2.9) herds were combined and households rotated responsibility for herding. Boys from poorer families constituted 20 percent of the labour, while own household labour was 12 percent. Goat herding was mainly the responsibility of young children, or goat herds were combined with cattle herds (Scoones 1992).

Table 2.5. Economic costs of livestock services per livestock unit (LU) in communal areas in Zvishavane District, Zimbabwe (after Scoones 1992).

Costs	Z\$/LU
Vet service and medicine	3.7
Dip depreciation (\$9000 over 25 years)	0.2
Dip maintenance (5% of \$9000)	0.28
Dip fluid (\$3750/15000-litre dip)	2.3
Dip cleaning (\$140/dip)	0.03
Water carrier (\$1394 pa)	0.3
Attendant (\$1802 pa)	0.2
Water supplies	0.28
Total costs per LU	7.3

3. OPTIONS FOR WILDLIFE PRODUCTION

The greatest advantage that wildlife production shows over domestic stock ranching is the sheer diversity of management and business operations possible. These can be divided into three broad groups, namely game farming/venison production (consumptive), hunting operations (consumptive) and ecotourism operations (non-consumptive). Pure venison production operations in which game is reared specifically for meat are not common in southern Africa, although there are very successful game farming enterprises in East Africa. This is probably partly due to the fact that there is limited demand for venison (Barnes & de Jager 1996). By contrast, hunting operations in Africa have grown dramatically, and the growth of tourism is almost geometric and does not seem to be near reaching a plateau of market demand saturation.

Due to the relative scarcity of pure venison production enterprises, this form of wildlife production will be ignored here, and emphasis placed on comparing the profits from ecotourism and hunting activities, which both fall under the broad category, tourism. Tourism is defined

“in a variety of ways, but the broad focus is on travellers away from home and the services they utilise, including transportation modes, food and lodging services, entertainment and tourist attractions” (Lundberg *et al.* 1995).

Globally, tourism is the fastest growing industry with the present rate of growth estimated at 23 percent faster than that of the overall world economy (WTO 1993). Tourism is now the world's greatest sector of employment with about 204 million people (about a quarter of the world's working population) employed directly or indirectly in tourism related activities (WTO 1993). More importantly, in South Africa the annual growth of ecotourist activities is estimated to be expanding at a rate of 30 percent annually (Shackley 1996). It is estimated that there are now over 4 000 private ranches with game fencing in South Africa which cover almost 80 000 km² compared to less than 10 000 km² in 1979. The significance of this can be appreciated by the fact that the total land controlled by the National Parks Board is less than 28 000 km² (Eloff 1996).

3.1. ECOTOURISM

Ecotourism is defined by the IUCN's Ecotourism Programme as:

“environmentally responsible travel and visitation to relatively undisturbed natural areas, in order to enjoy and appreciate nature (and any accompanying cultural features - both past and present) that promotes conservation, has low visitor impact, and provides for beneficially active socio-economic involvement of local populations” (Ceballos-Lascuráin 1993 cited by Ceballos-Lascuráin 1996).

It would appear that profitable ecotourism on private land is associated with larger, better stocked wildlife ranches (Barnes & de Jager 1996). It is thus reasonable to state that the number of mammal species on offer in a reserve will in part determine the attractiveness of a reserve to ecotourists. However if this were the only consideration, then zoos would suffice this desire in ecotourists. The IUCN definition given above hints at the second issue which makes game reserves attractive, that being the feeling of “nature” and “wilderness experience”. The significance of this factor can not be underestimated, and unfortunately very little research has been conducted to quantify the effect. Brown *et al.* (1980) surveyed wilderness hikers in Colorado quantifying factors contributing to their enjoyment (see Table 3.1.). Hikers placed the highest psychological value on achieving a relationship with nature (a value of 3.2 out of a possible 4), and the presence of large and small animals scored much the same value (2.7).

This psychological factor is difficult to quantify and cannot be correlated to space in any simple linear relationship, though it could possibly be curvilinear with a number of plateaux regions, from “little space” to “big space” to “vast wilderness”. Since the effect is emotional and can not be properly quantified, it will be excluded from the analysis as a separate variable. A simple way of accounting for its effect would be to assume a greater percentage of occupancy of available lodging at larger game ranch size. However the effect is probably compounded by the fact that the larger an ecotourist reserve is, the larger will be the amount of facilities offered to ecotourists.

Table 3.1. Values obtained from cluster analysis of perceived contributions to recreational experience of back country hikers in the Weminuche area of Colorado (Brown *et al.* 1980).

	Value*
Psychological attributes:	
relationship with nature	3.2
escape physical pressure	2.9
exercise	2.6
freedom	1.9
achievement	1.6
reflection on personal values	1.3
Wildlife values:	
larger wildlife (bighorn, sheep, deer)	2.7
small wildlife (beaver, ptarmigan, other birds)	2.7
Good fishing	2.4
naturally reproducing fish	2.4

* Scale: highest value = 4.0; no value = 0.0; strongest negative value = -4.0

Undoubtedly tourists are also attracted to reserves for the uniqueness and diversity of the landscapes, and therefore of experience. This project does not try to quantify “uniqueness” as the emphasis is placed on a single vegetation type, namely semi-arid savanna. By contrast, the biological diversity of landscapes is a clear function of size, with the relationship usually following a sigmoidal shape (see Soulé 1987). Diversity in landscapes is divided into a number of components for describing the patterns of species richness, of which α - and β -diversity are the most important: α -diversity refers to the number of species within a homogenous community, while β -diversity incorporates the concept of species turnover along habitat gradients and among different communities in a landscape (Cowling *et al.* 1989 citing Wittaker 1972). Tourists also perceive that greater size would mean increased diversity, thereby implying a concave curved relationship, which thus differs from the actual sigmoid relationship. Again this can simply be represented by greater percentage occupancy of available accommodation at greater reserve size.

Thus the key factor in terms of profitability for ecotourist operations is size, which increases the number of “safari” species that can be kept on a property and increases the α and β -diversity of a habitat. However the actual profitability of an ecotourist enterprise depends on what is offered. This in turn is a function of the objectives of the owner/company and the target group of potential customers.

3.1.1. Human carrying capacity

One of the key considerations which need to be made with regard to ecotourist operations is the concentration of people that can be accommodated without substantially changing animal behavioural patterns (Shackley 1996) and also without destroying the client’s sensibilities about being out in the bush and away from the “madding crowds”. McNeely & Thorsell (1987) thus define environmental carrying capacity (CC) as:

“the maximum level of visitor use an area can accommodate with high levels of satisfaction for visitors and few negative impacts on resources.”

Carrying capacity can be divided into a number of categories which all affect the overall environmental CC of the system (after Shackley 1996):

- biological or ecological CC - that is the CC of animals on the land which can be maintained without degrading the forage resource.
- tourist or visitor CC - that level which can be maintained without seriously affecting animal behaviour (once again what constitutes “serious” behavioural change in animals is not well studied and has not been quantified). In addition, some species are more sensitive to human presence than others.
- accommodation and transport CC - fixed by bedspace and available transport
- psychological CC - this is the level beyond which visitor satisfaction drops as a result of overcrowding.

While all parts of the overall CC concept should be considered to ensure responsible development that is sensitive both to the needs of people and the environment, it is the psychological CC that will determine the profitability of a game ecotourist operation. The WTO (1992) recommended a formula for estimating tourist CC as such:

$$CC = \frac{\text{area used by tourists}}{\text{average individual standard}} \quad 3.1.1.$$

the denominator is expressed as persons per m², which is carefully defined for each case by evaluating psychological and ecological carrying capacity. From this one can calculate total daily visits as:

$$\text{Total daily visits} = CC * \text{rotation coefficient} \quad 3.1.2.$$

where,

$$\text{Rotation coefficient} = \frac{\text{no. of daily hours open for tourism}}{\text{average time of visit}} \quad 3.1.3.$$

In order to determine environmental factors, it is necessary to know the following:

- size of area and usable space (some areas might be inaccessible)
- fragility of environment (certain soil types, notably sand dunes are very susceptible to environmental disturbance)
- wildlife resources (distribution and diversity of wildlife is not uniform across the property both spatially and temporally)
- topography and vegetation cover (these affect CC because more rolling terrain

and thicker bush can conceal both animals and people, while both are very obvious on flat grassy plains)

- behavioural sensitivity of certain species to human visits (i.e. some species are more sensitive to the presence of humans than others and are thus more likely to behave differently).

It is possible to overcome some constraints relating to CC. One method would be to reduce the impact of tourist CC by banning private vehicles and transporting tourists in open backed vehicles and buses. There are associated constraints such as the fee charges for such a service, which might put the cost beyond the range of the man in the street. These remain individual management decisions.

3.2. HUNTING

In South Africa, it is estimated that there are about 50 000 hunters within the country's borders. In addition about 6 250 foreign hunters visit the country each year who each spend more than R5 000 each a day (a minibus excursion through Kruger National Park earns R300 a day - Nel 1995) or R50 000 for a ten day hunt, and thus earn the country valuable foreign exchange. Almost half of this value (about R2 000) goes to the land owner, a further R1 750 goes to the professional hunter and the rest (R1 250) is spent on travel expenses, taxidermic services and other miscellaneous payments (Nel 1996). These tourist hunters must be accompanied by at least one of about 400 professional hunters according to the law in South Africa (Eloff 1996). It is estimated that South Africa could absorb another 100 000 hunters per season, which would mean the creation of a further 50 000 jobs related to the industry, such as trackers, chefs, taxidermists (Enderwitz cited by Nel 1995). Although hunting revenues are high, they are a relative measure, and in absolute terms hunting only generates eight percent of the gross tourism revenue in South Africa each year.

Hunting operations are diverse and often form part of hybrid ventures, either with ecotourist activities in game reserves or with domestic stock on ranches. The actual operation depends

both on environmental constraints (e.g. size, land primary productivity) and the objectives of the owner/company. There are two broad categories, namely meat hunting and trophy hunting (after Hearne & McKenzie 1997):

Meat hunting - Meat hunters pay for the opportunity to experience the hunt and they keep the meat that they shoot. Meat hunters shoot both poor trophy males and female animals, and the hunters themselves are drawn from the local South African market. The species taken are usually the commoner species of antelope which can be offered for hunting at a reasonably moderate price.

Trophy Hunting - safari hunters seek out animals with impressive trophies. Trophy animals are bought on an individual basis and the safari hunter is allowed to keep the head and skin. The game reserve normally retains possession of the meat. In general, trophy hunters are foreigners, as trophy hunting is costly because many of the species that are shot are rare or of large body mass.

A third form of hunting that is recognised is known as culling. However this is a management tool used by venison production operations as a means of off take for meat production, and by staff of other game reserves as a management tool to control game numbers of especially destructive animals such as elephant. Since it is of limited profitability (apart from the sale of terminal products such as meat) and has little application to the analysis at hand, culling will not be discussed further.

3.2.1. Meat hunting

Property size is the most constraining factor on any game operation as it determines the number of species which can reasonably be offered while maintaining viable populations of those species. Thus, at smaller ranch sizes, less profitable meat hunting is usually the only viable form of hunting as the number of trophy types which can be offered is very limited. Still, it can bring in money, and biltong hunting in the Northwest Province can earn between R 3 000 and R 20 000 a year for local communities (Nel 1995). Meat hunting is usually directed at the local

market and is therefore of limited profitability, and is most often found on hybrid domestic/game operations. In these instances, the hunting is generally a supplementary form of income generation with the main operation still domestic stock.

Barnes & de Jager (1996) examined and compared the performance of three ranch models in Namibia. Two of the models represent typical livestock production enterprises with supplementary wildlife cropping and trophy hunting, of which one is a model of this form of land use on grass-tree savannas in the north of Namibia, and the other is based on karroid shrub savanna in the south. Because of the large differences in vegetation, the livestock on the properties are quite different. The northern farm is stocked with beef cattle and gemsbok, kudu, some springbok and warthog, while the southern farm is stocked with sheep combined with springbok and some gemsbok and kudu. The third model was a pure wildlife non-consumptive ecotourist operation in the northern savanna. The results of the exercise indicated that all ranching systems in Namibia generally had low profitability. However, of the two hybrid ranching systems, the southern karroid ranch was the more profitable because of the higher value of springbok night culling activities in the south, relative to those for gemsbok and kudu in the north. Barnes & de Jager (1996) attribute this to the higher value of springbok venison (which is more abundant in the south) as compared to kudu and gemsbok.

3.2.2. Trophy hunting

Trophy hunting properties are often stocked at lower stocking rates than those for biltong hunting (see Figure 2.1.). This is because the objective is to maximise individual animal performance while biltong hunting aims to maximise meat production. This further compounds the effect of land size - though the impact becomes less restrictive at large land sizes - as the amount of land available will determine the available forage which in turn will determine the total number of livestock units possible and as such the number of species that can be stocked.

Trophy hunting of some herbivore game species is possible on cattle/game hybrid systems. Generally though, the range of species under such circumstances is very limited. For a broader range of species, which includes more dangerous animals (e.g. buffalo), pure game operations are better. The prices that can be charged for hunting safaris increase geometrically as species

range offered increases, especially if the enigmatic “Big Five” are on offer. In direct relationship, these most expensive/profitable species require large areas for foraging and home ranges (especially the predators) further compounding the effect of land area on the profitability of a game hunting enterprise.

Since trophy hunting generally focuses on male animals in most species (this is especially the case for antelope species), it has been suggested that animal population structures should be manipulated to promote the male trophy fraction (McKenzie 1997). In contrast, there is little need to select between sexes for biltong hunting since the desired product is meat. While manipulating population structure at small population sizes may be useful and readily achieved, the chance that it could be achieved on a large scale (say for a population of a few thousand animals) is not likely. In addition, the effect of changing the sex ratio is not well understood and could have serious effects on the stability and viability of the population.

3.3. OTHER FORMS OF ECONOMIC USE OF GAME RANCHES

3.3.1. Selling game

Game selling can be a lucrative way of generating income, and this is especially the case in South Africa where the game ranch market is rapidly expanding and there is a need for animals to stock those ranches. Game selling is usually a side industry that accompanies the main thrust of the game operation, be that hunting or ecotourism. However there are cases when it can form a major part of the generated revenue. For example, Kuduland Ranches in the Northern Province of South Africa raise 50 percent of their revenue from hunting, 40 percent from game selling and only 10 percent from photo safaris (Nel 1995).

3.3.2. Resource use

While there are no other financial benefits from game ranching, there are resources on game ranches that do have value for rural communities. These include thatching grass, firewood and medicinal plants which can all be harvested to some degree without degrading the system. In

the case of firewood, tree harvesting can have a positive effect on the carrying capacity of the land by thinning out the thickets that arise from bush encroachment.

3.4. THE COSTS OF WILDLIFE PRODUCTION SYSTEMS

Game farming enterprises are expensive to set up, and this often proves to be the key factor that prevents game operations starting up. Eloff (1996) states that for a typical game farm 20 km² in extent, the setup costs which include the perimeter fencing, tourist accommodation and other infrastructure and equipment, range between \$ 300 000 to \$ 400 000. The game required to stock the ranch costs a further amount in the order of \$ 300 000.

In South Africa, the problem of raising enough capital for set-up costs has been overcome by the introduction of “share blocking”. A number of people buy blocks of shares in a company that has acquired ownership of a farm, and thus become co-owners of the movable and immovable assets of the farm. In addition, they acquire the right to use the land and certain of the assets, such as the use of a house. The share block company is run by directors and a management committee while voting rights are apportioned according to the number of shares owned (Hearne & McKenzie 1997).

Apart from the perimeter fence and in some cases the provision of water points for animals, the division of investment costs associated with game-related operations vary substantially according to the objectives of the managers. For example, costs associated with a trophy hunting safari could be divided into the following groups:

1. Transport

- ▶ vehicles
- ▶ aeroplane

2. Safari camp equipment

- ▶ fridges, generators, tents, furniture, kitchen equipment etc

3. Hunting equipment

4. Staff

- ▶ kitchen staff
- ▶ trackers / game scouts

5. Miscellaneous

- ▶ medical equipment

By contrast, the simplest facilities required for a tenting ground in a game reserve, would probably include the provision of water (by tap) and toilet amenities, and possibly also electricity. At the other end of the ecotourist scale, for very up market operations, everything is provided from a three bedroom luxury lodge to servants and meals.

Another important consideration which affects profitability is location. In general, while location can be essential for the success of a game operation, game enterprises are less dependent on proximity to a market than a commercial domestic stock enterprise, as people are prepared to travel to them. Success is thus dependent on what the enterprise has to offer to its potential clients; the more a game reserve has to offer, the less dependent it becomes on distance from tourist centres if the market exists at a regional scale and the infrastructure to get to the game reserve exist. I make this point, because many national parks in central Africa are poorly utilised by tourists, for a number of reasons. Firstly, there is little infrastructure for people to get there, either from within the country's borders or from other countries. Secondly, the countries in which these parks are found have a small market of people who can afford and are interested in going to stay in them, and are thus largely dependent on external tourists to make any revenue. Thirdly, these international tourists are not inclined to go to poorly developed Central African countries because of the high risks involved which include poor emergency medical services, tropical disease risks and high crime rates.

South Africa, in contrast to almost all other African countries does have a large market of local people interested in wildlife-related activities. Location of game ranches in relation to the

major urban regions (Pretoria-Witwatersrand-Vereeniging Region, Greater Durban Region, Port Elizabeth Region, Cape Town Region) does have an effect, especially in the case of smaller game ranches and parks which are likely to be highly successful simply due to their proximity to a large market source. Since this exercise is not designed to fully assess the effect of location, percentage occupancy is a simple method of accounting for the effect of distance from the market source.

4. QUANTIFYING AND MODELLING THE CONSUMPTIVE LAND-USE OPTIONS

Having explored the theory behind each of the three possible land uses in a semi-arid savanna, it is now necessary to try to quantify each use so that they can be compared. This is achieved by constructing simple algorithms of the factors which affect each land-use into which established quantitative results are substituted to obtain absolute values for the comparison. At this point it is necessary to reiterate that the models can be divided between those which are consumptive in their nature (commercial beef production, subsistence production and wildlife harvesting) and those which are non-consumptive (ecotourism). Because the two groups have rather different focuses in their modelling, they have been placed in separate chapters. This chapter deals with the modelling requirements for the consumptive land-uses, while Chapter 5 deals solely with ecotourism.

The key factor behind consumptive land usage is that it is dependent on the production potential of the land. In the case of livestock and wildlife, the production potential relates directly to the stocking rate (SR). Stocking rate is the number of animal units (AUs) per hectare. An animal unit is defined by Klug & Webster (1993) as:

“a non-lactating animal with a mass of 450 kg gaining 0.5 kg per day on forage with a digestible energy of 55 percent.”

AU is thus a measure of the feed requirements of herbivores and is related to forage availability on a rangeland by carrying capacity (CC). CC is the maximum number of AUs that can be carried by the land without depleting the long-term productivity of the land. CC is not a fixed quantity, as indicated in Chapter 2, and varies between seasons and years in accordance with mean annual precipitation (MAP). The feed requirements of most herbivore species have been related back to the AU system and thus are easily incorporated into comparative models of performance. Thus for ease of comparison, each model constructed is directly related back to stocking rate.

In this regard, an important issue is to standardize the environmental conditions for all three land-use options. This is because the response by each system to different environmental conditions (especially with regards to vegetation) varies quite substantially. Thus a semi-arid savanna has been chosen as the environmental background for the Cost-Benefits Analysis. The vegetation choice is tactical as this is the area to which a broad range of large African herbivores are most suited and is thus the most suitable for multi-species wildlife production.

4.1. DESCRIPTION OF THE LAND SITE

4.1.1. Physical characteristics

Since the analysis conducted here is theoretical, the characteristics of the site for the Cost-Benefits Analysis are fairly generalized. The site is in a region of semi-arid savanna typical of that found in Zululand, north-eastern KwaZulu-Natal. Bioclimatic zones 9 (lowland to upland), 10 (riverine and interior lowland) and 11 (arid lowland) all form part of the area (Klug & Webster 1993). Mean annual rainfall ranges from 600 to 800 mm an^{-1} (the average is 650mm an^{-1} , but arid lowveld can go down to 320 mm an^{-1}), with 70 percent of the rainfall falling in the summer months from October to March (Goodman 1990). Temperatures are high (mean annual temperature ranges from 18 - 23 °C) with long dry periods. Frost is rare to nil and evaporation rates are high from 1448 mm an^{-1} upwards (Klug & Webster 1993). The soils are mesotrophic to eutrophic and of sandy texture, while the grass component is sweetveld, with a feed availability of 3500 kg $\text{AU}^{-1}\text{an}^{-1}$. However the low rainfall means that the potential stocking rates are low at 0.2 AU ha^{-1} or 5.0 ha AU^{-1} (Klug & Webster 1993).

There are a variety of vegetation types in the region but a definition of these is not necessary for the purpose of this study. The vegetation must however be divided into the grazing components. Hearne *et al.* (1996) divided the vegetation according to the requirements of the different animal types, namely bulk grazers, selective grazers, mixed feeders and browsers. Bulk grazers tolerate tall, high fibre grass stands while concentrate grazers and mixed feeders require short grass which is of better quality. Mixed feeders are about 60 percent grazers and 40 percent browsers, and as such share the browse resource with pure browser species. In

terms of domestic animals, cattle are broad range grazers while goats are mixed feeders. Since the average tree : grass ratio can vary substantially from region to region in savanna, the forage ratios have been assigned arbitrarily. These ratios will remain constant as the size of available land increases. The amounts of different forage components per hectare have been set at the following forage capacities:

Tall grass = 0.06 AU ha⁻¹ (21 % of available forage)

Short grass = 0.14 AU ha⁻¹ (50 % of available forage)

Browse = 0.08 AU ha⁻¹ (29 % of available forage)

Hearne *et al.* 1996 indicate that tall grass forms a much greater part of the sward than presented here, which is shown by this analysis to favour wildlife production (see section 6.5.).

4.2. COMMERCIAL BEEF PRODUCTION

For a commercial beef venture, profit is a function of gross revenue from beef sales and variable and fixed (establishment) costs.

$$\text{Maximum } P_c = R_b - C_v - C_f \quad 4.2.1.$$

The research into assessing and correctly apportioning the costs and profits from commercial beef production systems is a well- established science. In South Africa the COMBUD Enterprise Budgets (Department of Agriculture: KwaZulu-Natal) provide very accurate assessments of the costs and income generated by the most appropriate forms of commercial production in the different bioclimatic regions of KwaZulu-Natal. The estimates for revenues and costs are presented as total (absolute) values, per AU values and per cow values (the latter two are both relative values). (It must be noted that the COMBUD analyses are based on a particular farm size of 1200 ha, working with a 100 cow system.) Since the analysis undertaken here is based on using comparable stocking rates, the values on a per AU basis (Table 4.2.) will be used. For bioclimatic regions 9,10 and 11, the beef production system of choice is the production of two-year-old steers completely off veld. The only form of supplementation is the

provision of licks in both summer and winter. Further assumptions of the COMBUD steer production system are as follows:

3. Spring calving from August to November.
4. Calving percentage = 80 %; Calving mortality = 4 %.
5. Herd mortality excluding preweaners: 2 %.
6. Heifers bred at two years of age with mass of 300 kg.
7. Culling replacement rate: 20 %. About 30 % of all would-be culls are pregnant and run another summer to rear their last calf.
8. Average weaning mass: 200 kg.
9. Cull cows sold September/October weighing 500 kg live mass or 235 kg cold dressed mass.
10. Bulling percentage: 4 %.
11. Two-year-old steers finish at an average mass of 470 kg.

Table 4.1. Division of cattle herd by size and the related feed requirements (Department of Agriculture: KwaZulu-Natal 1996).

Class	Class fractions		AU equivalents	
	Summer	Winter	Summer	Winter
Breeding cows	0.394	0.298	1.25	1
Breeding heifers	0.07	0.081	0.86	0.94
Calves/weaners	0.103	0.204	0.32	0.53
Cull cows	0.035	0.13	1.25	1
Heifers 1-2 years	0.09	0.124	0.6	0.68
Steers 1-2 years	0.099	0.138	0.65	0.74
Heifers 2-3 years	0.058	0	0.76	0.84
Steers 2-3 years	0.128	0	0.84	0.93
Bulls	0.021	0.025	1.3	1.3
Total	1	1		
Stocking rate			0.21	0.17

The off take of steers, heifers and cull cows along with spring calving allows the farm manager to use the different feed requirements of the age classes which vary between winter and summer (see Table 4.1.) to match feed availability.

Table 4.2. Gross income from two-year-old steer production system (Department of Agriculture: KwaZulu-Natal 1996).

Class	Average mass (kg)	Average price/kg live mass (Rands)	Per AU (Rands)
38 Steers	480	3.6	526.45
19 Heifers	446	3.6	133.31
16 Cull cows	450	3.3	103.83
Total gross income			763.59

The variable costs indicated in Table 4.3. are fairly high, and will of course vary from region to region. Hatch (1996) cites values of R 156.50 AU⁻¹ for commercial beef ranches in northern Zululand in 1993 (about R 197.14 AU⁻¹ in 1996). The large difference in value could be due to rainfall variation (good versus bad year).

Table 4.3. Variable costs allocated to steer production (Department of Agriculture: KwaZulu-Natal 1996).

Cost item	Cost per unit	Total per AU (Rands)
Summer lick	@ R 984/tonne	19.78
Winter lick	@ R 880/tonne	74.6
Veterinary	@ R 45 per AU	45
Labour	@ R 500 per person per month	52.44
Railage and transport	@ R 35 per slaughter head	11.17
Marketing: Abattoir	@ R 106.34 per slaughter head	52.27
Purchase replacement bull	@ R 4 000 per bull	17.48
TOTAL ALLOCATED COST		272.43

The COMBUD budgets do not take into account any long-term fixed costs, which include physical (e.g. fencing, roads, water provision), information and transaction costs. As indicated in Chapter 2, fixed costs introduce economies of size. Lyne & Ortmann (1996) state that the choice of production technique is dependent on size. For example machinery may replace human labour on larger farms because the fixed costs can be spread over greater volumes of output (Lyne & Ortmann 1996). However machinery can be hired and thus is feasible on small properties, depending on the capital available to the smallholder. On this basis Lyne & Ortmann (1996) defined a number of enterprises with low, medium and high technology based on the ratio of capital input to human labour per unit output. The results of their analysis indicated a minimum feasible farm size in the KwaZulu-Natal lowveld of 450 ha, below which the effect of fixed costs per hectare increases geometrically. At this size fixed costs were R39 ha⁻¹, but the fixed costs only reduced by R6 to R33 ha⁻¹ for farms of 3000 ha. Therefore between 100 ha to 450 ha, a parabolic function can be used to indicate the relationship between size and fixed costs:

$$C_f = -0.06163 S^2 + 55.467 S + 5069.925$$

$$; 100 \text{ ha} \leq S \leq 450 \text{ ha} \quad 4.2.2.$$

Below a certain size, it is probable that an absolute minimal value for the fixed costs is reached. For this analysis, this cut-off size has been identified as 100 ha, and the cost given as R 10 000.

$$C_f = 10000 \quad ; S \leq 100 \text{ ha} \quad 4.2.3.$$

Above the 450 ha mark, a linear function is used for simplicity. In reality the function is still curvilinear, but the curve is so mild that a linear function provides a sufficiently accurate representation of the relationship:

$$C_f = (-0.00235 S + 40.0575) S \quad ; S > 450 \text{ ha} \quad 4.2.4.$$

However, this relationship will mean that fixed costs will deteriorate to zero which is incorrect, so a minimum fixed cost value of R 25.00 AU⁻¹ ha⁻¹ is assigned on the assumption that the actual change in fixed costs per hectare beyond this point is extremely small.

4.3. SUBSISTENCE LIVESTOCK PRODUCTION

One of the key dilemmas faced by rural rangeland farmers is the problem of open access to the land resource. Under the open access system, each stock owner will try to maximise his stock since there is no levy on use of the grazing resource. Gordon's (1954) seminal article demonstrates that, under conditions of open access, the stocking rate will approach an equilibrium where the Value Average Product (VAP) of the herd (which includes the value of all products - meat, hides, milk, manure, etc.) is equal to MC (which includes levies or taxes on livestock). Consequently, the naive view advocated by Hardin (1968) that stocking rates will be maximized when land is an open access resource is only correct when the MC is relatively low. Lyne (1998, personal communication) suggests that this is probably the case in KwaZulu-Natal where there are no cattle taxes and certain costs such as dipping are subsidized, as supported by findings by Hatch (1996) of stocking rates in excess of 0.7 AU ha⁻¹ for the region. When limits on individual herd sizes are enforced, as would occur under common property conditions, the stocking rate will usually be reduced and lie somewhere between open access and private property extremes (Lyne 1998, personal communication).

Unregulated use for and overexploitation of grazing and other land resources is unsustainable. It is obvious from the comments made above that the type of enterprise undertaken by a community has strong implications both for stocking rate and the realization of capital gains.

A system which has been proposed as a solution to the overutilisation dilemma is to make each adult member of the community a shareholder in all assets of the land, including grazing and arable land, water resources, wood fuel and dipping infrastructure (Bembridge & Tapson 1993). The advantage is that all work on the farm is centralized under one body which removes the inefficiency of small independent farming units. The community then has the option of managing the entire farming enterprise themselves or leasing the land out to a few farmers. Either way the profits can then be split up equally among members of the community. Since

individual farmers form part of the community, all benefits/profits remain internal to the community as a whole. When profits are shared proportionately according to the investment of each individual (e.g. in proportion to the number of cattle each farmer contributes), there is a strong incentive, like any other private land owner, to maximise profit by equating the Value Marginal Product (VMP) of the herd with the MC of keeping livestock on the land (Lyne 1998, personal communication). Under such conditions, Lyne suggests that stocking rates will tend towards those on commercial ranches (i.e. 0.2 AU ha⁻¹).

Since this is a subsistence farming system, at least some of the land must be suitable for dryland cropping of maize, sorghum and some melon species. We will assume that ten percent of the land can be put to dryland cropping. As pointed out in Chapter 2, an advantage of subsistence production is that draught power costs are absorbed internally by using cattle to carry out the work.

4.3.1. Modelling subsistence livestock production

There still appears to be little data clearly relating productivity in subsistence livestock systems to stocking rates on either a per hectare or per AU basis. Consequently accurate analysis of the costs and benefits through use of a linear optimization is difficult. It has been recorded that stocking rates in the communal areas of Ciskei and Transkei are over 100 percent greater than considered suitable for the vegetation (Bembridge & Tapson 1993). In the semi-arid region discussed here, that equates to approximately 0.4 to 0.5 AU ha⁻¹. This however may be fairly conservative, as Hatch (1996) gives estimates for the communal cattle herd in KwaZulu-Natal at 0.7 to 1.0 AU ha⁻¹. At this stage, a value of 0.5 AU ha⁻¹ shall be used for the subsistence systems.

Herd composition for communal herds is similar to those of commercial farms (Table 4.4.) except for the large number of oxen which are important to subsistence farmers for draught power/work uses (Bembridge & Tapson 1993). The high stocking rates and low management inputs in the Ciskei and Transkei reflect in the calving and weaning rates, and calf and herd mortality rates which are much higher than off take rates (Bembridge & Tapson 1993) (compare with commercial mortality rates which are about three percent per annum).

There was no clear data indicating the ratio between cattle and goats. However using census data (DAS 1996) for the total number of cattle and goats in the former TBVC states and self-governing regions in South Africa for the years 1992 - 1994, a ratio of 2.70 cattle to 1 goat was deduced. This translates into fractions of 0.73 cattle to 0.27 goats. Needless to say this value is broad-based and fairly inaccurate at a regional level, but is sufficient for a theoretical analysis.

It is important to note that the models below give the relationships for cattle alone. The reason for this is that while cattle have been divided into six classes (calves, heifers, cows, steers, bulls and oxen), goats are only divided into three classes (kids, ewes and rams). As a result they cannot be written into one equation phrase. It would be simple enough to add another separate phrase for goats, but I consider this unnecessary as the logic of the cattle equations given below is easily applied to goats. Thus values for goats, where they apply (as indicated in Chapter 2) are given below where appropriate.

Due to the paucity of data, I have had to use a wide range of values (from the mid-1980s up to the present) to account correctly for different costs and revenues. These values have been changed to appropriate values for 1996 using an inflation rate of 8 percent.

4.3.1.1. Milk

Revenue from milk is dependent on the amount of milk produced and the price of milk. Milk production in any one year is a function of the number of cows available, the fraction of cows in milk and the fraction of cows with calves. The fraction of cows in milk is dependent on the calving percentage of the population. A further factor affecting milk production is the condition of the cows, *cf*. In this case, condition is a function both of health and available forage:

$$R_{m,t} = 0.9 S F_3 F_{3,c} \frac{SR_t}{u_c} pm Y_m cf \quad 4.3.1.$$

,where $R_{m,t}$ is the total revenue from milk in year t

S represents the size of the property of which 0.9 is used for grazing
(0.1 is used for dryland cropping)

F_3 is the fraction of the population that are cows (35.6 percent)

$F_{3,c}$ is the fraction of cows that are with calf in any year

SR_t is the stocking rate in year t

u_c is the average stock unit for the weighted population distribution
(a value of 0.76 as indicated in Table 4.4.), which gives the actual
average number of animal units per hectare (0.526 animals)

Y_m is the yearly yield of milk per cow (243 $l\ yr^{-1}$)

pm is the price of milk per litre (R 2.50 l^{-1})

cf represents the condition factor for cows (0.8 in average years).

The condition factor, cf , is a function of the actual stocking rate at time t relative to
the desired stocking rate, SR_d (0.5 AU ha⁻¹ in average years),

$$cf = (SR_t - SR_d) + 0.9 \quad 4.3.2.$$

The weakness of the milk model is that it does not indicate fluctuations in milk
production through the year. Thus reductions in price during periods of excess
production are not accounted for and the value of milk is consequently overstated. The
excess milk should be valued at its farm gate price of about R 1.25 per litre for
commercial farmers (Lyne 1998, personal communication), but this was not done and
the overestimate remains. In any event, it is possible that there is always full demand
for milk due to its utility for uses other than food (tanning, skin cream, medicinal use
etc.). Another point which reduces the need to differentiate production through the
season is that maximum production occurs after calving and is thus utilised by the
calves.

Table 4.4. Data on milk production in cattle and goats in communal systems
(adapted from Devendra & Burns 1983, Scoones 1992, Bembridge & Tapson 1993, Hatch 1996)

Factor	Cattle	Goats
Adult female fraction	0.356	0.5
Females with calves / kids	0.41	0.56
u_c	0.76	0.15
Milk yield per female (l yr ⁻¹)	243	20

4.3.1.2. Sales, deaths and purchases

The money generated from sales and slaughters is determined by fraction of sales and slaughters in each age class of animals. Most sales occur during drought years, so the condition factor must be included. Oxen are most favoured for sale, and usually most calves are lost by starvation in droughts, thus the remainder of sales are bulls and old cows. Therefore the revenue from sales, R_s , is:

$$R_{s,t} = \sum_{i=1}^5 S \frac{SR_i}{u_c} cf F_i s_i (ps_i + ph_i) \tag{4.3.3.}$$

, where

- s_i represents the fraction of animals of class i that are sold
- F_i represents the fraction of animal class i in the population
- ps_i is the sales price for meat of animal class i
- ph_i is the sales price of hides of animal class i .

While sales account for the deliberate off take, for money and ceremonial needs, a large number of animals are lost to disease and particularly starvation as a result of the very high stocking rates which become unsustainable during drought years. The meat and hides from these animals are still used, and thus must additionally be accounted for in the subsistence model.

$$R_{sl,t} = \sum_{i=1}^5 S \frac{SR_t}{u_c} cf F_i m_i (pc_i + ph_i) \quad 4.3.4.$$

, where m_i is the mortality fraction of animal class i
 pc_i is the carcass price of animal class i .

Hatch (1996) calculated the sales value of meat from an animal on a Rands per kg live-mass basis, which is set at the average 1996 rate of R 3.60 kg live mass⁻¹. This value cannot be used for animals that have died from starvation or sickness as the quality of meat will have fallen dramatically as would the live weight of the animals (mass of dying animals assumed to be 60 percent of average condition animals). Thus an amount of R 1.80 per kg live mass (half that for live sales) is used to calculate the contribution of dead animals to the system (see Cairns 1988). The cost of animal hides was calculated as R 37.00 per hide based on Cairns' (1988) value of R 20.00 per hide.

Purchases represent a cost to the system. Only cows and heifers are bought to increase breeding stock after droughts.

$$C_{p,t} = \sum_{i=2}^3 pr_i pp_i \frac{SR_t}{u_c} S \frac{SR_d - SR_t}{SR_d} \quad 4.3.5.$$

,where SR_d is the desired stocking rate of 0.5 AU ha⁻¹
 $pr_i = 2,3$ is the purchase rate of heifers and cows
 $pp_i = 2,3$ is the purchase price of heifers and cows.

Since at the end of a drought there is a reduction in the number of cattle available for purchase and there is a high demand for those animals, it is reasonable to assume that the purchase price of cows and heifers will be greater than their sales price during average or high rainfall years when stock animals are plentiful. Consequently, a sales price of R 4.00 per kg live mass is used.

Table 4.5. Cattle data used in model calculations (adapted from Hearne & Buchan 1990, Scoones 1991, Bembridge & Tapson 1993, Hatch 1996).

i	Animal class	Age	Herd composition	AU equivalent	Mass (kg)	s_i	pr_i	Dying mass (kg)	m_i
1	Calves	0 - 1	10.7	0.2	100	0	0	60	0.2
2	Heifers	1 - 3	18.9	0.5	200	0	0.2	120	0.1
3	Cows	3+	35.6	1	300	0.1	0	180	0.1
4	Steers	1 - 3	22.5	0.6	200	0	0	120	0.1
5	Oxen	3+	9.2	1.2	300	0.4	0	180	0.1
6	Bulls	3+	3.2	1.2	350	0.2	0	210	0.1
	Herd			0.76					

Table 4.6. Goat data used in model calculations (adapted from Devendra & Burns 1983, Bembridge & Tapson 1993).

i	Animal class	Age	Herd composition	AU equivalent	Mass (kg)	sr_i	pr_i	Dying mass (kg)	m_i
1	Kids	0 - 1	30	0.08	15	0	0	9	0.2
2	Ewes	1+	50	0.18	30	0	0.1	18	0.1
3	Rams	1+	20	0.16	40	0.4	0.1	24	0.1
	Herd			0.13					

4.3.1.3. Biological productivity

Hearne & Buchan (1993) accounted for biological productivity by calculating the increase in livestock assets from one year to the next, as well as the increase in cattle prices due to inflation:

$$R_{a,t} = \left[(dc_i / dt) sp_i (1 + ix) + \sum_{i=1}^6 c_{i,t} sp_i ix \right] S \frac{SR_t}{u_c} cf \quad 4.3.6.$$

,where c_i is the number of animals in group i
 sp_i is the sales price for group i
 ix is an index representing the amount by which cattle prices increase in real terms (nominal value of zero chosen).

For simplicity only two animal groups are defined as changing from year to year. Calves are treated as one group and all other animal classes are placed together under the other group. The differential equations below include gains and losses to each of the two groups:

$$dc_1 / dt = c_3 cr - c_1 wr - c_1 cm \quad 4.3.7.$$

,where cr is the calving rate for the cows
 wr is the weaning rate of calves at the end of each year (fraction an^{-1})
 cm is the calf mortality rate (fraction an^{-1}).

$$dc_{2,3,4,5,6} / dt = c_1 wr - c_i hm - c_i s_i + c_i pr_i \quad 4.3.8.$$

,where hm is the herd mortality rate
 s_i is the previously used sales rate, which also serves as a measure of the off-take rate.

Table 4.7. Cattle and goat reproduction, mortality and off-take in communal areas (adapted from Devendra & Burns 1983, Bembridge & Tapson 1993, de Villiers 1996) (values expressed as percentages).

Factor	Cattle	Goats
Calving / kidding rate	41.08	100
Weaning rate	26.61	56.3
Calf / kid mortality	23.52	24.1
Herd mortality	13.09	13.5
Off-take rate	5.94	9.9

4.3.1.4. Manure

Calculating the potential revenue per year from manure is a simple process of relating manure production per AU to a fertilizer equivalent value. Thus,

$$R_{d,t} = S SR frc fr_{eq} Y_d cf \quad 4.3.9.$$

,where Y_d represents the constant of collectable dry manure per AU per year (879 kg - Scoones 1992)

fr_{eq} is the fertiliser equivalent per unit manure (200 g per 1 kg manure)

frc is the fertiliser cost at R 0.93 kg^{-1} (adapted from Cairns 1988).

It should be noted that production in subsistence systems in KwaZulu-Natal are changing and inorganic fertilizer use is increasing. Rodgers (1994) states that, in the South Coast Region of KwaZulu-Natal, 314.5 kg per hectare is being used which amounts to a cost of R 55.7 ha^{-1} (estimated fertilizer cost of 18c kg^{-1}).

4.3.1.5. Work power of cattle

Work power is drawn mainly from oxen and bulls, although cows can be used (see chapter 2). In addition, due to better infrastructure in KwaZulu-Natal as opposed to Zimbabwe (see Scoones 1992 in Chapter 2), little if any cattle power is used for transport other than of agricultural related products. Thus most cattle power is used for draught in agricultural fields. Pingali *et al.* (1987) cite Singh's (1977) research in Tanzania on the amount of time required by 20 - 25 horsepower tractors (5.5 hours ha⁻¹) in comparison to oxen (7.5 ox-pair days ha⁻¹) to plow an agricultural field. Based on estimates obtained (Directorate of Agricultural Economics 1989), the costs of purchasing and running a 18 kW tractor in 1996 would be R 404.83 ha⁻¹ or R 72.87 hr⁻¹, which converts to a draught value of R 53.97 d⁻¹ per ox-pair or R 26.98 d⁻¹. Thus if all the draught power of bulls and oxen could be used, the potential revenue that could be generated from cattle would be:

$$\text{Potential cattle } R_{w,t} = 0.9 S \frac{SR_t}{u_c} F_i Y_w dp \text{ cf} \quad 4.3.10.$$

,where $F_i = 5, 6$ is the fraction of the population that are bulls and oxen
 Y_w is the work yield per animal per year (200 days - Hearne & Buchan 1990)
 dp is the draught price per day at R 26.98 d⁻¹.

However, since cattle are only used for draught (and not transport) in KwaZulu-Natal, the true value of cattle to subsistence farmers is constrained by the amount of cultivatable land, which in this case is only ten percent. Thus the potential value is:

$$\text{Potential Land } R_{w,t} = 0.1 S 15 dp \text{ cf} \quad 4.3.11.$$

Note that the profits are now calculated on a per hectare basis as 15 represents the number of days it would take one ox to complete ploughing a hectare. Both work equations are important, since if the adult male population of cattle had to crash, or if

the relative amount of cultivatable land were to increase dramatically, the number of cattle would become the constraining factor.

4.3.1.6. Costs of subsistence production

The costs of subsistence livestock farming have been outlined in Chapter 2. To revise, there are health costs, management/herding costs and water supply costs. Scoones (1992) worked out these costs on a per AU basis and came to a value Z\$ 7.30 AU⁻¹. Hatch (1996) by contrast suggested a value of R 160 AU⁻¹, but concluded that human labour must be much cheaper as this value is unsustainable. For this analysis, values will be taken from the COMBUD harvest sheets already mentioned, where veterinary costs are R 45.00 per AU and labour costs R 52.44 per AU. Scoones also mentions costs for water carriers and dipping infrastructure. These are arbitrarily assigned a combined value of R 50.00, giving a probable cost of R 147.44 AU⁻¹. Obviously as stock numbers increase with property size, absolute herding costs increase in a stepped manner as more herders have to be employed and further dips have to be built once their full capacity has been reached. However for our needs this complexity is not necessary, so the relation is assumed linear, which gives a relatively simple equation.

$$C_{s,t} = S SR_t c_{LU} \quad 4.3.12.$$

,where c_{LU} is the cost per cattle livestock unit (@ R 147.44 AU⁻¹) .

4.3.1.7. Dryland cropping

Since draught costs and fertilizer costs are internal to the system, the only cost to the subsistence farmer comes in the form of seed purchases. Thus a simple empirical value of market price per hectare of dryland maize is given.

$$R_{cr,t} = 0.1 S M_s mp cf_m - 0.1 S sd p \quad 4.3.13.$$

,where M_s is the specific maize production of dryland cropping (t ha⁻¹)

mp is the maize price (R t⁻¹)

cf_m is the condition factor of maize which is dependent on mean annual rainfall

sdp is the seed price per hectare of dryland cropping (R ha⁻¹)

0.1 is the ten percent of land that is suitable for dryland cropping.

Cairns (1988) attempted to cost the value of maize production in the Nkandhla Region in central KwaZulu-Natal. Cairns priced the maize on the basis of replacement costs of buying maize from wholesalers in the region which came to R 562.50 t⁻¹ (or R 1041 t⁻¹ in 1996 values). Rodgers (1994) estimated the average maize yield of communal agriculture on the South Coast of KwaZulu-Natal to be 0.8 t ha⁻¹ at a value of 18 c kg⁻¹ (21 c kg⁻¹ or R 210 t⁻¹ in 1996 values). This region includes the Valley Bushveld (Bioclimatic region 10b) which has similar rainfall to the Zululand Lowveld, but it was not clear whether or not these fields were watered so production is further reduced for this analysis to 0.5 t ha⁻¹ at R 550 t⁻¹.

Cairns (1988) estimated that families were spending R16.00 ha⁻¹ on seed which was only 20 percent of the amount required for field seeding. By contrast, Rodgers (1994) gives a value of R 11.83 spent on seed per hectare. This might reflect a differing seeding rate which results from very different climatic conditions, as Nkandhla is at a higher altitude and has more rain per annum than the South Coast Region. Also, Rodgers (1994) does not state whether or not other seed is kept for sowing from the previous season's crop. I have thus used a value of R20.00 which lies between these two estimates at 1996 values.

4.3.1.8. Profitability of subsistence farming

The overall profit of subsistence livestock production is thus

$$P_s = R_m + R_s + R_{sl} - C_p - C_s + R_{cr} \quad 4.3.14.$$

Note that the benefits from biological productivity, manure and cattle work are not included in the profit function. The effect of biological productivity on profit margins is indirect as the variable affects the animal numbers from one year to the next, which in turn determines the overall profit margin from communal production. Benefits from dung and cattle work are savings which would otherwise have been incurred as costs if they had to be bought. Although they are not included in the net profit equation, both manure and cattle work make an important contribution to communal subsistence production, but their importance may vary according to the prevailing environmental conditions.

4.4. WILDLIFE RANCHING

As described in the previous chapter, benefits from wildlife ranching can be divided into consumptive and non-consumptive values. The sections that follow attempt to quantify these values against farm area size. Due to a lack of established theory in the areas discussed, a number of techniques will be used. Hunting profits can be established using linear programming which optimises population ratios for maximum profit. Ecotourism is less clear as there apparently has been little work done relating attractiveness of a game reserve to its size. A simple regression is established here on the basis of profits in parks and reserves in KwaZulu-Natal under the control of the Natal Parks Board.

4.4.1. The game harvesting optimisation

Since hunting and game sales both form consumptive uses of the land, they can be substituted into a single model designed to optimise profits from the three forms of harvesting, namely trophy hunting, meat hunting and game sales. The model used here is based on a model described by Hearne *et al.* (1996), which was used to optimise hunting off-take in a section of a game reserve.

4.4.1.1. Animal Purchase Costs

The animal purchase costs for a game ranch, $K_{t,j}$, are as follows:

$$K_{t,j} = \frac{x_j pc_j}{a_{p_{PB}} ix} \quad 4.4.1.$$

, where x_j is the number of animals of species j
 pc_j is the actual purchase cost of species j .
 p_{PB} represents the payback period (in years) for purchased animals, which is ten years (this assumes that animals are only bought initially).
 a is defined in the usual manner:

$$a_{p_{PB}} ix = \frac{1 - (1 + ix)^{-p_{PB}}}{ix} \quad 4.4.1a.$$

, where ix is the real interest rate ($ix = 0.03$) which shows the actual purchase cost of animals.

The payback period is fairly important when distinguishing between benefits from subsistence systems and high input commercial systems (beef and wildlife) which have large establishment costs. Obviously over a short term payback period, subsistence systems will be successful as they have low establishment costs to remove, whereas wildlife and commercial beef will suffer. By contrast, longer payback periods will favour the more financially profitable wildlife and beef systems.

4.4.1.2. Fencing costs

Fencing costs , C_{fn} , are a simple function of the area : perimeter relation of a square.

$$C_{fn} = \frac{\sqrt{S}}{10} 4 \frac{(\text{Cost of fencing per km})}{a_{PB}^{fix}} \quad 4.4.2.$$

Eloff (1996) estimated for the Thabazimbi case, that a 22 km fence of 2.4 m high with three electrified wires plus an entrance gate and separate gate for service vehicles would cost R 211 061, which converts to R 9 593.68 km⁻¹. However the costs of fencing vary because of the requirements of different species, such that larger animals require higher input costs (more electric fencing and higher fences of stronger wire) than smaller species. In this model, three fencing costs are devised (R 8 000, R 15 000 and R25 000 per kilometre) to account for these differences. The spreadsheet is set to increase fencing costs to the required level of the species included in the model. Note that the equation is also a function of payback period, again set at ten years. If it is necessary to provide water to the animals then the cost of troughs and pumps, C_{tr} , is:

$$C_{tr} = T_s S (\text{Cost of troughs per ha}) \quad 4.4.3.$$

,where T_s is the specific number of troughs per ha.

At this stage, water troughs have not been included in the model.

4.4.1.3. Profit

The total number of each species hunted in a year, $h_{t,j}$, which will maximise the revenue is:

$$\text{Maximise } J = \sum_{j=1}^m \sum_{t=1}^n p_j h_{t,j} - \sum_{j=1}^m \sum_{t=1}^n K_{t,j} - C_f \quad 4.4.4.$$

Note that C_f is a fixed cost and thus has no effect on determining the species composition. The value p_j is derived from a ratio of the total price charged for trophies, pv_j , to meat hunts, pb_j .

$$p_j = pv_j v_j + pb_j (1 - v_j) \quad 4.4.5.$$

The number of trophies in a year, v_j , is very few. Hearne *et al.* (1996) specified the trophy fraction as 0.04 of the total population. Thus,

$$v_j = 0.04 x_{t,j} \quad 4.4.6.$$

, where $x_{t,j}$ is the population of species j in year t .

NOTE: If $h_{t,j}$ is the number of animals harvested then p_j is as follows:

$$p_j = pv_j v_j + pb_j b_j + ps_j (1 - v_j - b_j) \quad 4.4.7.$$

, where b_j is the number of meat hunts in a year.

In this latter model, the profit of game sales, ps_j , is indicated. However, it may be reasonable to assume that selling game will always be less profitable than hunting because of the high management costs required for capturing and transporting game which hunting does not incur. Thus the true profit of game sales is dependent both on the sales price, which of course is the same as the cost price of purchasing animals, and the costs of management required for an individual of each game species in year t :

$$ps_j = pc_j - cs_{j,t} \quad 4.4.8.$$

This implies that any game sales are an indication that all animals are not able to be sold for hunting. The point might still be argued that since the system is being designed to maximise the value of the property for a rural community, the costs of the management in terms of human labour remain internal to the system, which implies that game sales are a better option. Either way, if both sales and meat hunting are included in the model without fixing a constant value to one of them, the design of the model does

not allow for an equilibrium point, and will thus favour one of the two activities completely which will lead to the exclusion of the other. One way it would be possible to get around this problem, if it is felt necessary that both activities should be maintained, would be to set a minimum requirement on the amount of animals used for the less profitable activity. So, for example, if game sales are less profitable than hunting, then say set a minimum of 0.1 of the total animal harvest that must be used by sales:

$$s_j \geq 0.10 x_{t,j} \quad 4.4.9.$$

Then the equation for p_j is:

$$p_j = pv_j 0.04 + ps_j 0.10 + pb_j (1 - 0.04 - 0.10) \quad 4.4.10.$$

4.4.1.4. Population constraints

Hearne *et al.* (1996) identified a number of constraints that the animal population must fulfill in terms of the objectives of the hunting operation:

1. A certain minimum population of animals must be maintained to keep a viable breeding population that will not collapse in unfavourable years (such as drought years). Thus,

$$\min_j \leq x_{t,j} \quad 4.4.11.$$

There is no maximum boundary since the suitable population of animals increases with increasing land area of the game ranch. However at small reserve sizes, the CC will constrain the number of species that will be viable. For the purpose of this analysis, the area required by the animal species mentioned here to supply sufficient forage for their minimal viable populations is used as the criterion for introducing additional species. In conjunction with this, species which require the least amount of land are the

first to be added into the system. This is reasonable to assume since they are generally also the cheapest species to purchase.

2. The animals are maintained in reasonable condition for a high quality hunting experience (Hearne *et al.* 1996). Thus the number of AUs will be maintained at the estimated SR of 0.2 AU ha⁻¹. Thus the number of bulk grazers, each of which has a specific AU equivalent, u_j , is subject to the constraint,

$$\sum_{j=1}^4 u_j x_{t,j} \leq CC_{BG} \quad t = 1, \dots, n \quad 4.4.12.$$

$j = 1, 2, 3, 4$ correspond to the bulk grazing species, white rhinoceros, zebra, buffalo and waterbuck, which are all subject to the carrying capacity for bulk grazing, CC_{BG} .

$$CC_{BG} = 0.06 \text{ AU ha}^{-1} S$$

Selective grazers are subject both to the available forage and the competition for resources by mixed feeders,

$$\sum_{j=5}^7 F_{f,j} u_j x_{t,j} + \sum_{j=8}^{11} u_j x_{t,j} \leq CC_{SG} \quad t = 1, \dots, n \quad 4.4.13.$$

, such that

$$CC_{SG} = 0.14 \text{ AU ha}^{-1} S$$

$j = 5, 6, 7$ represent the mixed feeder species impala, nyala and elephant.

$j = 8, 9, 10, 11$ are the exclusive selective grazers, warthog, wildebeest, common reedbuck and mountain reedbuck.

The grazing part of the total feed required by mixed feeders is represented by

the fraction, $F_{f,j}$, as they also obtain food from browsing. In this case, the graze fraction is 0.6.

Similarly, browsers are subject to the number of mixed feeders in the system.

$$\sum_{j=5}^7 (1 - F_{f,j}) u_j x_{t,j} + \sum_{j=12}^{16} u_j x_{t,j} \leq CC_{Br} \quad 4.4.14.$$

, such that

$$CC_{Br} = 0.08 AU ha^{-1} S$$

, where $j = 12, 13, 14, 15, 16$ are the browser species, red duiker, grey duiker, suni antelope, kudu and giraffe.

3. Changes in population levels from one year to the next are constrained by the population dynamics (Hearne *et al.* 1996). The population $x_{i,j}$ in the following year is a function of the harvest rate, h , of species j in year i and the specific growth rate, R_j , of the population.

$$x_{t+1,j} = (x_{t,j} - h_{t,j}) R_j \quad t = 1, \dots, n; \quad j = 1, \dots, m \quad 4.4.15.$$

4. Harvesting must be non-negative:

$$h_{t,j} \geq 0 \quad t = 1, \dots, n; \quad j = 1, \dots, m \quad 4.4.16.$$

5. The species should preferably exist at the population equilibrium which is most optimal for profits. The model does not allow for changes in rainfall which would affect the optimal population mix (for example, populations of species such as white rhino crash during droughts while steenbok are minimally affected). The equilibrium population is reached when the rate of harvest equals

the rate of population increase (a function of the intrinsic rate of increase of a species, r), so that the population remains at the same level from year to year:

$$h_j = r_j x_j \quad 4.4.17.$$

It is necessary to calculate this optimal population mix after first removing foraging land required for the minimum population constraint, \min_j . Thus,

$$C_{BG} = CC_{BG} - \sum_{j=1}^4 \min_j u_j \quad 4.4.18.$$

$$C_{SG} = CC_{SG} - \sum_{j=5}^7 F_{f,j} \min_j u_j - \sum_{j=8}^{11} \min_j u_j \quad 4.4.19.$$

$$C_{Br} = CC_{Br} - \sum_{j=5}^7 (1 - F_{f,j}) u_j - \sum_{j=12}^{16} \min_j u_j \quad 4.4.20.$$

To account for this minimum requirement, Hearne *et al.* (1996) demarcated the AUs in excess of the minimum requirement as z_j ,

$$z_j = (x_j - \min_j) u_j \quad 4.4.21.$$

The problem for bulk grazers can now be reformulated as:

$$\text{Maximise} \quad \sum_{j=1}^4 p_j \frac{r_j}{u_j} z_j - \sum_{j=1}^4 \sum_{t=1}^n K_{t,j} - C_f \quad 4.4.22.$$

Subject to the constraints,

$$\sum_{j=1}^4 z_j \leq C_{BG} \quad 4.4.23.$$

and

$$z_{t,j} \geq 0 \quad 4.4.24.$$

Similarly for selective grazers, mixed feeders and browsers,

$$\text{Maximise} \quad \sum_{j=5}^{16} p_j \frac{r_j}{u_j} z_j - \sum_{j=5}^{16} \sum_{t=1}^n K_{t,j} - C_f \quad 4.4.25.$$

subject to the constraints,

$$\sum_{j=5}^7 z_j F_{f,j} + \sum_{j=8}^{11} z_j \leq C_{SG} \quad 4.4.26.$$

$$\sum_{j=5}^7 z_j (1 - F_{f,j}) + \sum_{j=12}^{16} z_j \leq C_{Br} \quad 4.4.27.$$

Hearne *et al.* (1996) noted that the sales price, growth rate and feed requirement,

$$p_j \frac{r_j}{u_j} \quad 4.4.28.$$

provide a measure of the performance of each species in meeting the objective of maximising revenue. So species with high fecundity that fetch high trophy prices will have the highest ranking. However this equation does not take into account the effect of cost price, which must be included to properly measure the species performance. Thus,

$$p_j \frac{r_j}{u_j} - \frac{pc_j}{a_{pPB}^{fix} u_j p_{PB}} \quad 4.4.29.$$

5. From the last equation it is apparent that the structure of the model is such that certain species will always be favoured, and the spreadsheet-based model will try to maximise the number of these species in the species population mix. The effects of such a skewed population are not well understood in scientific research, and in addition, the skewed population mix is aesthetically unappealing to ecotourists and hunters alike. Thus it is necessary to create a more balanced population where the minimum number of any species increases as size increases.

$$adjusted\ min\ j = f_{min} \sqrt{\frac{CC_{Br}}{min_j}} (min\ j) \quad 4.4.30.$$

Thus the new minimum population at land size, S, is related to the minimum land requirement for a viable population of species j and the number of animals at that minimum land requirement. The value, f_{min} , is a factor of adjustment for the species population, which could be used to change the ratio of species subject to the maximum population constraint defined. However for this investigation, all species were assigned a value of 1.

6. While the above equation does adjust the population according to their feeding requirements and does help to create a more evenly distributed population, the remaining land capacity will still be dominated by those species which have the highest performance indices. This in turn will mean that the population will still be skewed. Therefore a maximum population constraint must be imposed to correct this to some degree. The maximum population was thus related both to the CC for each forage component (for mixed feeders it was set to the most constraining forage of short grass or browse) and the AU equivalent of each species.

$$max_j = \frac{f_{max} CC_{Br}}{u_j} \quad 4.4.31.$$

The equation is again adjusted by a factor, f_{\max} , which relates to the AU size of each species. The factor increases with increasing animal size, because the remainder of the equation works against larger AU equivalent species. The value of f_{\max} is thus:

- 0.5 for bulk grazers, elephant and giraffe,
- 0.3 for mixed feeders and kudu,
- 0.2 for concentrate grazers,
- 0.2 for small browsers.

It should be noted that in reality, the maximum population should also take into account habitat constraints other than direct food requirements. For example, distance from water has a strong influence on the distribution of animals, leading to a reduction in forage utilisation as one moves away from water. In addition, territorial behaviour of animals could further modify the utilisation of forage and therefore the maximum population. Neither of these effects have been included in the model.

Table 4.8. Species data used in the wildlife harvesting model calculations.

j	Species	r_j	u_j	\min_j	$(\min_j * u_j) / \text{SR}$ (ha)	p_{vj} (Rands)	p_{bj} (Rands)	p_{cj} (Rands)	p_j (Rands)	Performance index
1	White rhino	0.1	2.38	20	238	75 000	75 000	43 687	71 868.70	2101.9
2	Zebra	0.15	0.54	20	54	1 400	1 400	1 441	1404.1	256.6
3	Buffalo	0.18	0.99	20	99	20 000	8 000	30 000	10 680.00	426.67
4	Waterbuck	0.2	0.46	20	46	3 000	1000	3 029	1282.9	228.54
5	Impala	0.25	0.16	20	16	260	190	150	188.8	248.13
6	Nyala	0.3	0.22	20	22	2 500	420	1 345	695.7	415.73
7	Elephant	0.1	2.77	20	277	25 000	21 000	18 000	20 860.00	428.16
8	Warthog	0.4	0.18	20	18	260	190	150	188.8	400.12
9	Wildebeest	0.15	0.47	20	47	1 100	820	1 449	894.1	143.41
10	Common reedbuck	0.25	0.19	20	19	600	350	1 886	513.6	179.47
11	Mountain reedbuck	0.25	0.12	20	12	600	350	2 000	525	260.42
12	Red duiker	0.4	0.1	20	7	1 300	550	1 000	625	2857.14
13	Grey duiker	0.4	0.1	20	9	150	70	80	74.2	285.33
14	Suni	0.4	0	20	3	1 300	1 300	1 500	1 320.00	15 100.00
15	Kudu	0.15	0.4	20	40	1 800	900	1 054	951.4	225.02
16	Giraffe	0.1	1.45	20	145	8 000	9 000	6 024	8 662.40	389.68

5. MODELLING THE NON-CONSUMPTIVE LAND-USE, ECOTOURISM

While the wildlife harvesting model is fairly easy to construct, as indicated in the previous section, ecotourism is far more complicated. This is basically because the options available are extremely diverse (see Ceballos-Lascuráin 1996). Consequently decisions made when starting an ecotourist operation are often based on very specific questions regarding the local environment as well as the local and international tourist demand for any particular service (Lundberg *et al.* 1995).

It appears that there is little research into decision-making on the provision of ecotourism services to regional populations. Most work encountered in the course of this project dealt with the behaviour and trends in international travel and tourism. This is probably in part due to the complexity and specificity of local-tourist market initiatives.

Due to the paucity of data on local tourism development and also because of the high variability of these systems, this project makes no attempt to define the options available to ecotourism. Instead, an analysis of data from game and nature reserves controlled by the regional conservation agency in KwaZulu-Natal, the KwaZulu-Natal Nature Conservation Service (KZNNCS), has been undertaken. This was thought to be a fairly simple way of getting a large enough data set for statistical analysis. The KZNNCS is a parastatal that has recently been formed from two government conservation bodies, the Natal Parks Board (NPB) and the KwaZulu Bureau of Natural Resources (KBNR), that operated in the province during the Apartheid period. Unfortunately, as amalgamation of the two bodies has not yet been completed, data sets were only available for reserves controlled by the NPB. A total of fifteen game and nature reserves in the north, central and eastern parts of the province were chosen for the analysis, based on whether they were in savanna regions and / or whether they contained a number of large game species. The fact that the sample size was so small was a cause for concern, as it brings into question the accuracy of the relationships derived by any statistical procedure. However since the aim of the analysis (as for the project) was exploratory and intended merely to give some indication of the relationship between size and cost and revenue

curves, and remembering that ecotourist options are so diverse anyway, the small sample was considered sufficient for the needs and time allocated to this very coarse analysis.

Any data sets are usually subject to variability relating from a number of different factors. It was thus decided that a multilinear regression technique would be used to quantify the relative importance of each of the factors identified as possibly contributing to variation in the data set. The GENSTAT 5 statistical programme was used to derive multilinear regression models of cost and revenue data for the overall Cost-Benefit analysis of the effect of size. Each model was derived using backward selection to sequentially remove those factors which had low t-values and were therefore assumed to be having little effect on the distribution of the dependent data.

Subsequent to this analysis, it has been pointed out to me that the use of backward selection is problematic when data sets have predictor variables which are not independent, but rather collinear. Relevant variables may be omitted during backward selection because t-values are understated when collinearity exists and specification bias is a distinct possibility. Consequently some of the multilinear models derived below using the backward selection process may be incomplete and relevant variables could have been left out.

5.1. SELECTION OF THE MULTILINEAR MODELS

As already mentioned, the advantage of multilinear regression is that it establishes the relative importance of different independent factors on the cost and revenue curves. A further advantage of the statistical technique is that it indicates how size interacts with other independent variables, which is useful when the model needs to be tested by manipulating the environmental constraints. The multilinear technique can help identify inefficiencies in the system and provide information on ways in which to improve the profitability of the reserves. This was important for the current analysis as it became obvious from examination of the cost and revenue data that most of the reserves under NPB-control were working at a loss. Although this was not anticipated it should have been expected since the primary objective of the NPB, a government agency, is ecological resource conservation and not the generation of revenue from ecotourism.

Certainly it would have been useful to obtain data from private game reserve enterprises, which conceivably work at a profit, to compare with the models of state-owned reserves. However due to time constraints, this was not done.

In terms of the requirements for our analysis, data needs to be collected for fixed and variable costs as well as annual revenue. Both revenue and variable costs can be linked to annual data. Thus data collected for each KZNNCS reserve was for the 1996/97 financial year. The data collected was divided into dependent and independent categories as given below.

5.1.1. Dependent variables

5.1.1.1. Variable cost and revenue data

Since the reserves were mostly working at a loss and also because of the current project’s objective to determine how size affects variable cost and revenue curves, these were broken down into their components. This was in order to determine the relative contribution of each component of variable costs and revenues (expressed in Rands) to their respective models and also to understand how they were behaving independently (or dependently) of each other in relation to the environmental factors.

Table 5.1. Definitions of components of revenue and variable cost derived from KZNNCS data for the financial year 1996/1997.

Component	Definition
Revenue Data	
Accommodation	The revenue generated from sales of bed or camping space. This included the money generated from sales to the public as well as complementary accommodation given to employees.
Gate (entrance) fees	All moneys generated from entrance charges to reserves as well as from the sale of Golden Rhino cards.

Component	Definition
Sales	This included all sales of stock of any kind. Thus sales from the curio shop, petrol, liquor, food (both from shops and restaurants), and publications all fell under this category. In addition, the sale of natural products generated by the reserves, such as venison and vegetative materials, were included under this category.
Guided	All public activities within reserve boundaries that were guided by reserve employees at a fee, were included in this category. These included wilderness and day trails, guided day and night drives, river rafting and children's camps.
Donations	Conservation activities in the KZNCCS are publicised and the reserves receive moneys from the public on this account. In some reserves this was quite a substantial amount, and because this is not likely to be a source of income for private reserves, "Donations" was given a separate category.
Rents, permits, miscellaneous	The remainder of moneys earned was placed under this category. This was because the overall contribution of the three components was relatively small compared to the other components already listed. Rents and permits were most abundant in game reserves with dams, and were most usually associated with water activities. Miscellaneous income included sundry income and service fees, interest on loans, recycling fees, fines and pound fees.
Total revenue	Total revenue generated by each reserve, which is the sum of the previously described components.
Variable Cost Data	

Component	Definition
Personnel	All costs pertaining to staff. The costs include salaries, service bonuses, medical aid, unemployment funds, temporary appointments and pension funds.
Transport and vehicles	Any maintenance and running costs associated with board-owned or subsidised vehicles.
Conservation maintenance	Due to use of the facilities provided, erosion of the natural environment requires maintenance. Examples of damage include road and trail erosion.
Communication and stationery	Communication and stationery were placed under a separate category because it was assumed that this could be a large expense for reserves that were more remote and further away from urban centres.
Sundry	Sundry costs included an array of non-related groupings, such as medical examinations, photography, workshop consumables, uniforms, protective clothing, ammunition and drugs.
Power, water and sewerage	Initial perusal of the income and expenditure reports indicated that reserves with a large amount of accommodation and high visitation rates, used a lot more power, water and electricity. Thus the latter costs were all directly related to tourism.
Capital maintenance	Buildings and other assets require yearly maintenance and upkeep, which could be a function of the age and use of the facilities. This unfortunately did not include road maintenance costs, which are handled by the roads department of the KZNCCS, which forms a separate entity.
Miscellaneous	The remainder of the costs were placed in this group, and included costs for community projects, catering for trails, exhibitions, inventory expenditure, consultants fees and other non-regular costs.

Component	Definition
Total variable cost	As with total revenue, total costs is the sum of the above-mentioned cost components.

It will be noted from the table, that models for “Total revenue” and “Total variable cost” respectively were constructed in addition to the separate components. This was in order to compare the total models with the sum of the separate component models, to observe in each case how closely the two curves corresponded.

5.1.1.2. Visitor numbers and accommodation occupancy

While revenue data indicate absolute earnings for different reserves, they do not clearly show that there is a difference in the attractiveness of reserves of different sizes, but the difference in revenue could rather be due to differences in entrance fees and accommodation rates between reserves. Thus visitor numbers and percentage occupancy of available accommodation give a better indication of the attractiveness of reserves to tourists. It was intended to derive a regression model for these two variables. However the data sets obtained were incomplete for all the reserves and the method of presentation inconsistent, so no model could be derived and the data was discarded.

5.1.2. Independent variables

5.1.2.1. Size of reserves

Size affects the number of large game species that can be stocked and also the number of services (activities and amenities) that can be offered to the public. The more of these that can be offered, the greater should be the attractiveness of the reserves to potential tourists. As with the other models already established, size is measured in hectares.

5.1.2.2. Dams

Many of the reserves surrounded or bordered large dams and lakes (relative to the size of the reserve). Consequently there is a difference between those reserves with dams that can supply water-related activities (and possibly are largely dependent on them for revenue) and those which can not. Thus a dummy variable, “Dam” (1 = reserves with dam / lake, 0 = reserves without dams) has been set up to define two models, one for reserves with dams and one for reserves without dams.

5.1.2.3. Distance from large urban centres

Since large cities provide the major source of tourists, it is certain that the distance of ecotourist destinations affects how many people are prepared to travel the distance required to reach these destinations. These tourists will base their decision on the merits of the reserve relative to their requirements. Based on this, the reserves chosen for the analysis were roughly distanced from Durban (the only large metropolitan area in KwaZulu-Natal) in terms of 50 km intervals. Thus reserves could fall in any category from 1 (less than or equal to 50 km) to 9 (greater than 400 km, but less than or equal to 450 km) according to their distance from Durban.

5.1.2.4. Total number of large animal species

Animal species were divided into six categories, namely pachyderms, antelope, round-hoofed herbivores, carnivores, miscellaneous (e.g. crocodile, ostrich, baboon etc.) and total game species. Examination of the data showed that only pachyderms, carnivores and total species appeared to be constrained by size, so these were chosen for the multilinear regression. However, due to the small sample size there was a limited number of degrees of freedom. Thus only “Total species” was included in the final multilinear regression, as it was assumed that this group would supply the most amount of information to all reserve sizes.

5.1.2.5. Activities

Provision of desirable activities will contribute to the success of a game or nature reserve. Due to the presence of dams and lakes in a number of the reserves, activities were divided into three categories, namely land, water and total activities. Water activities were later excluded from the analysis as it was felt that they would be biased in the analysis due to the inclusion of the dummy variable, “Dam”, which separated reserves with water activities from those without. In addition it was decided to include land activities in the variable “Services” as described below, while “Total activities” was excluded from the analysis due to the inclusion of water activities in that variable.

5.1.2.6. Services

Due to the low number of degrees of freedom resulting from the small sample size, it was decided to group land activities and amenities (those services provided which are not activities, such as accommodation, conference centres, restaurants and curio shops) together under “Services”, since the aim of this analysis is to predict cost and revenue curves for game reserves where water activities are not available.

5.1.2.7. Age of game and nature reserves

The age of game and nature reserves is an extremely important consideration, as it is usually indicative of how well a public reserve has been developed for its economic potential. Thus older reserves *should* have an inherent advantage over more recently-proclaimed ones as the capital for development has been provided for many more years.

Table 5.2. below shows that, all the independent variables except for “Size”, have a normal distribution. The fact that “Size” has a skew distribution is unfortunate, but should be expected as there are bound to be fewer larger reserves due to constraints on land availability.

Table 5.2. Statistical descriptive data for independent variables

Independent variable	Mean	Minimum	Maximum	Number of values	Distribution
Size	22993	330	96000	15	skew
Distance	5.46	2	9	15	normal
Species	13.33	0	25	15	normal
Land activities	4.33	4	8	15	normal
Water activities	2	0	5	15	normal
Services	9.39	5	16	15	normal
Age	45.93	11	102	15	normal

5.1.3. Higher order independent terms

In addition to main effects (each separate variable in its simplest linear form), a number of higher order terms needed to be included in the regression, which belonged to two groups. The first group were the quadratic and cubic terms for the main effects, which indicate that their relationship to the cost and revenue data is curvilinear and not simply linear. The second group of higher order terms were the interaction terms which indicate that the independent variables are determined to some degree by the relationship between two independent variables. After careful thought, the following interaction terms were chosen for the analysis.

5.1.3.1. Size * distance

Since the size of a reserve is considered to be an attractive force to tourists and distance acts as a disincentive, it is possible that the overall psychological attractiveness of a game reserve resulting from individual consideration of the two factors is non-linear and therefore indicative of an interaction variable.

5.1.3.2. Total species * distance

In a similar manner to the previous interaction, it was again possible that a non-linear

relationship existed between the attractive force of the total number of big game species and the negative effect of distance on the success of a game reserve.

5.2. RESULTS OF THE MULTILINEAR REGRESSION

5.2.1. Points on the regression process and the selection of models

As has already been indicated, a backward selection process was used to select the most appropriate model by removing highly insignificant variables first. During this process it became obvious that a number of variables were not significant for most of the regression models. “Water activities” was excluded, as previously mentioned, because it was biased with the dummy variable, “Dam”. However it soon became apparent that “Dam” was only important to the revenue component “Rents, permits and miscellaneous” (RPM) (see Table 5.3. below for results of the final models), because both rents and permits were closely associated with “Water activities”. None of the other cost or revenue models had this close association to “Water activities”, so “Dam” was excluded as a factor from them.

The second variable to be excluded was distance, which showed no significance as a mainline effect. However it did continue to exert influence as part of the interactive terms, “Size * distance” and “Species * distance”. Thus the influence of distance on cost and revenue for the reserves is maintained in the models by these interactive terms (see Table 5.3. and Table 5.4.).

“Age” showed little significance in either its main effect or quadratic form. In the end “Age” only shows up in “Gate fees” and “Conservation maintenance” (Table 5.3. and Table 5.4. respectively), although it was tested in all the models. This was surprising, considering the points made about age in the previous section. It was considered possible that the reason for this could be that size of reserves varies similarly to their age. The oldest reserves in KwaZulu-Natal are also the largest, partly because there was less competition for available space and partly because additional land has been acquired adjacent to these reserves over the ensuing years. A regression of “Age” against “Size” was significant (f-probability = 0.003), but accounted for a relatively low amount of variance ($R^2 = 46\%$).

Later on in the analysis process it became clear that a number of the cost models were incomplete. This was because the costs are ‘variable’ and their magnitude relate directly to reserve utilisation by tourists. Since data on visitor numbers and accommodation occupancy rates were incomplete, the revenue components, accommodation and gate fees, which relate directly to visitor numbers and occupancy, were used in their place as predictor variables for the cost components.

5.2.2. The multilinear models

Table 5.3. and Table 5.4. contain the estimates (and t-probabilities for each estimate) for the models for each component of revenue and cost respectively, as well as the f-probability and accounted data variance (R^2) of each regression model. For example, the predictor multilinear model for “Accommodation” is:

$$\begin{aligned} \text{Accommodation} = & 753933 - 49.9(\text{size}) + 1.3\text{E-}8(\text{size})^3 + 642.9(\text{species})^3 \\ & - 13901(\text{land activities}) \end{aligned} \quad 5.2.1.$$

Before proceeding further, it should be noted that the large variation in the orders of magnitude of the estimates, does not necessarily indicate different degrees of importance to the model. Instead it is more indicative of the different orders of magnitude of the independent variables, as the values have not been standardised prior to the analysis.

Given the small sample size, it was interesting that almost every regression was highly significant, however this may have been quite simply because a relatively large number of variables have been used to predict the regression for a small number of data points. All the variable cost models were highly significant with the smallest R^2 -value being 92 %. The revenue models were also significant, except for the “Rents, permits and miscellaneous” component. The latter was a poor regression by comparison with the rest, only accounting for 48 % of the data variance even including the dummy variable, “Dam”. Looking at the two predictor models for “Rents, permits and miscellaneous”, it appears that while the estimates for the ‘dam=1’ model were fairly significant, the ‘dam=0’ model estimates were highly insignificant. Since the interest in this project is to concentrate on a semi-arid environment with no big dams, it was decided to leave the “rents, permits and miscellaneous” revenue model out

of the separate components model, partly based on the poor estimates and partly on the earlier observation that rents, permits and miscellaneous revenue were largely associated with those reserves that had dams anyway.

Table 5.3. Derived multilinear models for components of revenue from ecotourism (t-probabilities are given below individual model estimates).

Revenue component	F-prob.	R ² -value (%)	Dummy variable (dam)	Constant	Size	Size cubed	Size * distance	Species	Species cubed	Species * distance	Land activities	Land activities cubed
Accommodation	<.001	90.7		753933	-49.9	0	-	-	642.9	-	-	-13901
				0.083	0.056	<.001			<.001			0.005
Gate fees	0.01	64.2		93393	-8.29	1.20e-09	-	62894	-	-9411	-	-
				0.466	0.214	0.071		0.089		0.086		
Sales	0	86.1		187511	-25.89	4.70e-09	-	-	209.7	-	-	-4380
				0.222	0.012	<.001			<.001			0.013
Guided	<.001	93.5		109610	50.55	-	-8.97	-32877	104.7	-	-	-
				0.169	<.001		0.001	0.005	<.001			
Donations	<.001	90		299662	34.79	-5.2e-10	-6.7	-	-	-	-153870	3732
				0.009	<.001	0.046	<.001				0.002	<.001
Rent, permits, miscellaneous	0.07	48.2	Dam=0	-6813	-0.09	-9.0e-12	0.076	-	-	-	-	-
				0.761	0.977	0.928	0.893					
			Dam=1	-6813	37.89	-5.6e-09	-4.61	-	-	-	-	-
				0.761	0	0.025	0.008					
Total revenue	<.001	91.2		1091263	-82.5	0	-	-	952	-	-	-18893
				0.104	0.045	<.001			<.001			0.012

Table 5.4. Derived multilinear models for components of costs resulting from ecotourist activities (t-probabilities are given below model estimates).

Cost component	F-prob.	R ² (%)	Constant	Size	Size cubed	Size * distance	Species	Species cubed	Species * distance	Land activities	Land activities cubed	Services	Accommodation	Gate fees
Personnel	<.001	98.4	192024	125.8	-	-20.9	-	113.4	-	-1277218	12780	654297	-	3.634
			0.786	0.032		0.086		0.091		0.01	0.036	0.002		<.001
Transport and vehicles	<.001	98.4	282909	29.99	-	-5.65	-	31.1	-	-132368	2929	-	-	0.322
			0.019	0.002		0.004		0.01		0.005	<.001			0
Conservation maintenance	<.001	92.9	12351	-11.49	-	2.687	5855	-	-	24139	-	-23462	-	-
			0.608	<.001		<.001	0.014			0.025		0.019		
Communication and stationery	<.001	98.2	-27367	-	1.9e-10	-	-	12.95	-508	-	-334	11769	0.01	-
			0.084		0.003			0.011	0.063		0.012	0.008	0.067	
Sundry	<.001	98.5	-28058	3.929	2.2e-10	-0.876	-3657	16.84	-	-	-426.3	13763	-	-
			0.016	0.002	<.001	<.001	0.01	<.001			<.001	<.001		
Power, water and sewerage	<.001	99.3	293	1.372	-	-	-	-	-	-	-	-	0.0329	0.353
			0.972	0.002									<.001	<.001
Capital maintenance	<.001	96.2	26812	5.86	-	-0.975	-	-	-	-	-	-	0.056	-
			0.074	0.054		0.093							<.001	
Miscellaneous	<.001	96.1	950	5.85	2.0e-10	-1.21	-	14.22	-	-	-	-	0.0306	-
			0.93	0.032	0.034	0.033		0					0.001	
Total variable cost	<.001	99.5	460853	175.4	-	-29.5	-	202.5	-	-1591357	17224	736042	-	4.988
			0.548	0.01		0.034		0.014		0.005	0.014	0.002		<.001

5.2.3. Graphical interpretation of the regression models

In order to understand the effect of size on the cost and revenue curves, a macro was constructed in Quattro Pro 8 to simulate the response of the regression models to a range of sizes from 300 ha to 100 000 ha. This is necessary to translate the models into graphical output for interpretation. However, since these are multilinear regressions, there are a number of variables affecting each model. Therefore in order to interpret the effect of size, one would be forced to keep all the other variables constant. This may be unrealistic, especially if some of the predictor variables are not fully independent of size. In the case at hand, “Total species”, “Land activities” and “Services” are all at least partly dependent on size. Since they are the attractive force to tourists, keeping them constant while changing size, is unrealistic. With this in mind, regression models were created of each of the three variables predicted using “Size” as the only x-variate. The models are presented in Table 5.5. below.

Table 5.5. Model equations using size to predict some of the independent variables
(t- probabilities for each term are given below the values).

Independent variable	F-prob.	R ² -value	Constant	Size	Size squared
Species	0.004	53.2	5.46	0.00052	-3.4e-09
			0.051	0.01	0.096
Land activities	0.013	34.3	3.159	0.0001	-
			<.001	0.013	-
Services	0.008	38.4	5.695	0.0001	-
			<.001	0.008	-

The regressions are all significant, but the R²-values are all fairly low. This may be due to the small sample size, so the models have been used on the spreadsheet to allow size to drive the model. The two variables , namely “Distance” and “Age”, which are independent of “Size” have been kept at their mean values (see Table 5.5. for the means). Later if the effect of age or distance needs to be tested, these values can be manipulated in the spreadsheet to observe their effect.

Initially it was decided to test only quadratic and first order terms of the variables. The revenue graph plotted, as expressed in Figure 5.1a., shows the revenue calculated from the “Total revenue” model and the sum of the separate components, hereafter known as the “Separate component” model. The two models are fairly similar in their shape, but the “Total revenue” model dips below zero rands for sizes below approximately 20 000 ha, which the separate component model does not. Unfortunately, because of the quadratic terms and the small sample size, both revenue models have the curved dip below 20 000 ha which drops down as one moves to 10 000 ha and then starts to rise again to 0 ha. (In the case of the “Separate components” model, this dip stays above zero, whereas for the “Total revenue” model, the curve dips below the x-axis.) This of course is not correct as the lowest revenue values should be at 0 ha. In addition, both curves start flattening out dramatically beyond 80 000 ha which is probably due to the small number of sample game reserves in this range, but is nevertheless too dramatic.

It was interesting to see that the “Total revenue” model produced lower revenue values than the “Separate components” model in the small size range below the 30 000 ha mark, but then produced higher revenue values than the latter beyond this point. Considering that the component “Permits, rents and miscellaneous” was excluded from the separate components model, one would assume that the total revenue model would be higher in all ranges and most especially the smaller ranges, where reserves with dams were more abundant. The main reason for this is that the separate component model has been set up to exclude any negative values from the total since it is impossible to have negative revenue. Thus the separate component model can never enter the negative range. A further factor which would have contributed to the reduced curvature in the separate component model, is the individual response of the components to statistical regression (see Figure 5.2a.), which has resulted in the turning points being spread out along the x-axis. The net result of this is that the curvature in the lower end of the separate component model has been smoothed out substantially.

In order to try and avoid the curvature in the small size range and the sudden flattening out of the curves above 80 000 ha, the models were reconstructed by regression using cubic terms in place of quadratic terms. The cubic models for total revenue and revenue generated by each separate component are presented in Figure 5.1b. and Figure 5.2b. The two total revenue

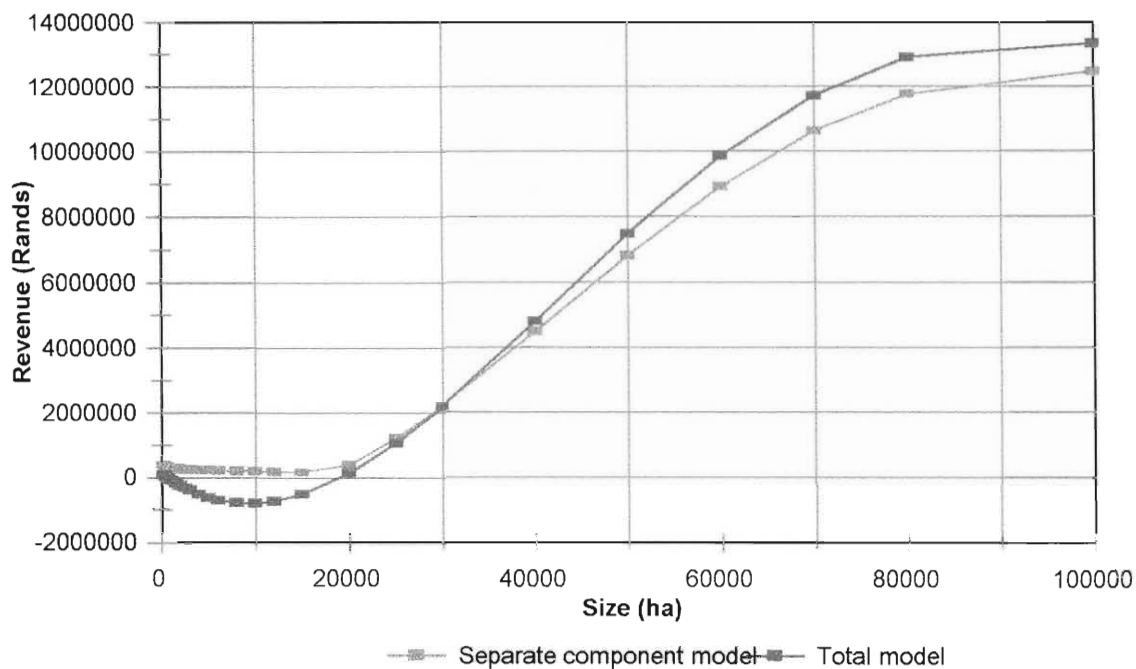


Figure 5.1a. Comparing the total and separate component models of revenue derived using quadratic polynomial terms.

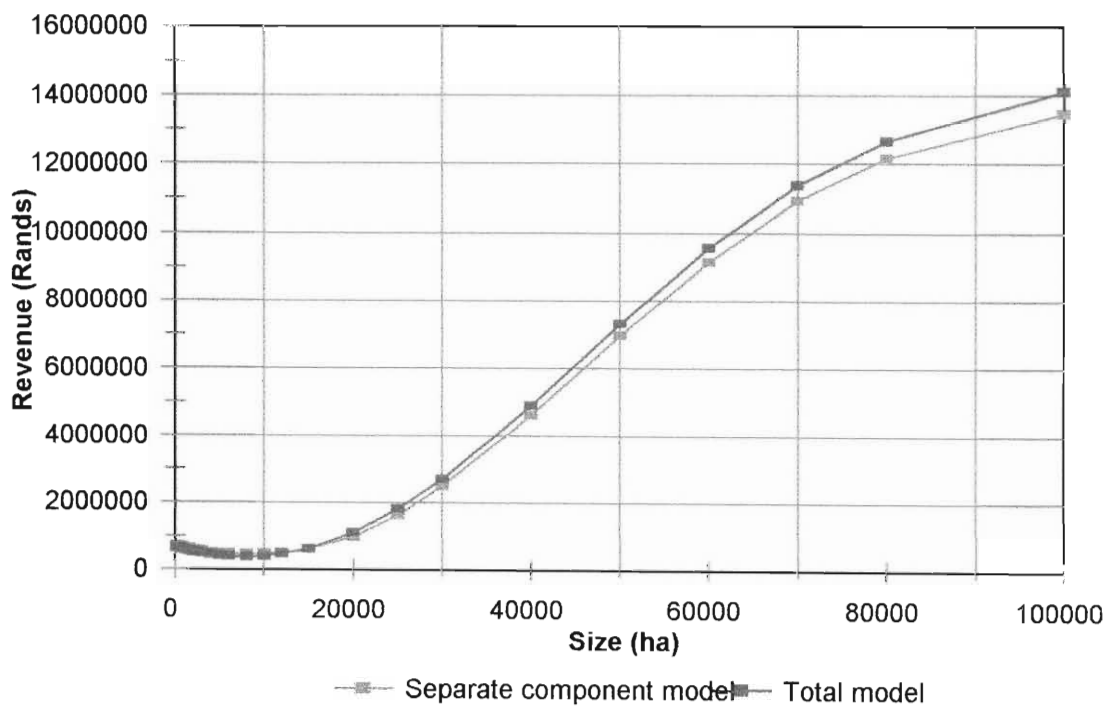


Figure 5.1b. Comparing the total and separate component models of revenue derived using cubic and polynomial terms.

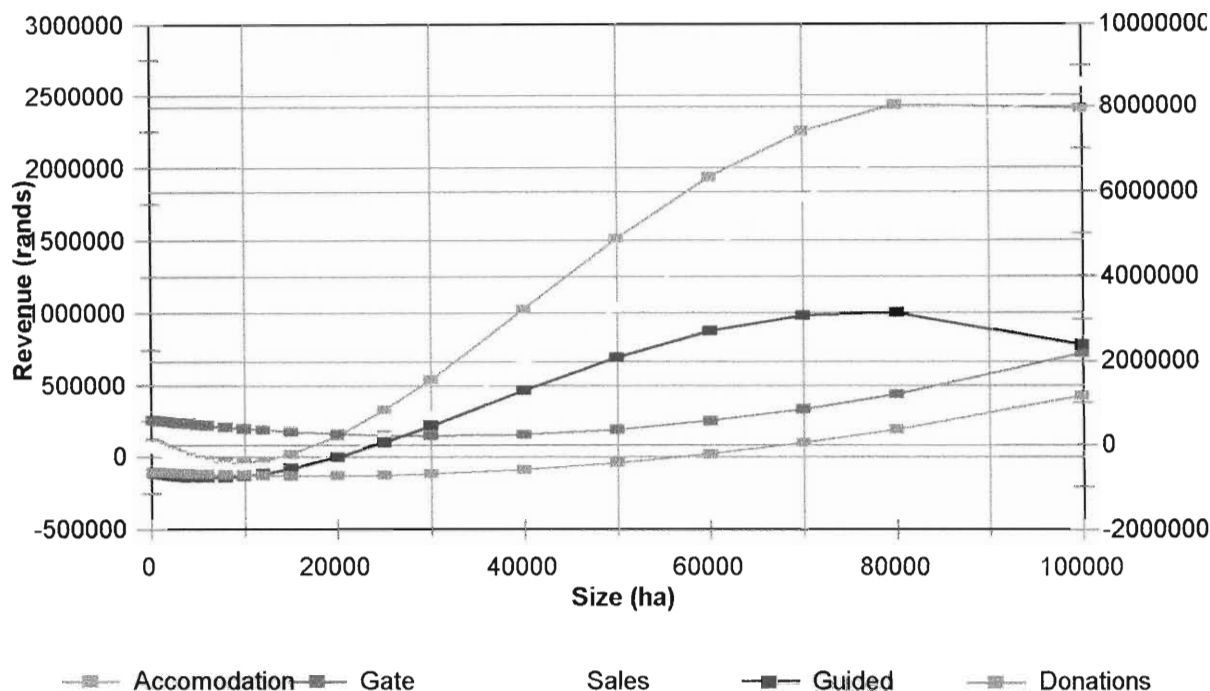


Figure 5.2a. Comparing the effect of size on the different component models of revenue derived using quadratic polynomial terms. (Accommodation has been set to the secondary y-axis due to its much larger values).

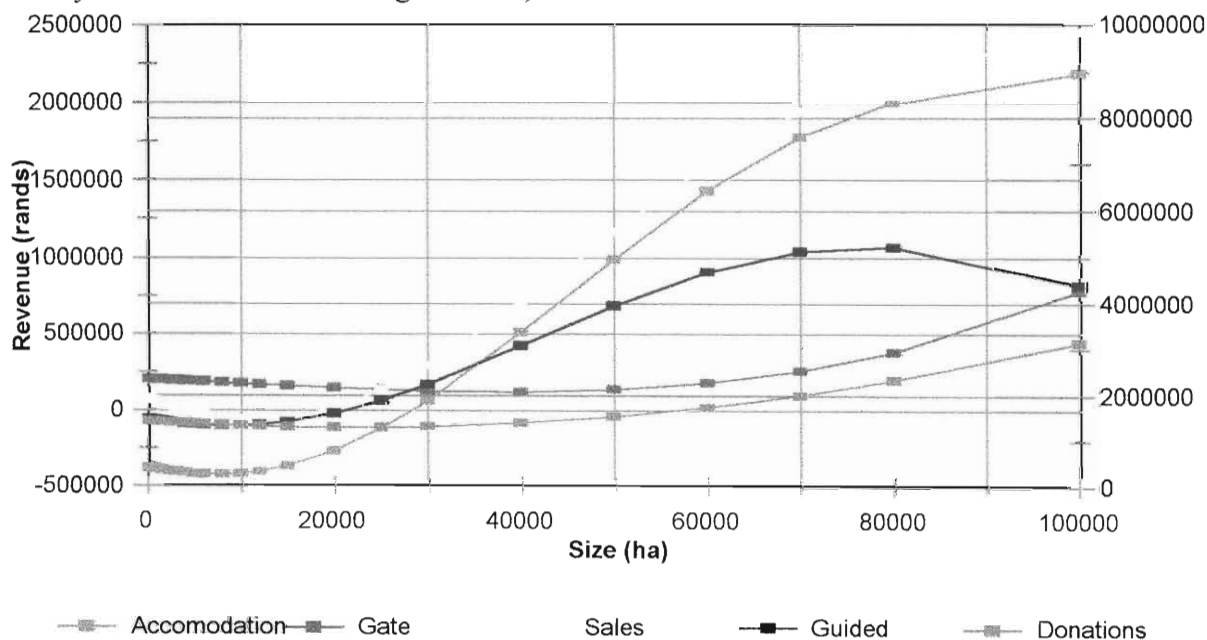


Figure 5.2b. Comparing the effect of size on the different component models of revenue derived using cubic polynomial terms. (Accommodation has been set to the secondary y-axis due to its much larger values).

models (Figure 5.1b.) are now much closer together and the dramatic flattening of the curves above 80 000 ha has been removed. However the turning point in the lower size range still exists, though it is much less strong and remains positive. Comparison of the separate components of revenue as produced by quadratic and cubic functions (Figure 5.2.) appears to show that the predictor curves for “Gate”, “Sales”, “Guided” and “Donations” have not changed much. By contrast, “Accommodation”, which is by far the greatest contributor to total revenue, has due to the cubic effect, shifted entirely above the x-axis and continues to increase beyond the 80 000 ha mark, whereas under the quadratic function it had started decreasing beyond this point.

Based on the improvement associated with the cubic terms, it was thought possible that even higher polynomial terms might further improve the accuracy of the model. This was tested using quartic terms in place of cubic for polynomial terms. The resulting model had further reduced curvature in the lower size range but had reintroduced a downward curve in the upper size range beyond 80 000 ha. This of course is unrealistic, so the cubic model of revenue was chosen as most representative of the relationship. However there still existed the problem of curvature in the lower size range. Re-examination of the cubic model for revenue led to the observation that the resultant curve (Figure 5.1b.) was very similar to the curve of a sigmoid function:

$$y = \frac{A}{1 + Q e^{-\lambda x}} \quad 5.2.2.$$

Where, A = the maximum value of the data. In this case, A was the maximum revenue value for the range of the sample, that is about R 14 million
 λ is the rate of change or the gradient of the curve
 x and y are the predictor and dependent variables
 Q is a constant relating to the y-intercept, such that:

$$y = \frac{A}{1 + Q} \quad , for \quad x = 0 \quad 5.2.3.$$

Since a sigmoid would be a simple means of representing the change in revenue in the size range under analysis and would by its very nature remove curvature from the lower size range, it was necessary to find the sigmoidal function which most closely followed the shape of the cubic function. This was achieved quite simply by using the optimizer function in Quattro Pro to minimise the Error Sum of Squares (ESS) between the cubic function and the sigmoid function, where A , λ and Q were optimised by the programme to minimise the ESS. Figure 5.3a. shows the cubic component revenue model and the sigmoidal curve that most closely resembles it. At this point, $A = R\ 12\ 600\ 000$, $\lambda = 1.07e-04$ and $Q = 172.062$. Note, however, that due to the low value of A , the sigmoid curve starts to flatten out dramatically beyond 80 000 ha as the curve asymptotes towards R12 600 000. This was unrealistic, so a higher value of A had to be fixed in order to remove this dramatic flattening.

In addition, the chosen sigmoid curve starts at zero, whereas the lowest value of the revenue curve is R 443 704.63. In order to correct both problems, it is necessary to fix the values of A and Q , thus restricting the optimisation to varying λ . A was fixed at R 15 million to remove flattening from the large size region, and then Q was adjusted to bring the y-intercept, and as such the minimal revenue value, to R 433 000. The optimizer then set λ at $6E-5$ to minimise the ESS between the sigmoid function and the revenue curve. The resultant curve is given in Figure 4.3b.

This section has predominantly dealt with the revenue models. The multilinear regressions derived from the variable cost curves are presented in Table 5.4. Graphical representations of the models are presented in Figure 5.4a. and b., which show the alternate total variable cost models and the separate variable cost components respectively. The regression models of variable cost are simple concave curves without the unrealistic curvature that had been expressed in the revenue curve. Figure 5.4a. indicates that the “Separate components” model of variable cost is apparently over-predicting the total variable cost when compared to the “Total” model. However in order to maintain consistency, the “Separate components” model will still be used for the analysis that will follow since the “Separate components” model of revenue was used to construct the predictor sigmoid of revenue.

Figure 5.4b. shows that the main contributor to variable cost is “Personnel” (set to the

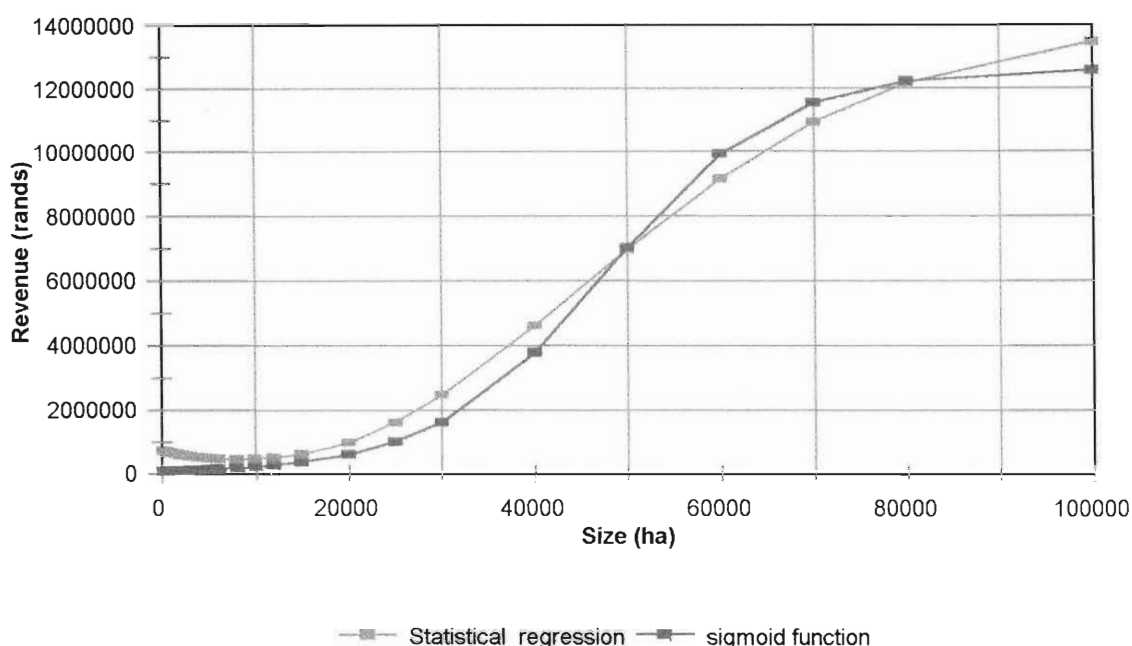


Figure 5.3a. Graph showing the sigmoid function constructed by Quattro Pro 8 to minimise the ESS between the sigmoid and the separate components revenue model. (Solution values selected by the programme are: $A = 12600000$, $\lambda = 1,07e^{-4}$, $K = 172,062$). Note that the sigmoid model chosen asymptotes towards zero.

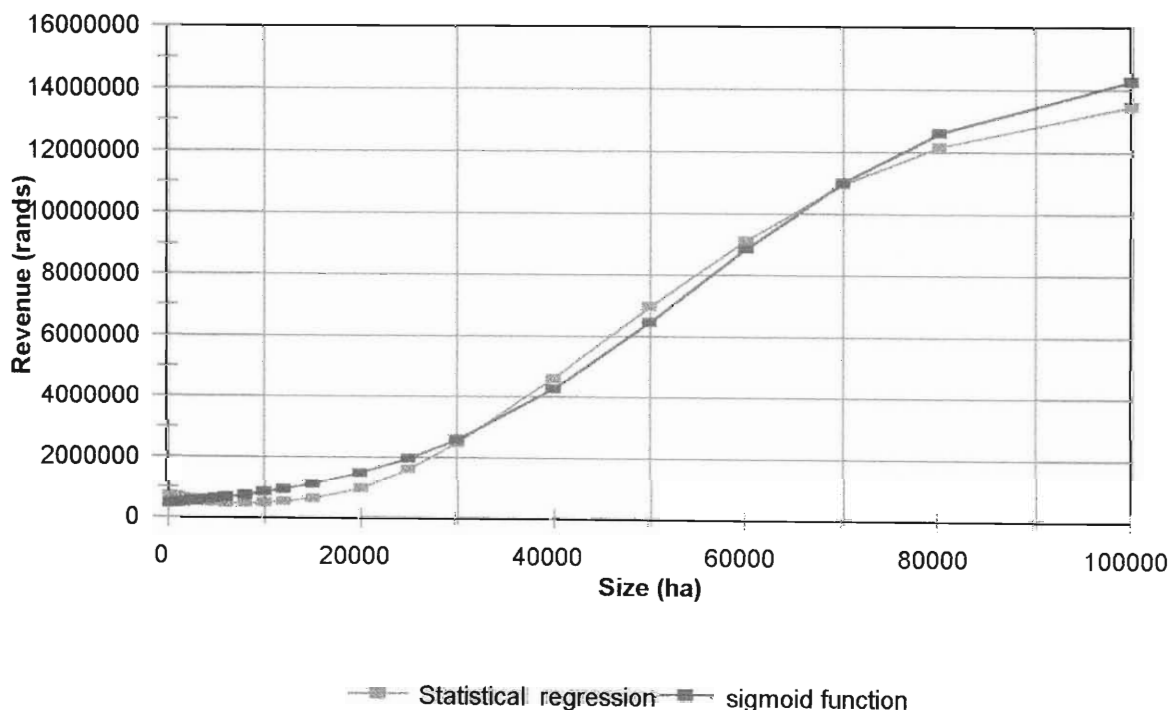


Figure 5.3b. Graph showing the sigmoid function constructed by Quattro Pro 8 to minimise the ESS when A and K have been fixed. (Solution values are: $A = 15\,000\,000$, $\lambda = 6.0e^{-5}$, $K = 33.207$). Note that the sigmoid function now asymptotes towards about 400 000.

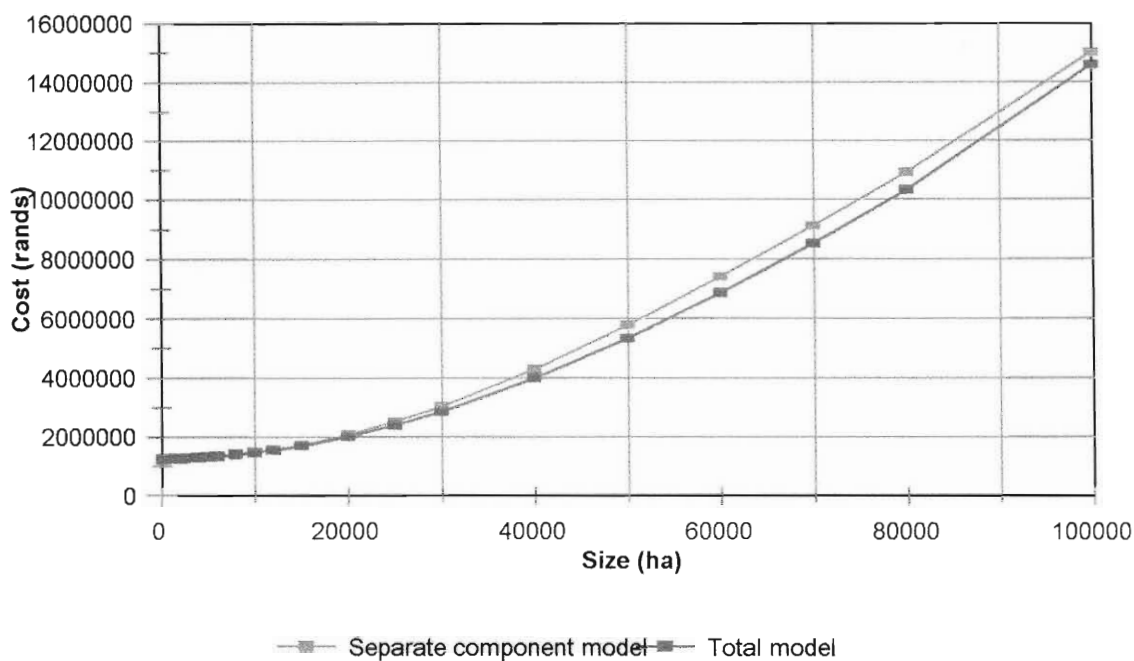


Figure 5.4a. Comparing total and separate component models of variable cost derived using cubic polynomial terms.

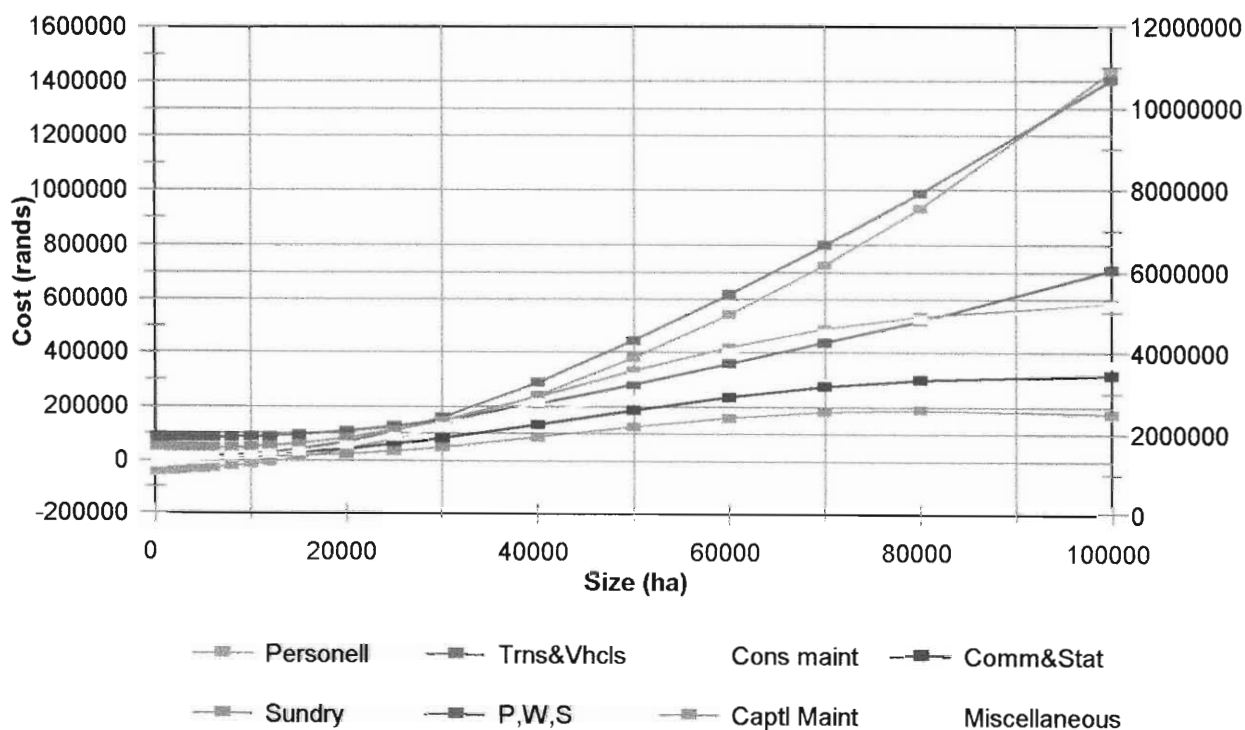


Figure 5.4b. Comparing the effect of size on the different component models of variables costs derived using cubic polynomial terms. (“Personnel” has been set to the secondary y-axis due to its much larger values. (Abbreviations: Personell = Personnel; Trns&Vhcls = Transport and vehicles; Cons maint = Conservation maintenance; Comm&Stat = Communication and stationery; P,W,S = Power, water and sewerage; Captl Maint = Capital maintenance.)

secondary y-axis) which differs by a whole order of magnitude from the other variable cost components, indicating the service nature of ecotourism. "Transport and Vehicles" is the second largest contributor to variable cost and, together with "Personnel" and "Power, water and sewerage", shows an increasing value per unit area with increasing land size. This indicates the service nature of ecotourism as these are all direct service costs. The remaining cost components all have convex curves indicating that they are not directly related to ecotourism impact, although they may be (and most probably are) indirectly related to ecotourism.

5.3. CALCULATING FIXED COSTS OF WILDLIFE PRODUCTION

It has been reasonably simple to construct models for the revenue generated and variable costs incurred by ecotourism operations using data from game reserves under the control of the KZNNCS. However, it is not possible to make any accurate estimate of the fixed costs incurred in these reserves, as capital required for any infrastructural development project is obtained from a central fund in the KZNNCS. Thus the profit of individual reserves does not take into account any loan payback for fixed asset development. This is unfortunate and given that almost all the KwaZulu-Natal reserves I have used are working at a net loss based on their variable costs alone, the actual deficit of some reserves must be quite substantial.

Capital inputs into wildlife production systems can be very large, depending on the enterprise employed. As previously mentioned, costs include infrastructure development (roads, fences, water etc.), reserve management assets (vehicles, staff housing etc.), tourist-related costs and game purchasing costs. The latter has already been accounted for in the harvesting model (see equations 4.4.1. to 4.4.3.), as has the cost of fencing (equation 4.4.4.). These two cost were included in the harvesting model because they relate directly to the chosen species mix.

Data on the remaining components of fixed cost are few, and I was only able to track down two very different estimates at very different land sizes, which in itself was quite fortunate for the present analysis: Eloff (1996) gives estimates of the capital input for a 2000 ha game ranch at

Thabazimbi while Davies *et al.* (1997) give estimates for capital input into the 75 000 ha Madikwe Game Reserve in the North west Province of South Africa.

Eloff (1996) recorded total capital input into a 2000 ha ranch to be R 2 707 146, which when adjusted to remove his estimates for land, fencing and game purchases, came to R 1 644 368 or R 822.18 per hectare. Davies *et al.* (1997) estimated total infrastructural capital investment to be in the order of R 35 million (R 70 million when including the cost of land). In addition, a further R 120 - R 150 million investment was estimated to be necessary to establish lodges to accommodate 500 to 700 people per night at a cost of R 200 000 to R 300 000 per bed. Using this data, I chose conservative values of 500 beds at R 200 000 per bed, which gives an accommodation cost of R 100 million in addition to the R 35 million for infrastructural development. This converts to a total fixed cost input for the 75 000 ha reserve of R 1800 ha⁻¹. The large increase in capital input per hectare between the small and large reserve sizes was expected as the options available to reserve managers increase with size (see Table 5.5.), as does the attractiveness of reserves to tourists. Based on this theory, it was decided to derive a parabolic relationship between the two points, which would show the non-linear nature of the relationship between size and fixed cost (C_f) input:

$$C_f = 1.835 * 10^{-7} S^2 - 7.34 * 10^{-4} S + 822.91 \quad 5.3.1.$$

The derived concave function which is shown graphically in Chapter 6 (Figure 6.8.) has its turning point at 2000 ha, so it was thought that below this size, absolute fixed cost input probably not drop much further (similar to the economies of size function used for fixed costs in commercial systems). The fixed costs per hectare were maintained at R 1 644 368. In reality, a few of the costs, such as infrastructure (roads, power, water, communication) could all drop further below the 2000 ha mark, but this could not be validated from the research collected. Therefore it was decided better to overestimate costs for comparative analysis rather than to underestimate them.

6. RESULTS AND DISCUSSION

The form that this chapter will take is firstly to observe and discuss the behaviour of the models of each land-use option separately. In each case a projected maximum and minimum profit curve will be derived. Thereafter the projected maximum and minimum profit curves of the three models will be compared with one another to assess the effect of size on the profitability of, and as such the opportunity cost incurred by, each land-use. In the latter stage a number of simulations will be run to observe how size interacts with other environmental factors to determine the profit curves of each of the three land-uses.

6.1. THE COMMERCIAL BEEF PRODUCTION MODEL

Figure 6.1. show the profit generated by commercial beef production when variable costs are at R 272 AU⁻¹ as proposed by the COMBUD harvest budgets (Department of Agriculture: KwaZulu-Natal 1996). The profit curve rises fairly slowly with mild curvature in the lower size range due to the effect of fixed costs. The break-even point is reached just beyond 300 ha and due to the model for fixed costs, the curve starts to become almost linear beyond 450 ha. The profit achieved at 3 000 ha is R 56 612.11 and is only R 268 782.03 at 10 000 ha.

Hatch (1996) calculated values of R 156.50 AU⁻¹ for northern Zululand in 1993 which converts to about R 39.43 ha⁻¹ at 1996 values for a stocking rate of 0.2 AU ha⁻¹. The model was rerun using this estimate and the predicted values are presented in Table 6.1. below. Using Hatch (1996) estimate of variable cost, the profit margin has almost doubled it's value relative to the profit value derived using the COMBUD estimate of variable cost, and the break-even point has shifted down to below 300 ha.

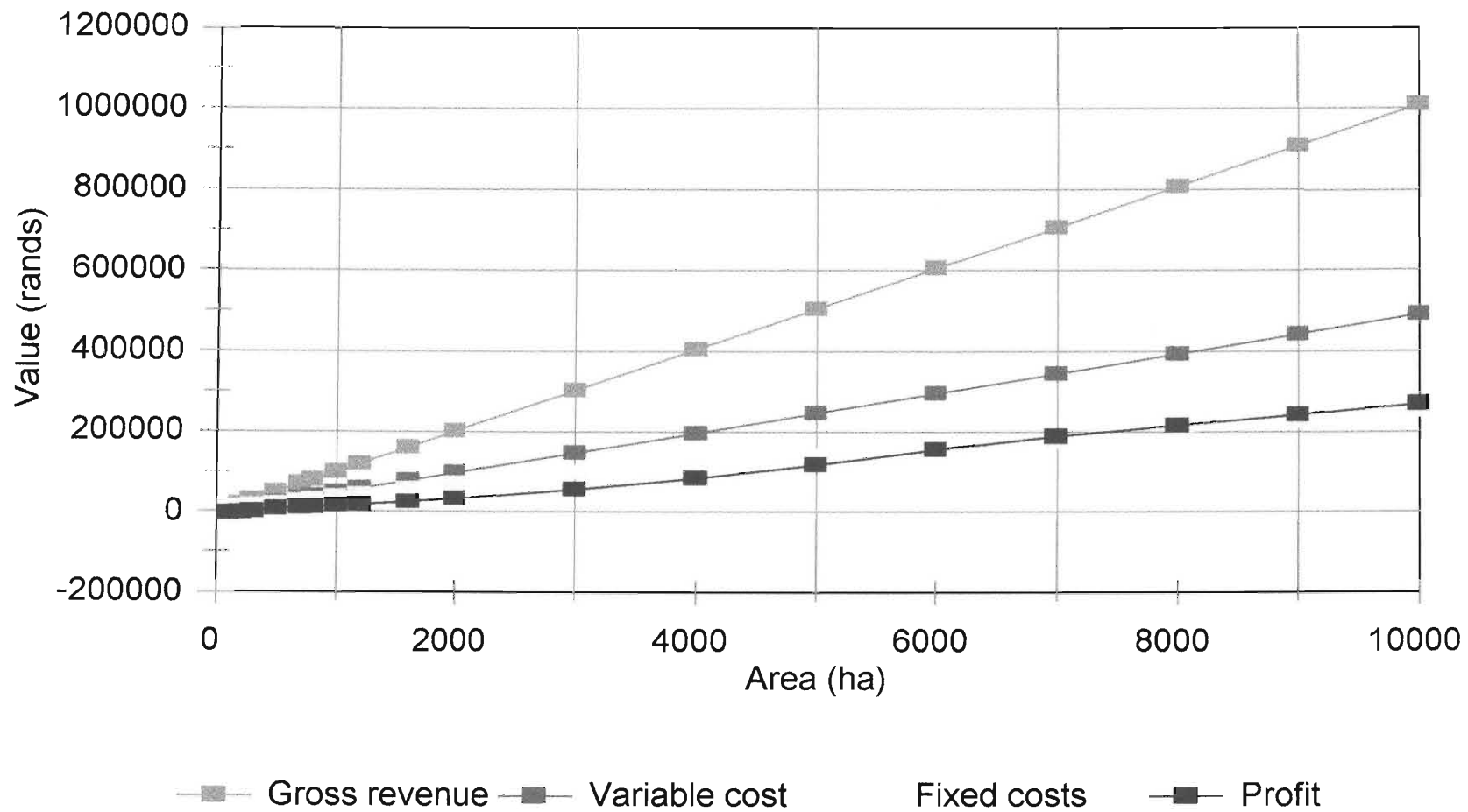


Figure 6.1. The effect of property size on the profits generated by commercial beef production.

Table 6.1. The change in the profit margin achieved by commercial beef production against size as a result of a shift in variable costs.

Variable cost value	500 ha	3 000 ha	10 000 ha	Break-even point
R 49.09 ha ⁻¹ (COMBUD 1996)	6 497.85	56 612.11	268 782.03	300 - 500 ha
R 39.43 ha ⁻¹ (Hatch 1996)	13 300.69	97 430.71	404 844.03	200 - 300 ha

The values chosen by the model using Hatch's (1996) estimate are similar to those predicted by Lyne & Ortmann (1996) who estimated profits of R 10 954 and R 90 514 for 450 ha and 3 000 ha respectively. They however used a variable cost value of R 23.00 ha⁻¹ because they were measuring profit as a return to management and not as a return to management and land as is assumed by Hatch (1996) and indeed for this analysis. For the comparative analysis that follows in Section 6.4., profit curves derived using variable costs of R 49.09 ha⁻¹ (COMBUD 1996 estimate) and R 39.43 ha⁻¹ (Hatch 1996 estimate) will be used as the minimum and maximum profit estimates respectively.

6.2. THE SUBSISTENCE PRODUCTION MODEL

Results from the subsistence model, as graphically expressed in Figure 6.2., indicate the linear nature of profit curve. This is due to the fact that fixed costs have been assumed negligible to the subsistence system. Profit from the system rises fairly rapidly to a value of R 207 702.72 at 3 000 ha (compare with the results of commercial beef in the previous section). The contribution of each component of revenue to this profit is given in Table 6.2. below.

Table 6.2. Contribution of component income generators to total revenue from subsistence production at a property size of 100 ha. (Note: values are expressed in rands and percentage contribution to total revenue.)

Component	Cattle		Goats		Maize	
	Income (Rands)	Contribution (%)	Income (Rands)	Contribution (%)	Income (Rands)	Contribution (%)
Milk (R 2.50 l ⁻¹)	3 475.80	25.61	1 067.36	7.86	-	-
Sales & slaughters (R 3.60 kg ⁻¹)	3 582.04	26.39	1 104.85	8.14	-	-
Deaths (R 1.80 kg ⁻¹)	1 601.34	11.80	466.69	3.44	-	-
Maize crop (R 550 ha ⁻¹)	-	-	-	-	2 275.00	16.76
Total	8 659.18	63.80	2 638.89	19.44	2 275.00	16.76
Total Revenue	13 573.07			100 %		
Work (actual)	3 642.30	21.26	-	-	-	-
Work (potential)	19 109.31	-	-	-	-	-
Manure	4 833.70	28.21	-	-	-	-
Total utility	17 135.18	-	2 638.89	-	2 275.00	-

Overall, cattle are making a much larger contribution (63.80 %) than goats (19.44 %). Since this may be due to the much larger proportion of cattle in the system, it is necessary to divide the revenue each animal type generates by the fraction of animals of each species, F_j (0.73 are cattle and 0.27 are goats), and the average animal unit equivalent of that species to get a measure of the income generated on an animal unit basis.

$$\frac{\sum Revenue_j}{S * SR(t) * F_j}$$

6.2.1.

This showed that cattle were worth R 371.86 per animal unit while goats were worth R 195.47

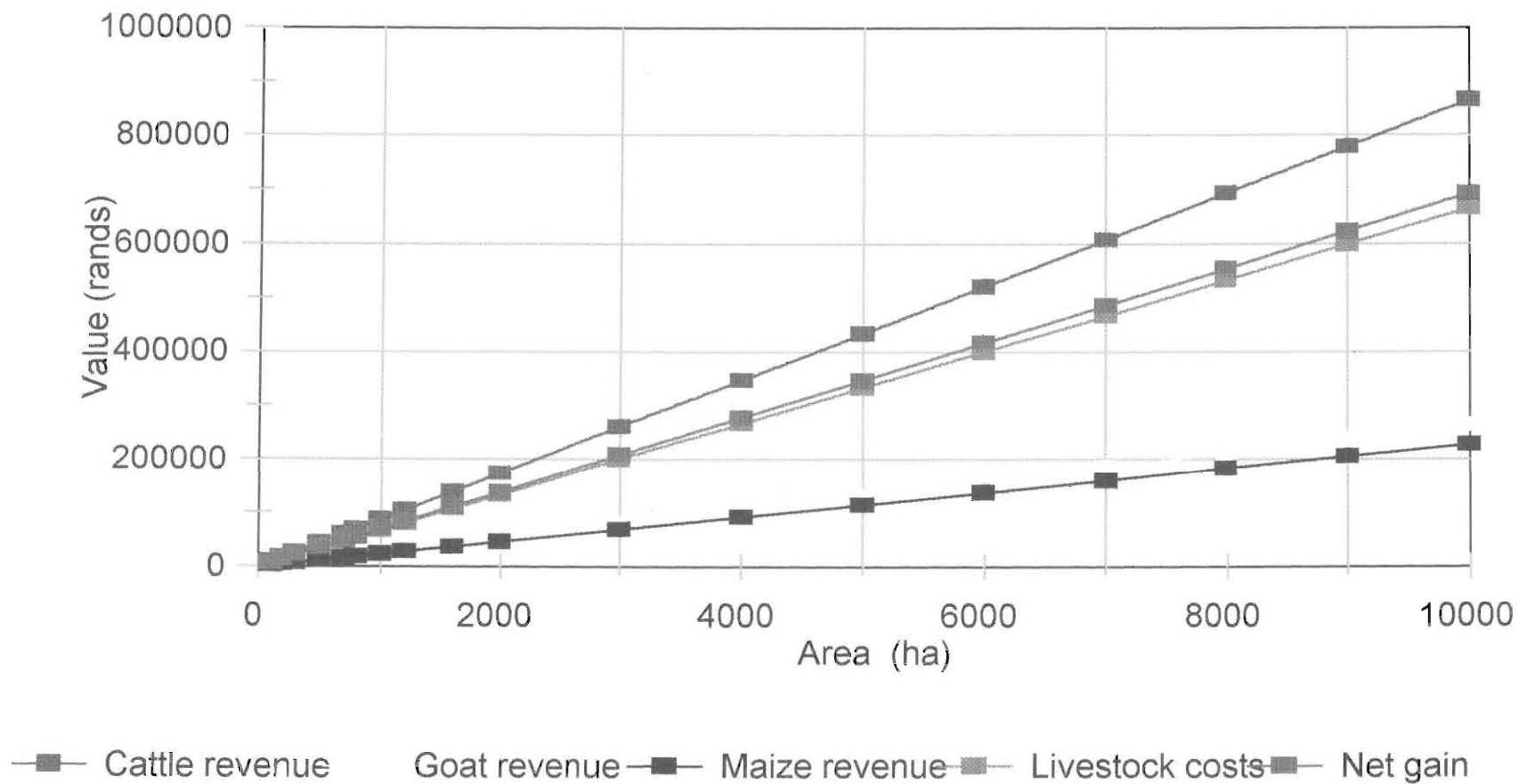


Figure 6.2. The effect of property size on the profits generated by subsistence production in semi-arid savanna (1. Meat price: R 3.60 kg⁻¹ for sales and R 1.80 kg⁻¹ for deaths; 2. Milk price: R 2.50 l⁻¹; 3. Livestock costs: R 147.77 AU⁻¹; 4. Maize price: R 550.00 ha⁻¹).

per animal unit, which indicates that cattle are more valuable than goats. Thus any shift in the population ratio that favoured goats would reduce the revenue generated by the system. The revenue values used here have not included the intrinsic costs that cattle save to the system through the provision of work and manure, which at 100 ha came to R 3642.30 (of the overall potential R 19 109.31) and R 4833.70 respectively. Thus the true utility of cattle to the system is R 17 135.18 or R 469.46 AU⁻¹.

The revenue contributed by livestock as opposed to maize (dryland cropping) is 83.24 % and 16.76 % respectively. This indicates that an increase in arable land would increase the overall revenue, since livestock is generating R 150.81 ha⁻¹ while maize is generating R 227.50 ha⁻¹. Any increase in revenue generated by an increase in arable land would be mildly tempered by the loss of manure fertiliser which will slightly reduce maize product. This effect cannot unfortunately be tested by the present model. The system will not be affected by work availability as this component is severely underutilised (work potential is R 19 109.31, but actual work is R 3642.30). Ultimately a point of complete work utilisation will be reached. By changing the ratio of arable to grazing land, it was possible to determine that the intersection point between work potential and actual available work was at 36 % arable land to 64 % grazing land, at which point the utilisable work was R 13 112.28 (potential work is R 13 588.84).

Having dealt with the main components of the model, it is necessary to test how a range of price shifts affect the profitability from subsistence production. The results are presented in Table 6.3. below. The first consideration is the price of meat. Since most meat sales and consumption is “in-house”, the actual value of meat to a subsistence community is less than it would be in a commercial market, as red meat is a minor component of the diet among subsistence agricultural communities. Additionally, the quality of meat of communal cattle is probably of a lower grade than commercial beef. With this in mind, it is unrealistic to assume a meat price of R 3.60 kg⁻¹ for communal cattle, so the meat price is reduced to R 2.70 kg⁻¹. In conjunction with this, the value of meat from dead animals has been dropped from R 1.80 kg⁻¹ to R 1.35 kg⁻¹.

The second value to be reduced is the price of milk which at its present value of R 2.50 per

litre may be too high if milk is consumed “in-house” by the community, as there may be a surplus on that demanded; The total amount of milk available on a 100 ha property from subsistence production is 3593.09 litres per year. If 40 people lived on the property, that would come to 89.83 litres per person per year. The milk price has thus been reduced to R 2.00 per litre.

A final price reduction was made to the value of the maize crop to indicate that there are fluctuations in the sales price of maize depending on the country-wide crop success, which if high can bring down the crop value. This effect is probably marginal so the value of the maize crop has been dropped from R 550 ha⁻¹ to R 500 ha⁻¹.

As can be seen in Table 6.3. the total revenue has shifted down by 19.75 % due to the price reductions. Since the model is linear, this relationship remains constant across size. The minor differences in revenue reduction between cattle and goats for sales, slaughters and deaths is due to the non-linear relationship in prices of hides of the two animal types (the actual price reduction is 25 %).

With the present variable cost of livestock set at R 147.77 AU⁻¹ (that is R 73.89 ha⁻¹), the total cost associated with livestock on a property size of 100 ha is R 6649.65. However, as indicated in Chapter 4, Hatch (1996) gave variable costs of subsistence systems at R 201.55 AU⁻¹ (R 100.77 ha⁻¹). When the model is rerun to include the new value for variable costs, the utility of cattle and goats is reduced, as is the overall profit (see Figure 6.3.). This latter profit curve and the initial curve derived for the subsistence model (as expressed in Figure 6.2. and Table 6.2.) will be used as the measures of minimum and maximum profit for subsistence production.

Table 6.3. The effect of price reductions on the revenue generated by subsistence production on a 100 ha property.

Component	Cattle		Goats		Maize	
	Income (Rands)	Reduction (%)	Income (Rands)	Reduction (%)	Income (Rands)	Reduction (%)
Milk (R 2.00 l ⁻¹)	2 780.64	20	853.88	20	-	-
Sales and slaughters (R 2.70 kg ⁻¹)	2 718.97	24.09	847.69	23.27	-	-
Deaths (R 1.35 kg ⁻¹)	1 258.40	21.42	382.06	18.13	-	-
Maize (R 500 ha ⁻¹)	-	-	-	-	2050.00	9.89
Total Revenue	10 891.64			19.75		

6.3. THE WILDLIFE PRODUCTION MODELS

6.3.1. The harvesting model

The harvesting model, as defined by equations 4.4.1. to 4.4.31., is fairly complex and a large amount of information can be derived from it. Since the harvesting model has been set up as a linear optimisation to maximise profit subject to constraints on species population numbers and ratios, available forage and the price index, K, the effect of each of these is discussed below.

6.3.1.1. Game species number and forage utilisation

Figure 6.4. show the species numbers, forage utilisation and returns and fencing costs per hectare against size. Species are added into the system on the basis of their AU-equivalent, with the smallest species being included first. Since some of the browser,

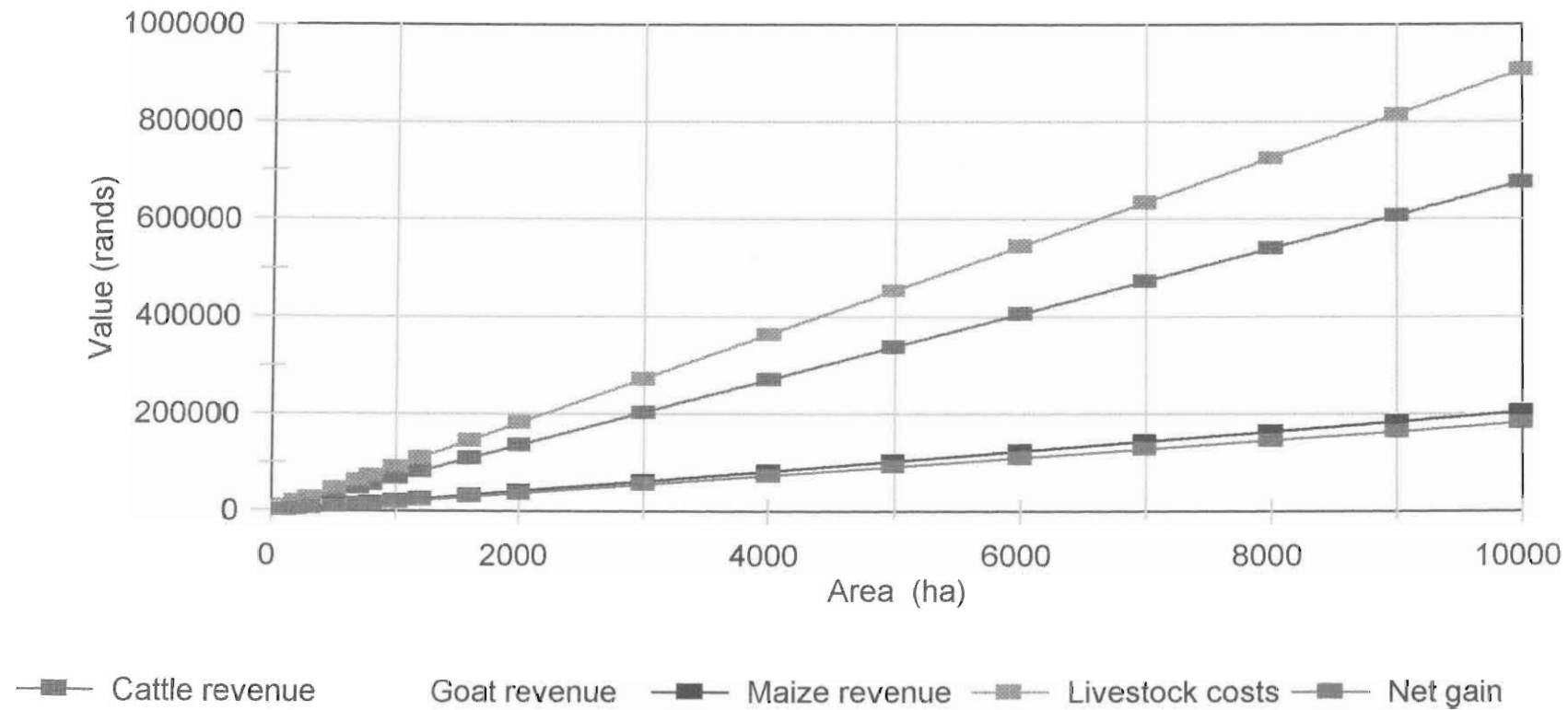


Figure 6.3. The effect of size on the profit generated by subsistence production in semi-arid savanna, subject to changes in prices for: 1. Meat (R 2.70 kg⁻¹ for sales and slaughters and R 1.35 kg⁻¹ for deaths); 2. Milk: R 2.00 l⁻¹; 3. Livestock costs: R 201.55 AU⁻¹; 4. Maize price: R 500.00 AU⁻¹.

mixed feeder and concentrate grazers have the smallest AU-equivalents, they are the first to enter into the system. By contrast most bulk grazers are large animals and in terms of the minimum population requirement of 20 animals, they are not able to enter the system until the smallest land requirement for the minimum population is passed (see equation 4.4.11. and 4.4.21.), which is 46 AU's for waterbuck. Thus at 1000 ha, the 60 AU's of tall grass are fully utilised by the single bulk grazer species, waterbuck, which is joined by zebra at 1500 ha, when there are 90 AU's of tall grass which can support the minimum populations of two bulk grazer species. It is important to note that the tall grass CC is fully utilised as soon as one species enters the system. By contrast, although a few species of concentrate grazers, mixed feeders and browsers enter the system at much smaller land sizes, they do not fully utilise the available forage CC of short grass and browse due to the constraints imposed on their maximum populations at each land size (see equation 4.4.31.). Be that as it may, browse CC is still the first to be fully utilised (by 700 ha), followed by short grass CC and then finally tall grass CC at 1000 ha. This may in part be due to the fact that tall grass is the smallest component of the system.

It should be noted that the model ignores the effect of feeder facilitation, whereby the grazing behaviour of particularly bulk grazers create forage sites for concentrate feeder species. This effect may increase the actual CC of the land, thereby increasing the profit generated.

6.3.1.2. Returns and fencing costs

Figure 6.5. shows how the revenue per hectare generated from the species mix changes with increasing size. Returns per hectare increase from R 299.17 ha⁻¹ at 100 ha to R 361.01 ha⁻¹ at 3000 ha, after which there is a dramatic increase in the returns to R 422.08 due to the inclusion of white rhino and elephant, which both have high performance indices and fetch high sales prices. After this point the change in revenue per hectare changes marginally as the optimal ratio of all the species has been established and remains constant with increasing size *ad infinitum*. It should be noted that the prices achieved per hectare at small land sizes are fairly high relative to the

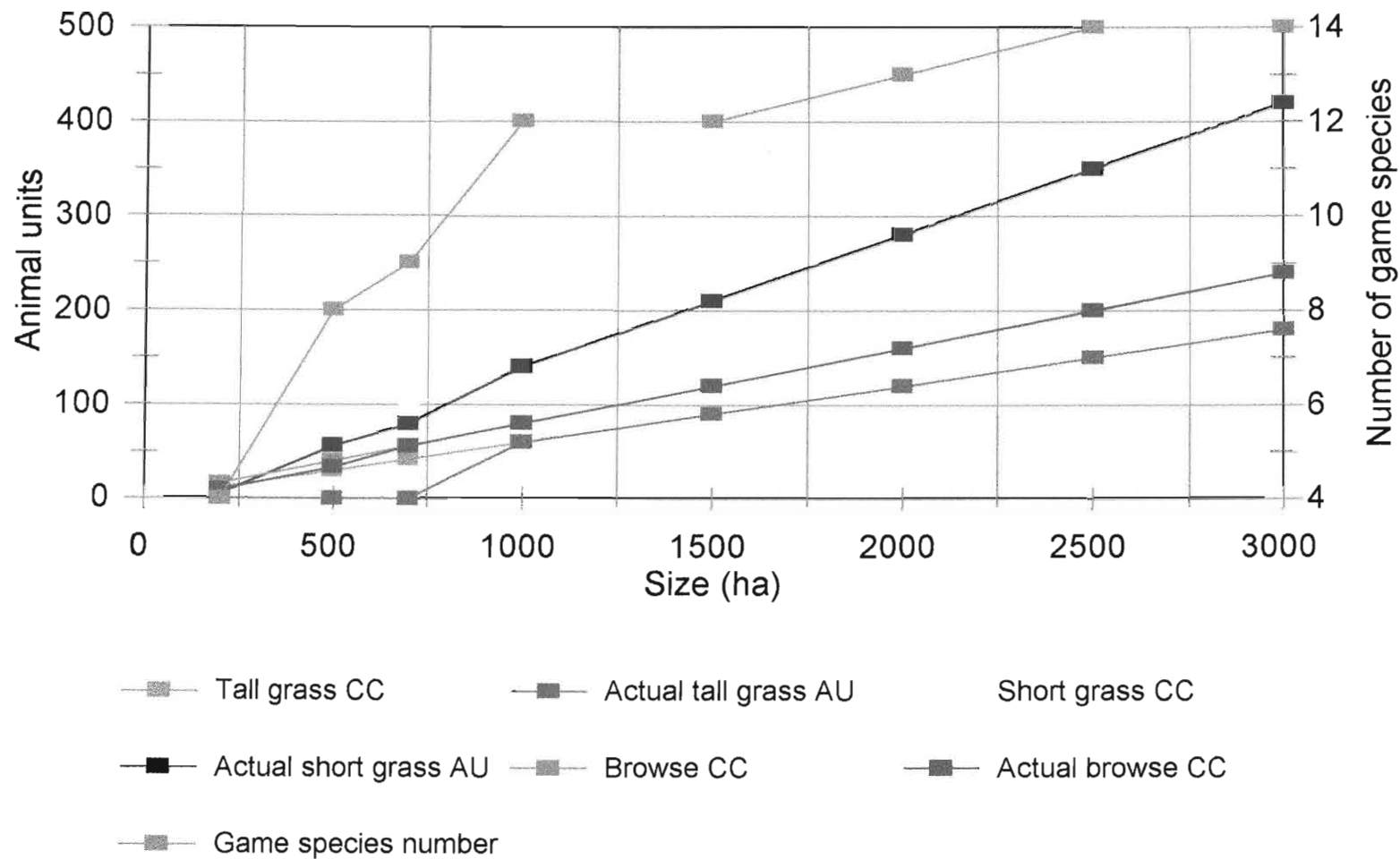


Figure 6.4. The effect of property size on the number of game species that can be accommodated and the utilisation of available forage by the selected species.

number of species present. This is due to the inclusion of red duiker and suni, which are species with high performance indices (see Table 4.8. in Chapter 4).

Fencing costs per hectare has a very jagged curve below 3000 ha, which is due to the inclusion of extra species which require extra fencing inputs (see section 4.4.1.2.). Between each fencing addition, fencing costs per hectare drop fairly quickly because of the relationship between perimeter and area (see equation 4.4.2.). From 2500 ha, fencing costs will continue to fall indefinitely as the most expensive fencing must be established at this size due to the inclusion of giraffe in the system which incurs the same fencing costs as elephant or rhino. Thus revenue generated by the harvesting model increases mildly per unit additional area 2500 ha, which would imply that hunting reserves should push to larger sizes where possible.

6.3.1.3. Income generated by harvesting

The actual revenue and income (after fencing and purchasing deductions) curves are shown in Figure 6.6. The values appear to be fairly large, with R 8 405 880.24 generated at 20 000 ha and R 1 055 634.57 at 3000 ha. Below 2500 ha, the income is of course non-linear, due to changes in fencing costs and the species mix. The model has made no attempt to quantify costs relating directly to hunting, such as ammunition and catering for a hunting safari, or the costs of game capture and maintenance in captivity which can be fairly high. Sale of animals “on the hoof” whereby the costs of capturing the animals and transporting the animals are incurred by the buyer can reduce these costs dramatically. However, no attempt was made to assess this effect and therefore a second line of revenue was constructed with revenue set to 80 % of its potential value to see how the income curves sit. The new income curve shifted down to R 839 030.43 at 3000 ha. In addition, it is probable that not all hunts or sale animals will be sold in a year, or they may fetch lower prices than expected. To account for this, a further loss of twenty percent of the revenue was made, so that the minimum income curve for wildlife harvesting was set at 60 % of maximum revenue. Using this calculation, the profit generated at 3000 ha had now shifted further down to R 622 426.29. Thus the 80 % and 60 % revenue curves will be used as measures of the

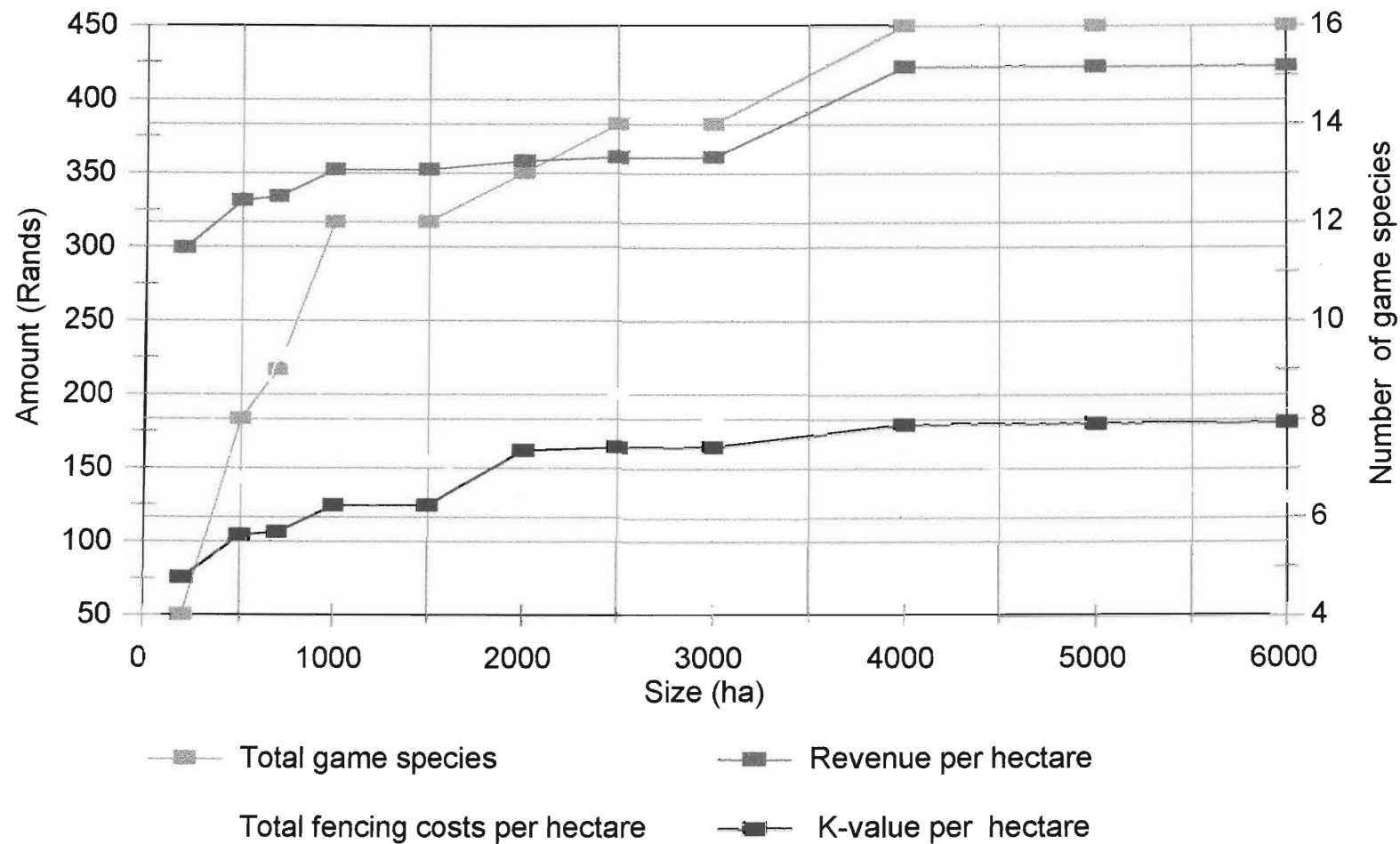


Figure 6.5. The effect of property size on the costs of fencing and animal purchases per hectare as well as the total harvesting revenue generated per hectare. (The number of game species selected at each reserve size has been included to show its relationship to the associated costs and harvesting revenue. Note also that the cost of animal purchases is given as K per hectare and is thus related to the payback period, which in this case is set at 20 years).

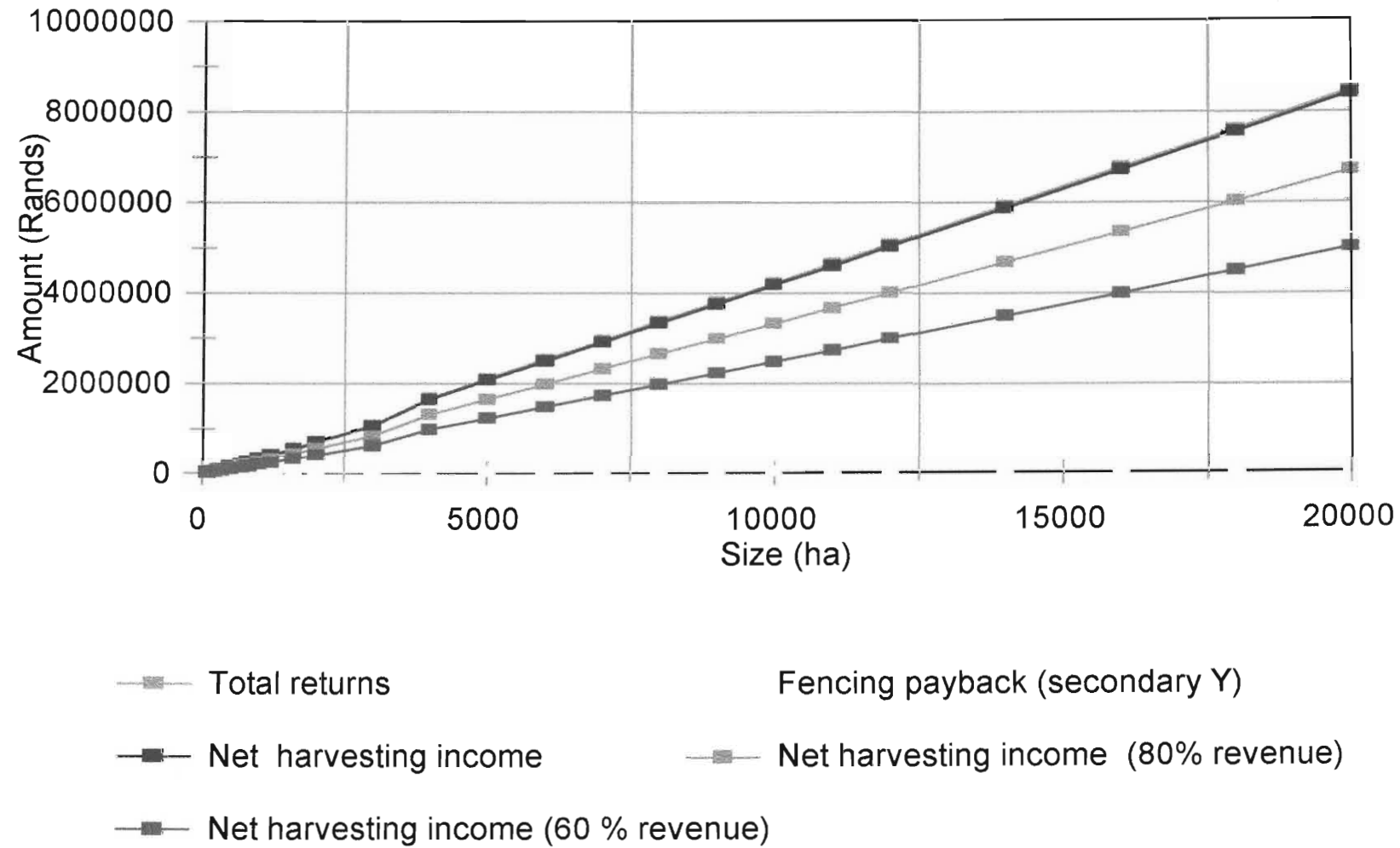


Figure 6.6. The effect of property size on the overall income generated from harvesting in wildlife production.

maximum and minimum generated income from wildlife harvesting.

6.3.2. The ecotourism model

The most interesting characteristic of the ecotourism revenue model derived using multilinear regression is its sigmoidal shape (see Figure 6.7.), which indicates a non-linear change in the attractiveness of reserves across size which at first rises rapidly and then begins to offer diminishing returns. It may be unrealistic for the revenue curve to start flattening off so soon and in this instance it probably indicates the underutilisation of the reserves economic potential by the KZNNCS. Be that as it may, it is probable that at some point along the size gradient the attractiveness of a game reserve will stop increasing, and the resultant reduction in land revenue per hectare may indicate that another type of land-use will be more profitable, however it is unlikely that very large tracts of land where this could be a possibility would ever be made available for consideration. In any event this possibility is not discussed further as it is beyond the capability of the present model.

It is unfortunate that the revenue generated by the regression model has a minimum value of R 433 000 as this is unrealistically high for 100 ha. Unfortunately this is a side effect of the statistical sample set which has few large reserves that have a strong influence on the resulting curve due to the Minimum Error Sums of Squares principle by which multilinear regressions are derived. The same effect has been incurred on the variable cost model, which has a minimal value of R 1 200 000. This is high, but may be quite fortunate as it will result in conservative estimates of overall profit from wildlife production. The variable cost curve is concave and indicates the service-industry nature of ecotourism as personnel costs rise rapidly with increasing size. Since variable costs are closely tied to revenue (see the model formulae in Table 5.4.), it is probable that these will at some point also start to flatten off in conjunction with the revenue, on the premise that the reserve is being managed efficiently. Again, the point on the size gradient at which this flattening off is reached is beyond the scope of the present study, and so it will not be discussed further.

At small land sizes, the variable cost curve is fairly flat, but it starts to rise rapidly beyond 20 000 ha, as does the ecotourism revenue curve. This would seem to indicate that the

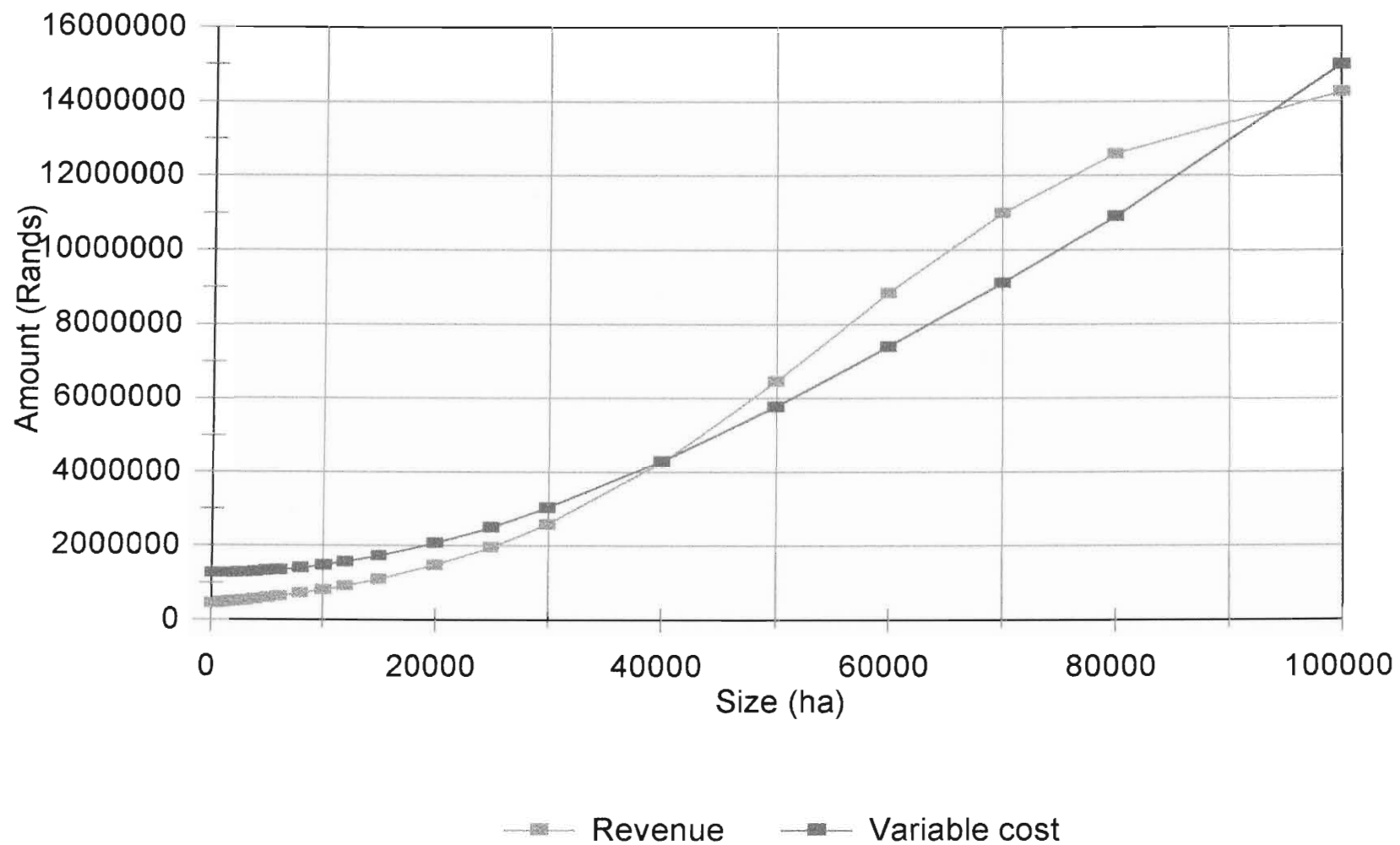


Figure 6.7. The effect of property size on the revenue generated by ecotourism and the variable cost incurred by game reserves.

attractiveness of ecotourist reserves - in terms of what they can offer - increases dramatically beyond this point. This is interesting since all herbivore species important for ecotourism can enter the system below the 5 000 ha mark. This may possibly be an indication of the importance of “wilderness experience” which, as pointed out in Chapter 3, is the desire to be out in large open and uninhabited spaces. It may also indicate the importance of large-ranging predator species (lion, leopard, hyena etc.) to tourists. This can not be proven from this work since the harvest model makes no allowances for carnivores. This may be a point of interest that should be tested in future to see if there is any similarity between the upturn in revenue and the size at which carnivores enter the system.

6.3.3. The fixed cost model

Figure 6.8. shows the total fixed cost, yearly fixed cost installment and fixed cost per hectare against size, incurred by wildlife production. Because the model is parabolic, it starts rising dramatically beyond 70 000 ha, which is probably unrealistic. However, the effect of this incline on the yearly fixed cost installment is apparently quite small.

The effect of assuming minimum fixed costs of over R 1 200 000 below 2000 ha on the cost per hectare is obviously quite dramatic, and in all probability unrealistic. However there will most certainly be a rise in the fixed costs per hectare as one decreases property size beyond some point. Due to the paucity of data it has been difficult to establish where this point would lie and, additionally, how the location of this point will vary according to the wildlife enterprise undertaken.

6.3.4. The combined wildlife production model

The combined wildlife production model as presented in Figure 6.9. shows the revenue generated by animal harvesting is far more profitable than that generated by ecotourism. This once again may be due to the underutilisation of ecotourist potential by the KZNNCS. As a result of the poor performance of ecotourism, no attempt has been made to distinguish between high profitability and low profitability, as has been done for all the consumptive uses. This was also done because of the small contribution made by ecotourism to overall wildlife profit

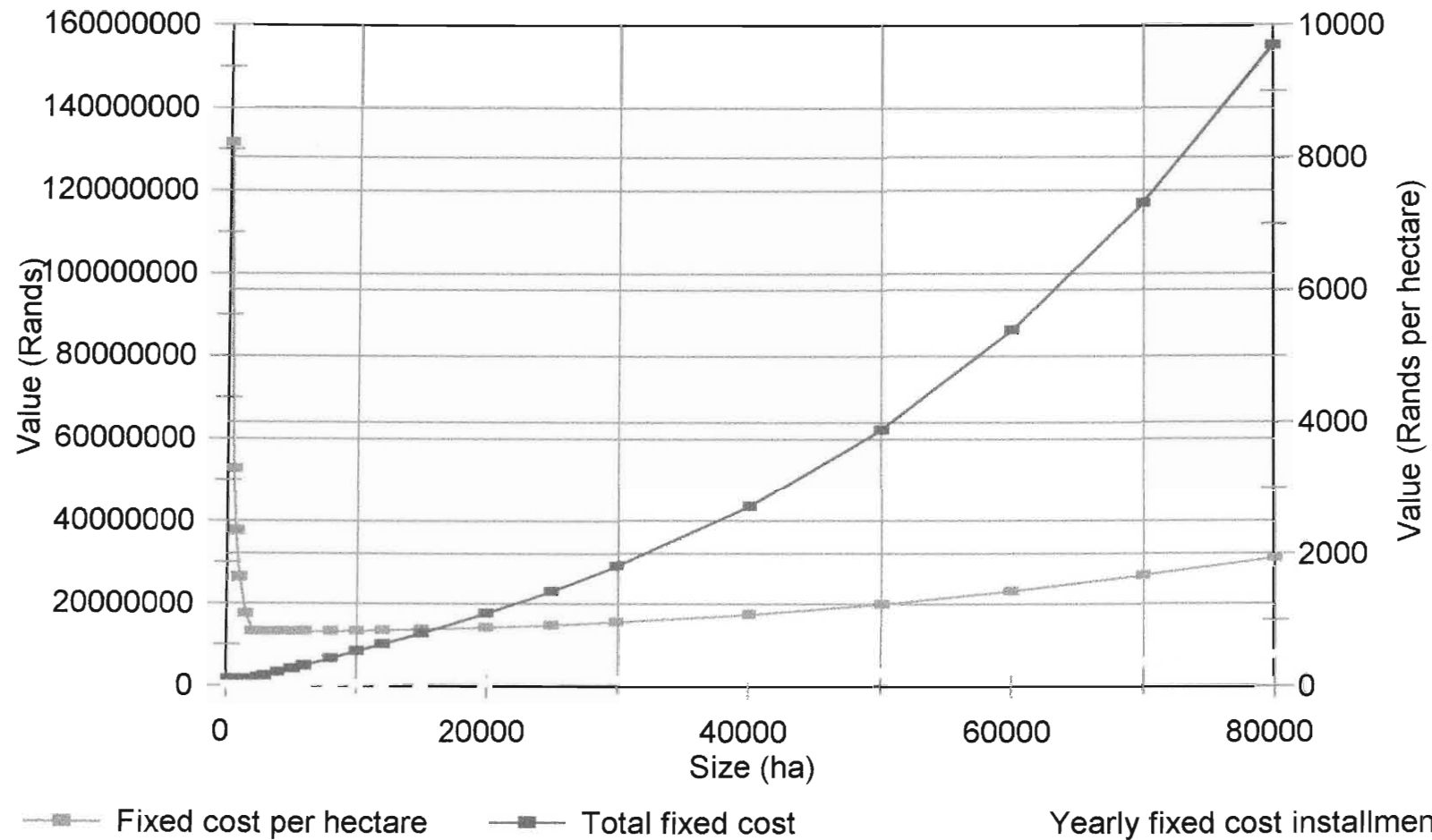


Figure 6.8. The effect of property size on total fixed costs, fixed cost installments and the change in fixed costs per hectare.

relative to the contribution of game harvesting.

Due to the upward turn in both fixed and variable costs together with the flattening off of the ecotourist revenue model, the overall profit curve starts to flatten off beyond 80 000 ha. This suggests that commercial beef production or subsistence production may be more profitable at very large property sizes. The model indicates that for 80 % utilisation in the harvesting model, the break-even point is between 3000 ha and 3500 ha. However if the revenue from harvesting is only 60 %, then the break-even point moves to larger land size between 3500 ha and 4000 ha, which is not that different and suggests a fairly rapid rise in the profits from both estimates.

6.4. COMPARING THE THREE LAND-USE MODELS

Figures 6.10. and 6.11. show the profit curves for the three land-use options under maximum profit and minimum profit scenarios respectively. The one key weakness with the present models is that they make no provision for time series analysis. This would have been useful as it would show the fluctuations in animal numbers, animal productivity and reproductive performance under the very variable CC's of semi-arid savannas, which would dramatically change yearly profits and might have fairly different projections of the long-term profitability of the three land-use options. However there was not enough time in the project to construct the adaptations to the models necessary for a time series analysis.

Having reflected on this point, it is necessary to continue with the present analysis. Figures 6.10 and 6.11 show that the region of overlap between the three land-use options under consideration is below 8 000 ha and that beyond this point wildlife production, which has a more dramatic incline than that for commercial beef production or subsistence production, is substantially more profitable than either of the two domestic livestock options. The graphs also show the large effect of high input costs (both fixed and variable costs) associated with wildlife which is a service industry. This results in wildlife being highly unprofitable at property sizes of less than 2500 ha. However this loss may be unrealistically high, due to the effect of the statistically-derived variable cost model which, if the venture were purely hunting, would be

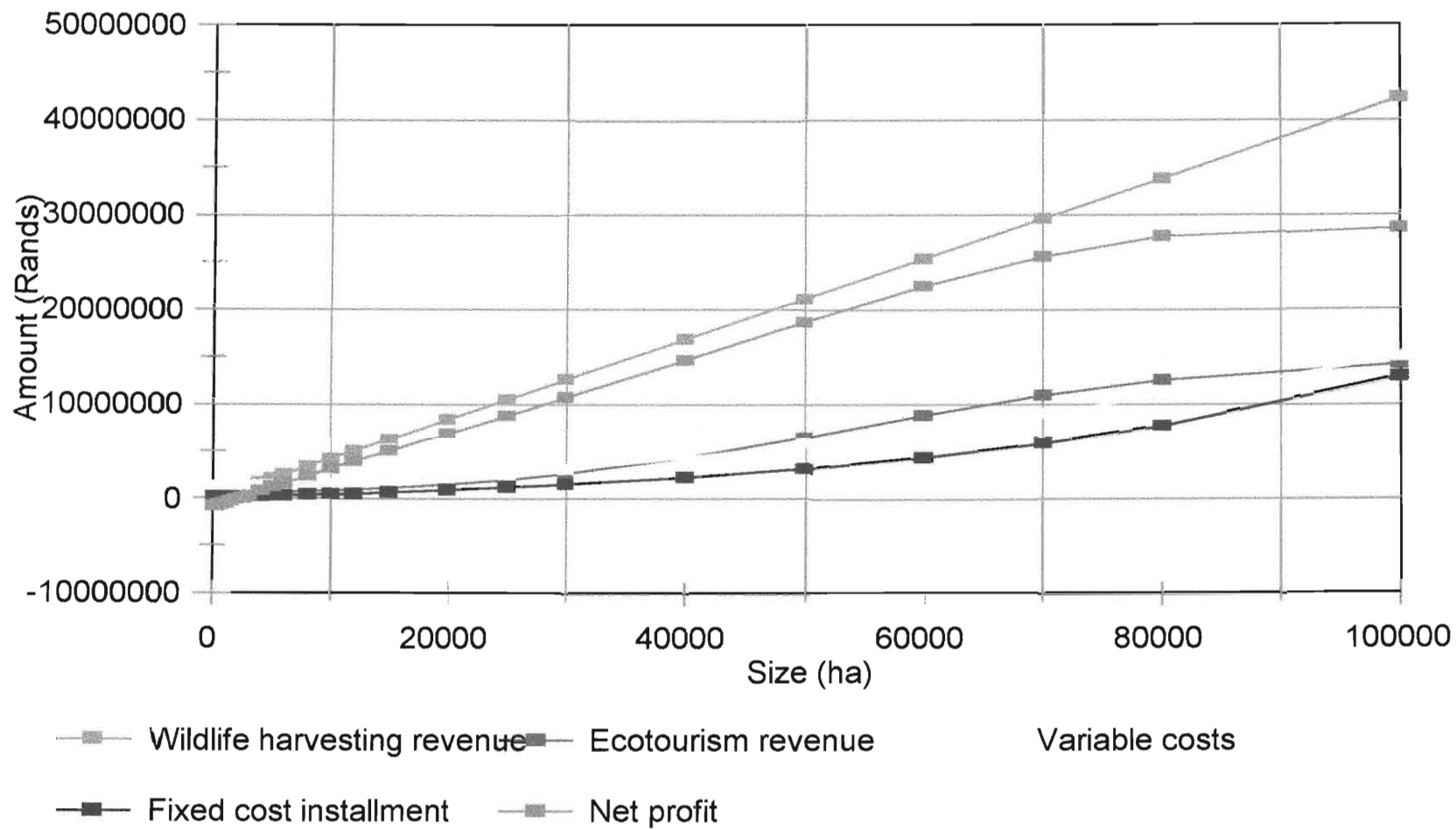


Figure 6.9. The effect of property size on the overall revenue generated by wildlife production.

much reduced from its present value. Even so, fixed cost inputs are high and the minimal profitable land size is probably not less than 1000 ha, at which point both commercial beef and subsistence production have both already established profitability.

It is most interesting to note that in both graphs, commercial beef falls below subsistence production. This indicates to some degree the effect of the higher stocking rates of communal herds and the relative value of the uses of cattle other than meat. Table 6.4. shows the intersection points between the three land-uses at both their maximum and minimum predicted values. Table 6.4. indicates that there is in fact no region of overlap between maximum subsistence production and maximum commercial beef production, which implies that under the optimal conditions specified in the model, commercial beef production is not as profitable as subsistence production.. This is unrealistic and indicates there is some weakness in the models and particularly the profits apportioned to commercial beef production. Lyne (1998 personal communication) has pointed out that a major component of the benefits accruing to private commercial beef farmers is capital gains on the land value (see section 7.1.3. for a fuller explanation). This has not been accounted for in the beef model presented here and is largely responsible for the poor performance given by the beef production model. Table 6.4. does show that commercial beef production achieves greater profitability than subsistence production when the values of subsistence production are reduced and suggests that commercial beef production is the best land use between 500 ha and 2500 ha.

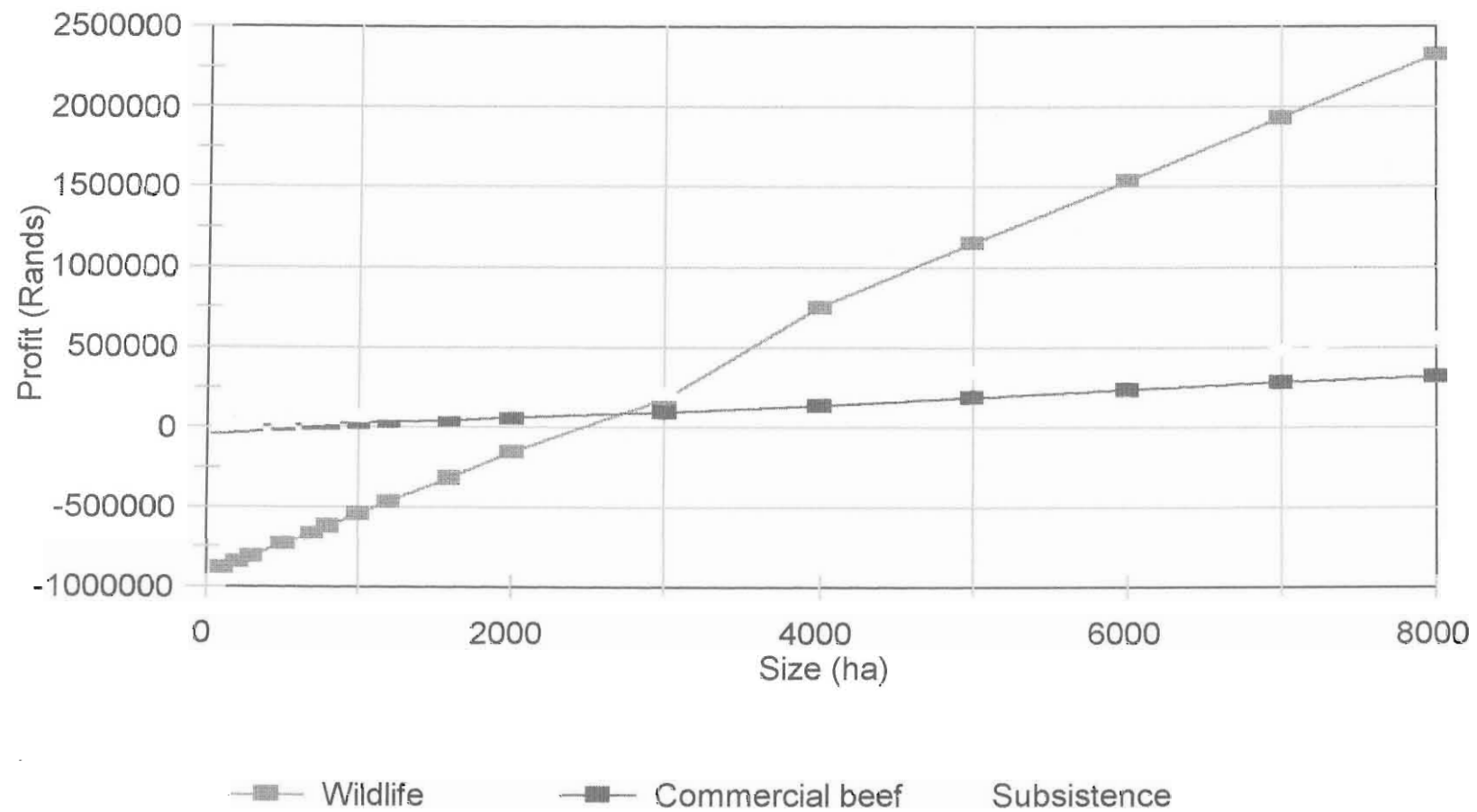


Figure 6.10. Comparing the effect of property size on the projected maximum profit curves for commercial beef production, subsistence production and wildlife production.

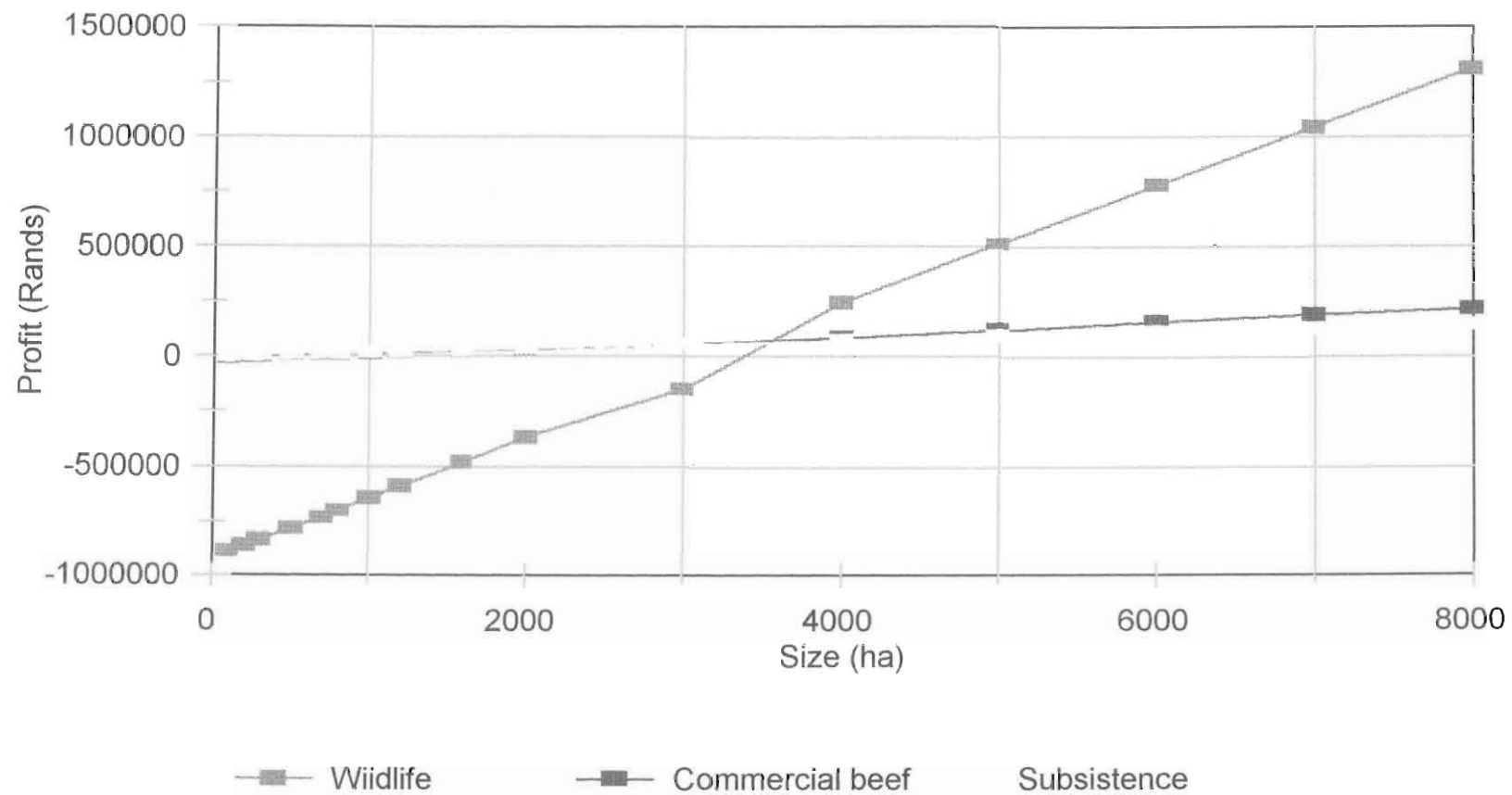


Figure 6.11. Comparing the effect of property size on the projected minimum profit curves for commercial beef production, subsistence production and wildlife production.

Table 6.4. The intersection points between the predicted profit curves and their break-even points for three land-uses in semi-arid savanna against property size.

		Commercial beef production		Subsistence production		Wildlife production	
		Min	Max	Min	Max	Min	Max
Break-even point (ha)		300-500	200-300	0	0	2000-3000	3000-4000
Intersection points							
Commercial beef production	Min	-					
	Mix	-	-				
Subsistence production	Min	2000 - 3000	300 - 500	-			
	Max	no crossing	no crossing	-	-		
Wildlife production	Min	3000-4000	3000-4000	3000-4000	4000-5000	-	
	Max	2000-3000	2000-3000	2000-3000	3000-4000	-	-

6.5. CHANGING THE VEGETATION STRUCTURE

It has already been mentioned that due to time constraints it was not possible to conduct a time series analysis, but the design of the model does allow one to assess how a change in vegetation structure would change the profit curves of the wildlife and subsistence models which have both grazer and browser species. It is not possible to determine the effect of such shifts on the commercial beef production system, since the commercial beef model has no browser (goat) component built into the model and would not realistically reflect the state of commercial ranches in areas of high tree density, where goats can form an essential part of the system.

Semi-arid savannas are typically composed of two layers of plants, namely a grass layer and

a tree/shrub layer, which provide forage for grazers and browsers respectively. The proportion of each layer, in terms of both absolute and relative values, determines the ratio of grazer to browser species (also mixed feeders) and the stocking rate of each layer. Thus any shift in the vegetation composition will affect the ratio of the various herbivore types, either shifting to more grazers or to more browsers. Since the income generated from different herbivore species varies quite dramatically, this effect has important consequences for generated revenue. On this basis it was decided to shift the ratio of browse CC up by 0.02 AU's and to reduce the grass layer component by the same amount in order to compensate for the shift and so as not to change the overall stocking rate. This may be unrealistic in that the inverse relationship between grass CC and browse CC may not be a linear replacement. In fact small increases in the tree layer may have minimal negative effects on the grass layer and may even be beneficial to it. The model is not designed to handle this level of detail so the effect will be ignored, and a linear replacement curve assumed the reality.

The wildlife model is easiest to manipulate as it relates all herbivores directly to the stocking rate and the ratio of grass to browse. Additionally, the wildlife model distinguishes between two grass components, namely tall and short grass. Since this affects the ratio of bulk to concentrate grazers, a shift in the tall grass : short grass equilibrium also affects generated revenue. So before changing the amount of browse, the effect of changing the tall grass : short grass ratio was assessed by increasing tall grass to 0.1 AU ha⁻¹. After running this simulation, and finding the results, the tall and short grass components were both changed to 0.09 AU ha⁻¹. The effect of these shifts on revenue are indicated in Table 6.5. The values are from a land size of 4000 ha as all species have entered the system by this point, so all variables are equal.

Table 6.5. The effect of shifts in the vegetation structure on the returns from wildlife harvesting.

Vegetation structure	Returns per hectare at 4000 ha (Rands)
Browse = 0.08; short grass = 0.14; tall grass = 0.06	422.08
Browse = 0.08; short grass = 0.10; tall grass = 0.10	462.2
Browse = 0.10; short grass = 0.09; tall grass = 0.09	526.12

Changing the ratio of tall grass to short grass increases profitability when the tall grass component is increased due to the high performance index species in the bulk grazer compliment (white rhino and buffalo), but the performance index effect is far more pronounced when the browse component is increased due to species such as suni and red duiker which offer extremely high returns.

When increasing the tree layer in the subsistence model, it is necessary to remember that goats are mixed feeders and have graze requirements. Since the structure of the subsistence model does not distinguish between vegetation types, the ratio of cattle to goats must be adjusted to account for the shift in the tree : grass equilibrium. By dividing the change in AU's (0.02 decrease for cattle and 0.3 increase for goats to account for the latter's requirements) by the AU-equivalent of each domestic stock species, it is possible to determine the amount by which each fraction of the population must be adjusted (0.0263 decrease for cattle and 0.2 increase for sheep) The new fractions are now 0.71 cattle to 0.29 goats, because of the graze requirement for goats. The profit from subsistence production will reduce as indicated by the performance indices for cattle and goats in Equation 6.2.1.

These facts from the model layout suggest that any shift in the tree : grass layer which favours the tree layer (e.g. bush encroachment) will promote wildlife production over domestic systems, as wildlife can be more profitable while domestic systems, which rely predominantly on cattle, become less profitable.

7. GENERAL DISCUSSION

Comparisons between wildlife and domestic stock production in semi-arid Africa have been conducted since the 1960's (e.g. Dasmann 1964, Roth 1966), but there has always been a poor degree of direct quantification between the different systems, both in terms of the biological aspects and the economic aspects (see Walker 1976). The biological differences of the systems are understood much more clearly now, but direct economic comparisons remain rare and incidental, possibly because the systems are so variable. However in order to provide direction for policies on land use, it is necessary that the economic benefits of the systems be more clearly comparable. In this light the present analysis attempted to investigate the effect of property size on profits that can be generated by the three land uses and the importance of different factors to that effect.

This project has indeed confirmed that wildlife production systems are subject to the "economies of size" effect, such that their fixed costs per hectare will firstly drop and then increase with additional land area due to an increase in the opportunities available which improves the attractiveness of a wildlife reserve to hunters and ecotourists, thereby increasing the costs per hectare in a non-linear fashion. Additionally, there are high input costs into wildlife operations, both in terms of fixed costs and variable costs. The relationship between variable costs and size at sizes below about 4000 ha is not fully understood as the model makes no attempt to distinguish between costs relating to hunting and those relating to ecotourism. This will have to be done at some stage in future research, as the variable cost curve derived here seems unrealistically high in the lower size ranges, which has a strong negative effect on the profits generated by small reserves. This is confirmed by Child (1990) who notes that trophy hunting farms in South Africa are generally less than 3000 ha, which stands in contrast to the findings of this study which suggest that wildlife operations are less profitable than domestic stock operations below this value. Be that as it may, the results indicate that there are high input costs associated with wildlife production, and consequently both subsistence production and commercial beef production can achieve higher profits at small property sizes. In fact the present model finds that reserves smaller than 2500 ha will battle to achieve the break-even

point between revenue and costs. That aside, the opportunity cost of investing in wildlife over commercial beef or subsistence production on property sizes of less than 3000 ha is high as the latter two systems have both already achieved profitability. This indicates a weakness in the present model in that it cannot distinguish between costs relating to hunting operations and those relating to ecotourism, the latter being far more capital-intensive.

Kreuter & Workman (1996) compared profits generated from wildlife and commercial stock production enterprises in semi-arid savannas in the Midlands Province of Zimbabwe. Although there was no differentiation across size, the ranches examined ranged in size from 1424 ha to 132 840 ha. Kreuter & Workman (1996) found that cattle ranching was more profitable than wildlife, but the most successful operation across all sites were mixed cattle-wildlife enterprises. It is unfortunate that a model of mixed cattle-wildlife was not constructed to observe the behaviour of such an operation across size, however this project is intended to be exploratory and defining the characteristics of a mixed enterprise might be quite complex.

The model analysis presented here also indicates that subsistence production is the best form of land-use at very small land sizes, due to the high capital requirements of commercial livestock and wildlife operations. This is confirmed by Barnes (1993) who found that commercial beef ranching systems have dramatic economies of scale as herd size increases to 200 head, beyond which the return per unit capital increases more slowly until it reaches a peak at 600 head. At the stocking rate of 0.2 AU ha⁻¹ used in this model, 600 head confirms the 3000 ha inflexion point for fixed costs determined by Lyne and Ortmann (1996). However Barnes (1993) also suggests there are economies of scale in subsistence systems, citing a study by Bailey (1982) in semi-arid Botswana which showed that the net benefits per livestock unit were negative with herd sizes less than 30 (excluding draft power and prestige). An economies of size effect has not been worked into the subsistence model in this analysis and this needs to be examined more closely to establish a minimum viable property size for any of the three considered land uses.

7.1. RECOMMENDATIONS FOR IMPROVEMENT OF THE ANALYSIS

There are a number of weaknesses with the present models which make the results of purely academic value. Until these are corrected, the three land uses cannot be accurately compared and optimal property sizes quantified.

7.1.1. The wildlife production model

The wildlife production model is fairly coarse in its present form and as such is of limited value to accurate interpretation of specific environmental situations where a choice must be made between the three land-use options. In order to make the model more useful, there needs to be refinement in a number of areas:

- The relationship between variable cost and size, as already mentioned, is not clearly understood as no attempt has been made to separate the costs relating to hunting and those relating to ecotourism. Both variable cost and ecotourism revenue curves need to be derived from a much larger sample set which should be derived from profit-orientated private enterprises. Additionally, an adaptation needs to be made to the statistical technique to account for the small number of large reserves that have a strong influence on the multilinear regression technique, which tries to minimise the error mean square value of the data set. The data set should distinguish between variable costs relating to hunting and those relating to ecotourism as well as areas of overlap.
- In relation to the ecotourism revenue model, data on occupancy rates will aid in determining both the effect of size and distance on the attractiveness of reserves to tourists.
- The fixed cost model in its present form is inadequate for detailed analysis. A clearer grasp of the division of fixed costs and how they change across property size is required. For example, road costs would increase dramatically with increasing size due to the increased quality of road surface and type required for heavy traffic loads. Again, there will be a distinction between costs relating to hunting and to ecotourism. This data

may be available in a suitable form from private operations.

- The harvesting model is well worked out in terms of its structure, but the revenue achieved seems very high and is probably unrealistic. The model requires “ground-truthing” to establish the accuracy of yearly off-take rates in reserves. Also hunting trips are often sold as packages, which may either increase or decrease the value of individual animals in each package. The prices of these package deals need to be calculated and worked into the model.
- Finally, research into the behaviour of tourists may help to establish the effect of size on reserve attractiveness to tourists and particularly how distance to wildlife reserves negates this attractiveness.

7.1.2. The subsistence production model

After examination of this thesis, it has been pointed out to me (Lyne 1998, personal communication) that the subsistence model fails to account for a number of the costs incurred by subsistence production:

- Labour costs are incurred by both the livestock and maize components of the system, for milking, gathering manure, sowing seed, harvesting maize etc.
- Costs of negotiating, policing and enforcing limits on individual herd sizes.
- Recently, farms acquired by land reform beneficiaries have had to be insured against the risk of fire damage to neighbouring properties and bear some part of the cost of fencing separating them from neighbouring commercial farms. They also have to finance and maintain the roads serving their homesteads.

7.1.3. The effect of capital gains on land value

In the preceding analysis, profits have been implicitly defined as the return to both land and management, whereas economists usually define it as a return to management. This in itself is not a problem, but there are two components of returns derived by commercial farmers: current returns (the cash income which could be earned by renting the land out) and capital gain, which are generated by the land as it increases in value (Lyne 1998, personal communication) in a similar fashion to equities purchased on a stock market. The latter has been ignored in this analysis, but can have a strong influence on the results, since there is no market value and as such no capital gains for subsistence land under conditions of open access or common property (Lyne 1998, personal communication). However if the rural community has set up as a company, then the land will acquire market value relating directly to the degree of land ownership. The effect of capital gains will obviously also contribute to returns to wildlife. Obviously the ownership of the land needs to be clearly qualified to determine the value of capital gains for each land use system.

7.2. SOME REMARKS ON USING LAND PROFITS TO MEASURE BENEFIT

The results of the project indicate that conservation bodies which are investing large sums of money in small community game reserves of under 3000 ha would not be able to justify them on the basis of profits alone, as significant opportunity cost is incurred by not using the land for commercial beef production or subsistence production. However this project has focussed on determining the financial profitability of the three operations against size and makes no attempt to calculate the full economic benefit of each of the three land-uses. In this line of thought, a full economic analysis would need to define how much of the variable cost will be ploughed back into the community, mainly in the form of wages and salaries. As already pointed out, wildlife production can be fairly labour-intensive as it forms part of Tourism which is a service industry. Since variable costs of wildlife are fairly high and these are predominantly related to personnel costs, the economic impact of this may be substantial if a large component of the available jobs for the wildlife enterprise can be given to members of the local community. This would strongly improve the relative performance of wildlife production with its apparent high

returns (also see Kreuter & Workman, 1996), especially against commercial beef production which is not labour-intensive (subsistence production by its non-mechanistic nature is labour-intensive). However it is still probable, given the high fixed costs involved, that wildlife would be shown to be a poor land-use choice at very small property sizes, and that the land is better put to either subsistence or commercial beef production.

8. CONCLUSION

Wildlife production is a rapidly growing form of land-use in southern Africa and has lately been seen by some rural communities as a solution to economic poverty. However wildlife operations have high input costs relative to domestic stock operations and it is probable that the latter are better forms of land-use at small property sizes.

This study has investigated the effect of land property size on the profits that can be generated by three conflicting land uses in semi-arid savannas, namely commercial beef production, communal subsistence production and wildlife production. The aim of the study was to conduct a Cost-Benefit Analysis between the three land uses in order to determine the intersection points between the profit curves of the different land-uses and thereby provide a tool for land use decision-making in semi-arid savannas.

Due to the complexity of the comparison and the components of the three systems and in order to make the technique of general applicability, mathematical modelling was used to conceptualise and quantify the requirements for the comparison. Mathematical formulations of annual revenue and cost curves were constructed for each of the land uses, from which were derived the profit curves. In addition, the models were designed with respect to the consumptive or non-consumptive nature of the land use. A key advantage derived using mathematical modelling was that the behaviour of the revenue, cost and profit curves against property size could be observed.

A number of different mathematical techniques were necessary for the requirements of the different systems. Commercial beef production was modelled using established productivity results and profits from subsistence production was derived using linear models. Wildlife was divided into a consumptive component, animal harvesting, and a non-consumptive component, ecotourism. Population structures for animal harvesting were set using a linear optimisation, while revenue and variable cost curves for ecotourism were derived using multi-linear regression of data sets of game reserves from the regional conservation agency.

The results clearly demonstrate that wildlife becomes increasingly competitive with increasing property size, but is certainly less profitable than either subsistence production or commercial beef production at small property sizes. There is some uncertainty regarding the exact cut-off point of property size where wildlife becomes more profitable than subsistence or commercial beef production due to poor data and some incorrect valuation of the costs and revenues of each land use. However the study has provided a suitable framework of analysis which would lead to a more accurate result should additional, more refined data become available.

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