

An investigation into the financial feasibility of
intensive commercial white rhino farming in
South Africa

A Strategic Approach

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(Photo: White rhino cow and calf, Arthur Hall)

to Him who created us all

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Executive Summary

There has been a drastic increase in the illegal hunting of rhino for their horns, due to a horn trade ban implemented by the Convention on International Trade in Endangered Species (CITES). By banning the trade in rhino horn, the risk of getting the horn illegally amplifies, which directly increases the cost of trading with the horn on the black market. Until very recently, rhino farming was seen as an economical venture to provide the growing trophy-hunting industry. However, since the drastic increase in the poaching of the species, rhino farming no longer makes economic sense due to the increased risk. By improving the economical feasibility of the commercial farming of the species, it will possibly aid in the rhino regaining its economical value and lead to better conservation efforts. The purpose of this feasibility study is to formulate an optimal strategic production plan for an intensive white rhino farm that investigates the financial viability of intensive commercial white rhino farming in South Africa, using a dynamic recursive mathematical model. Employing the dynamic recursive model over a ten year period, suggests that intensive white rhino farming is financially feasible.

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List of Abbreviations and Acronyms

CITES	Convention on International Trade in Endangered Species
GIS	Geographic Information System
Ha	Hectare
M	Million
VAT	Value added tax
WWF- SAPRO	World Wildlife Fund–South Africa Programme Office
ZAR	Zuid Afrikaanse Rand

1 INTRODUCTION

1.1 Background

1.1.1 *Poaching in the world*

Poaching is the unlawful taking of wild animals or plants, whilst opposing domestic and international conservation and wildlife management regulations. Animals are usually killed for their hide, ivory, teeth, horns and bones which are sold to dealers to produce various products. In certain foreign countries these animal products have religious value and are used for totems and witchcraft. Other reasons for poaching wild animals are the belief that their hide, ivory, teeth, horns and bones can cure cancer, increase fertility and improve physical appearance (Milliken et al, 2009).

1.1.2 *Rhino poaching in Southern Africa*

There has been a drastic increase in the illegal hunting of rhino for their horns. When looking at the factors that are causing this anthropogenic tendency it is clear that the value of the horn as a hunting trophy, ornamental carving and for the use in Chinese herbal medicine (Ellis, 2005) is the largest component.

In 1977 the Convention on International Trade in Endangered Species (CITES) listed the white rhino as part of the conventions Appendix I document. The Appendix I document lists all species threatened with extinction. The listing led to a ban on all the international commercial trade of this mammal. Since 1994 the white rhino in South Africa was moved from the Appendix I document to the Appendix II document, which allowed the trade in live animals and trophy hunting. The legalization led to an increase in the amount of investments made in this new escalating market; however the trade in rhino horn was not included in South Africa's Appendix II, which painted the picture that the world rejects the quite obvious demand for rhino horn. As John Hume, the only successful intensive rhino farmer in South Africa said: "A trade ban does not end trade" (Hume, 2011). By banning the trade in rhino horn, the risk in getting the horn illegally amplifies, which directly increases the cost of trading with the horn on the black market. Public ignorance, emotional outcries and misunderstanding

allow this policy to persist. On the bases of the simple economic principle of supply and demand, the restricted supply is leading to illegal trade becoming more and more profitable. The ban on the trade of rhino horn no longer makes economic or conservation sense, since rhino horn is a renewable resource that can be harvested without harming the rhino (Pienaar et al, 1991).

South Africa conserves 35% of the world's black rhino and 93% of the total white rhino population (South Africa Department of Environmental Affairs, 2012). Since 2006, illegal rhino horn trade has progressively worsened (Milliken et al, 2009) as a result of the increase in the demand for rhino horn.

1.1.3 Combat poaching

Strategies that are currently running to help combat the onslaught on rhino populations in South Africa are:

- South African Military Services being deployed in the Kruger National Park
- Dehorning
- Possible chemical deterrent injected into the horn
- Amplification of rhino-specific ranger training
- Dog unit implemented in 2012

Although these strategies are definitely helping to address the poaching problem to some extent, the root of the problem (the increasing demand and illegal supply) is not being attended to, leading to the escalation of rhino poaching (Figure 1).

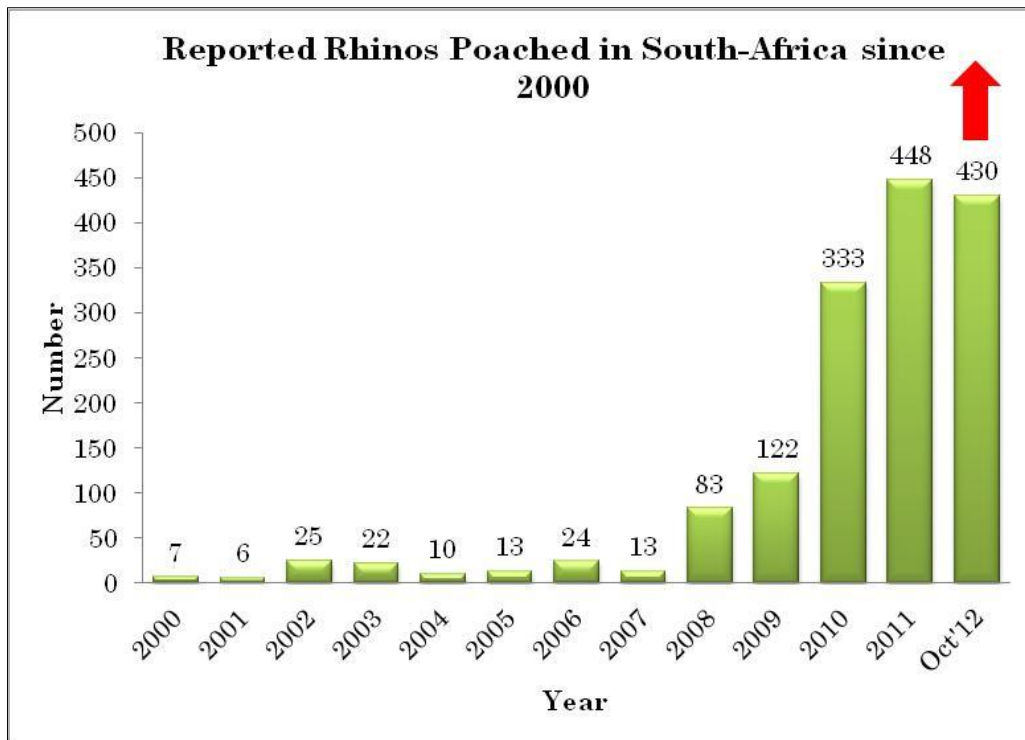


Figure 1-Rhino-statistics (Department of Environmental Affairs, 2012)

1.1.4 Intensive commercial rhino farming

Intensive rhino farming is where a number of rhino are kept in a large enclosure with the intent of forming part of a captive breeding operation. These rhino are generally supplementary-fed every day and most aspects of their management are intensive.

1.2 Problem Statement

Until very recently rhino farming was seen as an economical venture to provide the growing trophy-hunting industry. However, since the drastic increase in the poaching of the species, rhino farming no longer makes economic sense because of the increased risk. If the harvesting of rhino horn is legalised this situation may change. Improving the economical feasibility for the commercial farming of the species will possibly aid in the rhino regaining its economic value and lead to better conservation efforts.

1.3 Project Aim

The purpose of this feasibility study was to formulate a strategic production plan that investigates the financial viability of intensive commercial white rhino farming in South Africa, if the harvesting of rhino horn is legalised.

1.4 Research Design and Deliverables

An exploration of the current white rhino farming industry in South Africa will aid in identifying inputs as well as constraints that will influence the financial outcome of the investigation. Yet the immeasurable constraint that will influence the utilisation of the investigations output is the legalisation of the restriction on the trade in rhino horn. The likelihood of legalisation will be discussed at CITES upcoming 16th meeting at the Conference of the Parties (CoP16) in March 2013.

The primary deliverable from this study will be a comprehensive document outlining an optimal strategic production plan to intensively farm with white rhino. The mathematical optimisation tool developed will assist the rhino farmer to strategically farm with maximisation of profit being the main incentive. The profit output will quantify the analysis of the results.

1.5 Research Methodology

As stated above, the aim of this dissertation is to propose a strategic production plan for a future intensive commercial white rhino farm in South Africa. The report will contain the following chapters:

Chapter 1 Introduction: This introductory chapter gives the reader background to aid in understanding the identified problem.

Chapter 2 Literature Review and Industrial Engineering problem-solving techniques: A research summary is given to motivate commercial farming of endangered species, as well as identify the appropriate problem-solving techniques that will be incorporated in the study.

Chapter 3 Identification of input factors: Method of identifying and calculating factors that will be playing a role in the model.

Chapter 4 Model Formulation: This chapter deals with the construction of the mathematical model. The chapter also discusses the model results and sensitivity analyses.

Chapter 5 Conclusion and Recommendations: This chapter will discuss the outcome of the model, as well as give recommendations for breeding optimally with white rhino.

1.6 Project Stakeholders

The primary stakeholders will be future rhino farms within South Africa. However, current rhino farms and ranches could also benefit from such a strategic plan. Secondary stakeholders will include conservation groups, the hunting industry and the general public that has a love for nature.

1.7 Project Scope

Firstly, in-depth research needs to be completed to investigate why rhino poaching has increased over the last few years, as well as what has been done to combat the current poaching onslaught on rhino. The research will be used to exemplify that the legalising of rhino horn will lead to a possible solution to the problem at hand.

Secondly, market research is done to identify current intensive white rhino farms. This will assist in the identification of input factors that will play a role in the formulation of a feasible production plan. These factors will include environmental, economic and agricultural factors.

The final part of the project will consist of constructing a mathematical model to optimise intensive commercial farming of white rhino and the legal harvesting of their horns; taking into account cost factors, biological factors and identified constraints.

This project only focuses on the feasible intensive production and trade of white rhino in an enclosed area.

1.8 Potential Risks/Setbacks

Owing to the sensitive nature of the current poaching situation in South Africa this project carries many risks that may cause set-backs to the project as a whole. One of the major areas that will play a definite part in the utilisation of the financial feasibility model is the international ban on the commerce of rhino products. Prior to awaiting this decision, the model will not reach its full potential.

1.9 Chapter Summary

Until very recently rhino farming was seen as an economical venture to provide the growing trophy-hunting industry. However, since the drastic increase in the poaching of the species, rhino farming no longer makes economic sense because of the increased risk. The aim of this dissertation is to formulate a strategic production plan that needs to investigate the future financial viability of intensive commercial white rhino farming in South Africa if the harvesting of rhino horn is legalised.

An exploration of the current white rhino farming industry in South Africa will aid in identifying inputs as well as constraints. The primary deliverable for this study will be a comprehensive document outlining a strategic production plan.

2 RESEARCH

2.1 Wildlife Farming and Conservation

According to Damania and Bulte (2006), there have been proposals to embark on farming with wildlife for specific commodities. These authors further state that: ‘Supply-side conservation has also been recommended to curb the buoyant illegal trade in live endangered species’ (Damania and Bulte, 2006, p 1222). Supply-side conservation naturally rests on the implicit theory that the current market for wildlife products is considered to be in perfect competition; meaning hunters and poachers see the price of wildlife products as a given and beyond their control. In Figure 2, Damania and Bulte (2006) make it clear that additional supply of wildlife products from intensive farming initiatives decreases the price of the wildlife products from s (price level that balances demand and supply) to S (new, lower market price).

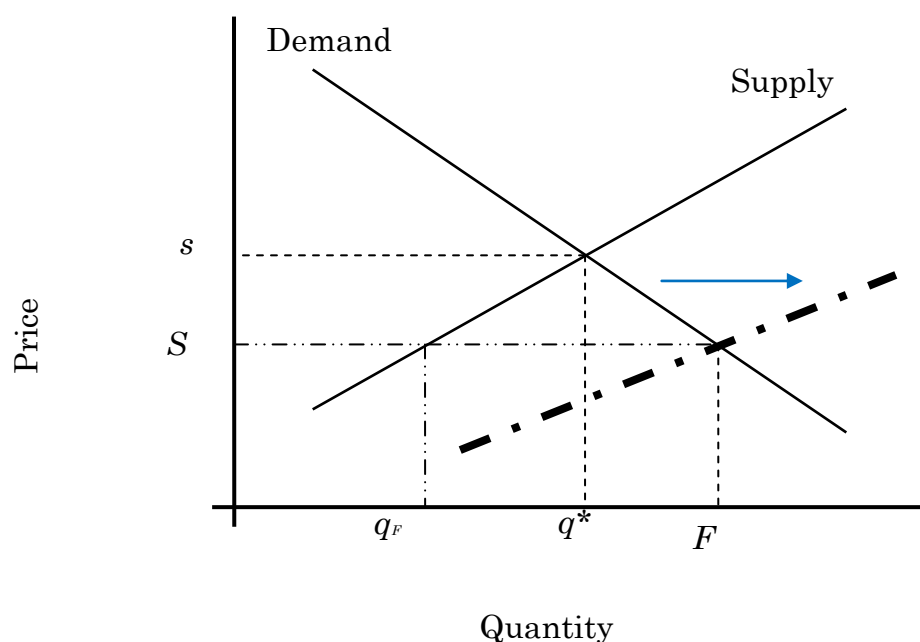


Figure 2-Supply and demand curve for wildlife commodities (Damania and Bulte, 2006).

2.2 Application of Industrial Engineering Techniques and Models in Farming

Wilton et al (1974) used linear programming (LP) to describe an on-farm beef cattle production enterprise. It is clear that ‘the main objectives of the authors was to simultaneously determine the economical optimal cropping, feeding and breeding programs within the confines of available resources’ (Wilton et al, 1974, p 693). The benefit of the specific case is profit driven. For the implementation, LP was used to find the optimal solution to the problem at hand. ‘LP assumes linearity; the total input or output of any activity is proportional to the level of that activity used’ (Wilton et al, 1974, p 697). Furthermore, when it is observed that certain relationships required for the generation of the LP are not linear—for example feed requirements, it is possible to either calculate in advance the technical coefficients for the activity considered, or subdivide the activity into several activities for an LP estimation to the non-linear situation. To solve the problem successfully the writers made three assumptions. These assumptions are frequently made in other research methods such as partial budgeting in farm administration or simulation of animal reproduction. The assumptions are the following:

Linearity and additively: This implies activities to be directly proportional to each other as well as the requirement that different activities should be independent. Applying this theory to the model will aid in non-linear relationships such as the feed requirements for the maintenance of rhino at different maturity levels.

Divisibility: When interpreting the solution of the optimal LP, fractional resource and commodities figures are allowed. This insures irrational figures being a justifiable answer.

Finiteness: Generally only a limited number of activities are considered in an LP. This is due to limitations on data, cost and interpretations. The selected activities should clearly be motivated, as this will aid in the conclusions made from the optimal solution.

Qingzhen et al (1991) developed an optimal production plan for crops and livestock in Chan Qing Country, China. The aim of the production plan was to increase the net profit without unfavourable effects on the environment. Large scale LP models were used to find the optimal solution. The following LP recursive equation was used in the solution procedure:

$$\text{Max } f(P) = C_1(P) X_1(P) + C_2(P) X_2(2p) \quad (2.2.1)$$

Where:

$f(P)$ = the total net profit from crops and animals over a two-year period, under weather conditions p .

p = 1,2,3 and 4 denote the normal year, drought year, flood year and drought-flood year, respectively;

$X_1(P)$ = a vector of the activity levels for crops. Its components are the various types of fields supplied for different combinations of crops under weather P ;

$X_2(P)$ = a vector of the activity levels for animals, including the number of animals on ranges;

$C_1(P)$ = a vector of the net profit coefficients over a two-year period from various types of fields for the combinations of crops per month under weather A ;

$C_2(P)$ = a vector of the net profit coefficients per head of various kinds of animals over a two-year period under weather p .

To develop an optimal production plan, the authors maximised the net profit equation for the farm (equation 2.2.1). The activity level for the two primary farming commodities is taken into account.

In a journal written by Janssen and van Ittersum (2005) the focus falls on the integration of LPs with a Bio-Economic Farm Model (BEFM). The target the farmer wants to reach and the activities that will aid the farmer in reaching his target is perceived as the objective function of a BEFM. Realistically, a farmer's decision will not always be motivated by profit maximisation; frequently they

will be motivated by multiple objectives such as finding an optimal farm-production strategy for crops or livestock.

More often than not, BEFMs don't overtly take account of time; they model for a single time period (Janssen and van Ittersum, 2005). To overcome this limitation, Janssen and van Ittersum recommend that a dynamic recursive modelling approach be used.

2.3 Methods, Techniques and Tools For Problem Solving

2.3.1 Linear programming

The Business Dictionary.com defines a mathematical equation as linear when no independent variable has a power greater than one. In 1947, George Dantzig developed an efficient method, the simplex algorithm, for solving LP problems (LP) (Winston and Venkataramanan, 2003, p 49.). Classic LP problems are incorporated in business modelling, business or organisation operations and to help in any decisions that have to do with minimising costs and maximising profit. Since the development of the simplex algorithm, LP has been utilised in a diversity of fields including agriculture and forestry (Winston and Venkataramanan, 2003).

Van der Linden (2005, p 47) defines the steps for the process of modelling a LP assembly clearly:

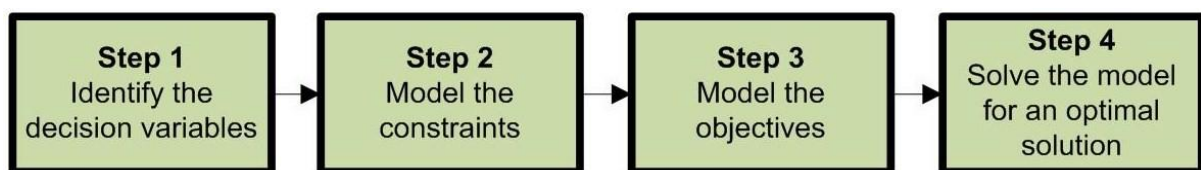


Figure 3-Modelling an LP assembly

In Figure 3 Van der Linden (2005) breaks the modelling process of an LP into four fundamental consecutive steps. The first step is to identify decision variables correctly. For the successful identification the model builder should clearly understand and grasp the problem at hand. In the second step it is essential to have a comprehensive picture of the environment surrounding the model. This will be a key for determining relationships and constraints that play

a significant role in the solution. Van der Linden (2005) also relates that sufficient time must be spent to complete step one and step two as successfully as possible. This will lead to the formulation of step three and step four being very straightforward.

The biggest advantage of the LP method is that the solution will always give the best possible strategy for utilising available resources. Taking into consideration the problem statement, an optimal production strategy for the intensive white rhino farm with limited resources, a linear representation could aid in solution finding. Unfortunately, this solution finding method has two noteworthy disadvantages. Firstly, the objective of the model, as well as the constraints, has to be linear for the model to be executed at all. Secondly the model does not take into consideration risk factors such as uncertainty and weather conditions. These factors should be kept in mind when designing such a model. Assumptions should clearly be stated to give the user a better understanding of the outcome.

2.3.2 Dynamic recursive programming

Blanco Fonseca and Flichman (2002) classify dynamic models as models that take time as an explicit function, so that decision variables can be captured as a function of time. More simply put, the Business Dictionary.com term dynamic programming as a problem-solving technique for breaking large LPs into smaller LPs, which are all interlinked (Business Dictionary, 2012). More often than not resource-management problems fall under dynamic programming (Kennedy 1986, preface).

‘Dynamic recursive models optimise over the whole period, while explicitly accounting for the dynamic interactions across years by using each years starting value as the end values of the previous year’(Janssen and van Ittersum, 2005, p 629). In the case under investigation the optimal solution will be of more worth to the farmer if the time period chosen is broken down into smaller intervals. However, the outcome of the posterior interval will depend on the outcome of the precursor interval.

2.3.3 Incorporating time value of money in dynamic programming

Dynamic recursive models are usually formulated to get the optimal solution over a long period of time. 'A weakness of the current dynamic programming formulation is that profits received during later years are weighted the same as profits received during earlier years' (Winston and Venkataramanan, 2003, p 780). For the purpose of the model an annual profit investigation will need to be done for the determination of the farm's feasibility. For this reason the future annual profits should be weighted the same as current profits.

2.3.4 Sensitivity analysis

Sensitivity analysis is defined as the process of altering key model inputs to determine their effect on the outputs (Evans, 2010). Not all the data used in the model will be known accurately; thus a sensitivity analysis will be included as part of the investigation to determine the effect of input substitution. The understanding of how the model behaves in response to changes in the inputs of the model is of fundamental importance to ensure the correct use of the constructed model.

2.4 Chapter Summary

LP has been used in finding optimal solutions to agricultural problems for a number of years. The method is seen as favourable for the farming industry because it incorporates all available resources and limitations for finding the best possible answer. This technique also benefits long-term- and short-term explorations, which is very beneficial to a farmer. Multiple conclusions can be drawn from the results. However, linearity is a definite requirement for this method to be applied.

Classic LP problems are incorporated in business modelling, business or organisation operations and to help in any decisions that have to do with minimising costs and maximising profit. An outflow of the LP method is dynamic recursive optimising models. These models optimise over the whole period, while clearly taking into account the dynamic interactions across time periods, by using each time period's starting value as the end value of the previous time period.

3 IDENTIFICATION OF MODEL FACTORS

This chapter discusses the factors used as inputs for the strategic production linear model. This discussion is followed by an explanation of the model results and sensitivity analyses to determine the functionality of the model.

3.1 Methodology

For the successful construction of the linear model, the factors that will give functionality to the optimal production strategy must be as realistic as possible. The dynamic recursive model method has the important advantage of delivering the best possible strategy for utilising available resources first time. The factors will play a significant role in the execution and reliability of the model. Techniques that were used to guide the factor identification process are set out below.

Research: Books and journals were studied.

Interviews: From the start of the project key persons in the field of intensive farming, wildlife management and operations research were consulted. Face-to-face formal and informal interviews were carried out and e-mail correspondence took place to assist and support the problem to be addressed.

Questionnaires: It became quite clear that research resources about intensive commercial white rhino farming were not widely available. However, after some market research was done, intensive commercial white rhino farms were located in the North West Province, South Africa. These farms are owned by a game ranger, Mr. John Hume. With the available research and interviews done, questionnaires could be compiled and sent out to the relevant parties, for the capturing of realistic input figures.

3.2 Basic Model Formulation

The following cost factors need to be utilised in the formulation of the model:

- Agricultural land cost
- Infrastructure cost
- Current white rhino trade data
- Insurance cost
- Horn harvesting cost
- Veterinary services cost
- Habitat requirements cost
- Inflation
- Labour cost

In conjunction with the financial factors, the following biological characteristics could play a role:

- Life expectancy of the animal
- Intensive area required for breeding
- Number of bulls needed to stimulate breeding
- Number of cows per bull recommended for intensive wildlife production
- Fruitful breeding years for a rhino cow
- Age of cow at birth of first calf
- Gestation period
- Weaning age of calf
- Mean time between successive calves
- Habitat requirements
- Labourers per rhino
- Horn growth and re-growth rate

A common characteristic between the financial and biological factors is time. Worldwide farming is seen as a long-term endeavour and investment. The success of a farmer can generally only be measured after a long period of time. Thus, for the purpose of the dynamic LP model a possible period of ten years needs to be analysed.

3.3 Financial Factors

The focus of the model will mainly fall on the direct cost factors surrounding the intensive farming of white rhino. These cost data mentioned are only an indication of the reality and for analysis purposes. The factors are set out in the paragraphs that follow.

3.3.1 Land

In the book, *Rhino Ranching: A Manual for the Owners of White Rhinos* (1998), du Toit makes a clear statement that white rhino should not be farmed with cattle because of the danger of getting entangled in fences and endangering the cattle at water points. Furthermore, Bothma (2005, p31) gives a figure for the stocking density of free roaming white rhino to be 0.5 rhino/100ha. However, in the questionnaire (Appendix A) that was sent out to rhino farmer, Mr. John Hume in 2012, a 400ha enclosure is currently an optimal size for breeding intensively with white rhino. For the purpose of the study, a 400ha enclosure will be analysed.

3.3.2 Infrastructure

The rhino will be fenced in for safety as well as control reasons. TNH Fencing (2012) was consulted to help with the determination of the fencing type and costs associated with this kind of enclosure. TNH Fencing has more than 15 years' experience in the wildlife and agricultural fencing business. They have rendered services to Tswalu Kalahari Reserve and Marakele National Park, to name only a few.

TNH Fencing identified the following factors as playing a role in the costing of such an enclosure:

- Length of fence-line required;
- Terrain and accessibility for vehicles;
- Soil type, as this will affect length of posts and ability to dig;
- Whether or not the line area has been cleared of bush and graded;
- The animals to be kept in the enclosure;
- Purpose of the enclosure;

- Requirements of relevant authority (nature conservation etc.);
- Environmental weather conditions and whether rust and lightning will have an effect on the equipment used;
- Security of the area and whether or not materials will require protection from theft prior to handover;
- Availability of water for concrete;
- Distance from material manufacturer;
- Possibility of establishing an on-site camp for labour;
- Availability and cost of local labour; and
- If electrification is required, the availability of power at the fence-line is important.

From TNH Fencings' experience it was determined that on average a 400ha enclosure would have a minimum fence-line length of 8km. If this is the farm perimeter fence, most conservation authorities would require a high game fence which would cost on average ZAR 45/m, value added tax (VAT excluded). If, however, it was an internal fence, a lower fence would be sufficient. In both cases, the fence would need to be electrified at a normal cost of ZAR 15/m (VAT excluded). Currently VAT is levied at a standard rate of 14% (South African Revenue Services, 2012).

Thus:

(8km x 1000)fence – line = 8000m fence – line for 400ha enclosure

$$\frac{\text{ZAR } 45}{\text{m}} (\text{Vat excl.}) + \frac{\text{ZAR } 15}{\text{m}} (\text{Vat excl.}) = \frac{\text{ZAR } 60}{\text{m}} (\text{Vat excl.}) \text{for fence – line}$$

$$\therefore 8000\text{m} \times \frac{\text{R}60}{\text{m}} = \text{ZAR } 480\,000.00 (\text{Vat exclu.}) \text{for the fence – line}$$

$$\therefore \text{Fence – line cost (14\% VAT included)} = 1.14 \times \text{ZAR } 480\,000.00 = \text{ZAR } 547\,200.00$$

The ZAR 547 200.00 is a once-off expense for the time period of the investigation of the project. Maintenance expenses regarding the fence-line are discussed in paragraph 3.3.6.

3.3.3 Rhino trade

Legal buying and selling of live wildlife mostly takes place at accredited game auctions. In South Africa there are presently two types of game auction:

1. Centralised auctions: game is darted and taken to a central game auction boma where game is auctioned off; and
2. Catalogue auctions: the buyer buys the game through a catalogue and receives the game directly from the seller farm.

In both cases the seller pays 7% of the selling price to the auctioneer (du Plessis, 2012).

Annual figures for the average wildlife auction prices are made available to the public by the *SA Game and Hunt Magazine* (Appendix B). The average auction price of a white rhino for 2011 (R199 794.00) will be used as an input for the model. Thus:

- Rhino bull/cow selling returns, less auction deductions of 7%:

$$\text{ZAR } 199\,794.00 \times (1 - 0.07) = \text{ZAR } 185\,808.42/\text{rhino}$$

- Rhino bull/cow purchasing cost:

$$\text{ZAR } 199\,794.00/\text{rhino}$$

3.3.4 Dehorning and rhino horn trade

In a study carried out on populations of white rhino by Rachlow and Berger (1997) it was found that regeneration of rhino horn takes place subsequent to the removal of the existing horn. 'The horns of the white rhino grow continuously throughout its life' (du Toit, 2005). On average a pair (anterior and posterior) of horns has a weight of 4 kg. Re-growth differs between sexes (Rachlow and Berger, 1997). White rhino bulls have an estimated re-growth rate of 1kg/annum and white rhino cows 0.6kg/annum (Hume, 2012).

Owing to the current international ban on the trade of rhino products, reliable retail horn price data are unavailable. An estimated black market price in Vietnam currently yields ZAR 210 000/kg (Tung, 2011).

The de-horning process takes about 20 minutes. The rhino is darted from a helicopter with an appropriate sedative. The horn is removed as quickly as possible, using a chain-saw. The horn butt is then treated with an antibiotic. This whole procedure is painless to the rhino (Appendix C). An approximate cost of ZAR 7000.00/rhino is associated with the entire procedure (du Plessis, 2012).

3.3.5 Veterinary services

With reference to a personal interview done with a wildlife veterinarian, Dr. DP du Plessis (2012), the annual average veterinary cost would come to ZAR 300/rhino. This amount includes annual de-worming and vaccinations.

3.3.6 Maintenance cost

A daily check of the fence-line needs to be done on foot or by vehicle. With the help of TNH Fencing (2012) it was determined that two labourers would be needed for this duty of two hours per day (the labour cost will be taken into account in paragraph 3.3.8). Furthermore the fence would need to be kept clear of vegetation. This would encompass slashing of grass and spraying twice yearly with herbicides. Electronic equipment such as energisers can be affected by lightning and repair of these should be budgeted for. Average annual infrastructure expense:

$$\text{Herbicide} = \frac{\text{ZAR 2000}}{\text{year}}$$

$$\text{Fence line spares} = \frac{\text{ZAR 150}}{\text{month}} = \frac{\text{ZAR 1800}}{\text{year}}$$

$$\text{Energiser Repairs} = \frac{\text{ZAR 2000}}{6\text{months}} = \frac{\text{ZAR 4000}}{\text{year}}$$

$$\begin{aligned} \therefore \text{Total Maintenance Cost} &= \frac{\text{ZAR 2000}}{\text{year}} + \frac{\text{ZAR 1800}}{\text{year}} + \frac{\text{ZAR 4000}}{\text{year}} \\ &= \text{ZAR 7800/year} \end{aligned}$$

3.3.7 Insurance

One Commercial Investment Holdings Pty Ltd (2012) was approached for calculating insurance attached to the keeping of white rhino. Two cover options

were quoted for. The first option is a 30-day veldt cover option. This option covers only costs associated with the escape of the insured animal due to fire, accidents or in transit. This option amounts to a cost of ZAR 7070/month per rhino. The second option is a 365-day veldt cover. Over and above the escape cover in option one, option two includes limited cover for animal loss due to fire, lightning, storm and flooding. This option only amounts to an annual cost of ZAR 9070/rhino. One Commercial Investment Holdings Pty Ltd recommends option two, especially for long-term cover.

3.3.8 Labour

Bothma et al (2010) state that through experience the preferred labourer: rhino ratio can be assumed as 0.33 labourers. South Africa's Department of Labour (2012) gives a clear standard that a minimum wage of ZAR 1375, 94/month (requirement since 1 March 2011) should be paid to a farm worker, working full-time in the agricultural industry. After consulting with various farmers, an acceptable monthly wage of ZAR 2500/labourer was decided upon for use in the model. Thus the annual labour cost per rhino is calculated as follows:

$$\frac{\text{ZAR 2500}}{\text{month}} \times 12 \text{ months} = \text{ZAR 30000.00 annually}$$

$$\frac{0.33 \text{labourer}}{\text{rhino}} \times \frac{\text{ZAR 30000 annually}}{\text{labourer}} = \frac{\text{ZAR 9900.00}}{\text{rhino}} \text{annually}$$

3.3.9 Habitat requirements

The findings of a study done on the habitat preference of white rhino in the Kruger National Park (Pienaar, 1994) state that white rhino are selective grazers and that the animal concentrates itself around short grass grasslands.

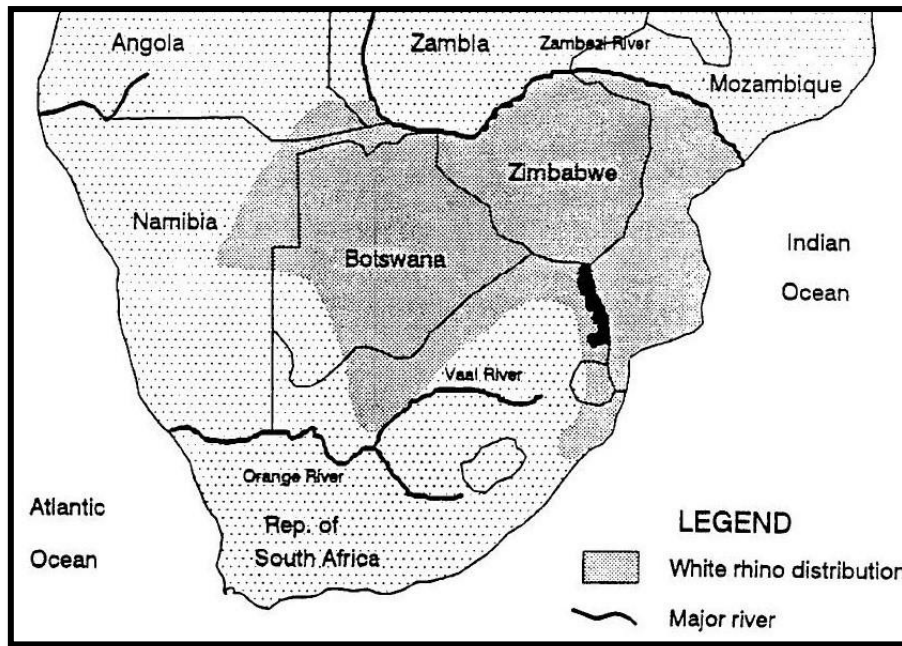


Figure 4- Historical distribution of white rhino in Southern Africa (Joubert, 1983)

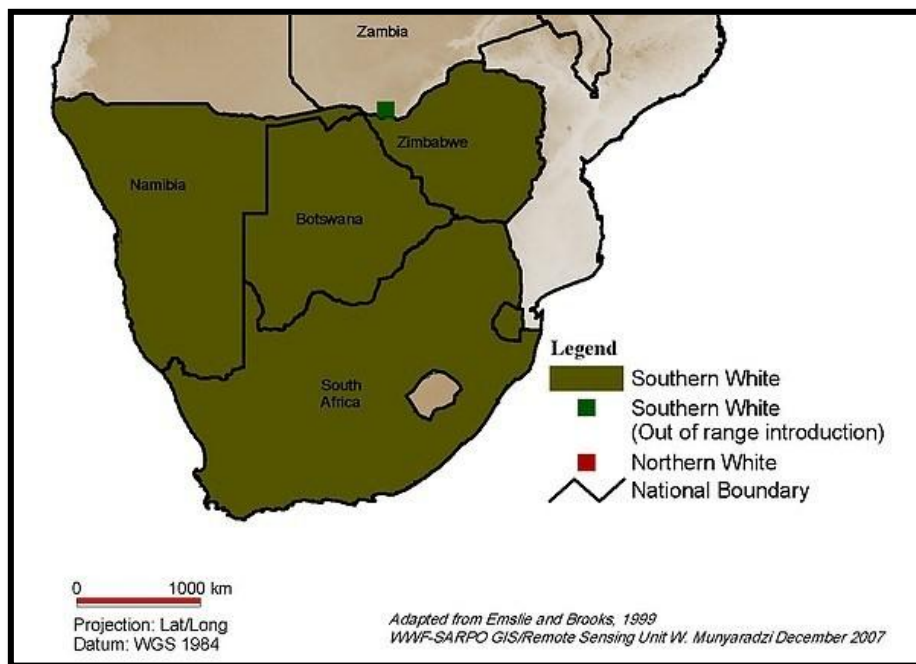


Figure 5- Recent distribution of the white rhino in Southern- Africa (WWF-SAPRO GIS, 2007)

When comparing the white rhino distribution in Southern Africa in Figure 5 with the historical white rhino distribution in Figure 4, it can clearly be seen that the white rhino have significantly dispersed over Southern Africa in the past 24 years. This spread can possibly be attributed to the increase in fenced-in game areas. Fenced-in game is not in a position to be self-reliant. Healthy

farming practices such as supplementation of feed must therefore be applied to counter the potential economic loss of animals.

For the nutrition requirements of the enclosed rhino, Driehoek Feeds (Appendix D) was consulted. The company is recognised as being one of the national leaders in the highly specialised game-feeding industry. Currently, the company caters for the captive white rhino at the *Pretoria Zoological Gardens*. The feed used for the zoo's rhino is the *Driehoek Standard Game Cubes*. However, because an all-in-one feed is required and no additional roughage will be made available to the animals, Driehoek Feeds recommended the *Standard Game Meal* product. The current market value (August 2012) for *Standard Game Meal* is set at ZAR 120/40kg bag. Thus:

$$\frac{\text{ZAR 120}}{40\text{kg}} = \frac{\text{R3}}{\text{kg}} \text{ of Standard Game Meal}$$

Bothma et al (2005) advise that a captive rhino needs to consume 2% of its body weight every day. On average the weight of an adult white rhino is found to be the following (Cillié, 1997, p102):

- White Rhino Adult Bull Weight: 2300 kg

Thus the required daily feed for adult rhino bull:

$$2\% \text{ of body weight} \times 2300\text{kg} = 46\text{kg feed/day}$$

Annual expense of feed for an adult rhino bull:

$$46\text{kg} \times \frac{\text{ZAR 3.00}}{\text{kg}} = \frac{\text{ZAR 138.00}}{\text{day}}$$

$$\frac{\text{ZAR 138.00}}{\text{day}} \times 365 \text{ days in 1 year} = \text{ZAR 50370.00/year}$$

- White Rhino Adult Cow Weight: 1600 kg

Thus the required daily feed for an adult rhino cow:

$$2\% \text{ of body weight} \times 1600\text{kg} = 32\text{kg feed/day}$$

Annual expense of feed for adult rhino cow:

$$\frac{32\text{kg}}{\text{day}} \times \frac{\text{ZAR } 3.00}{\text{kg}} = \frac{\text{ZAR } 96.00}{\text{day}}$$

$$\frac{\text{ZAR } 96.00}{\text{day}} \times 365 \text{ days in 1 year} = \frac{\text{ZAR } 35040.00}{\text{year}}$$

Additional to nutrition, the rhino also has a minimum water requirement. The authors of *Intensive Wildlife Production in Southern Africa* (2005) recommend a sufficient open water source to be available, since the animal is quite water dependent. An estimation of 72ℓ/day is required per adult rhino. For the purpose of the project, an assumption will be made that borehole water is freely available.

3.3.10 Inflation

Inflation is a general rise in the amount of money necessary to obtain the same amount of product or service before the inflated price was present (Blank and Tarquin, 2008). The Reserve Bank of South Africa calculates the inflation rate on a monthly basis. Owing to the fact that the investigation period is set to ten-time periods, the profit made in time period ten will need to be inflated to time period zero. This is done to give the prospective farmer a realistic capital figure at time period ten. However, expenses over the ten years will have also been influenced by inflation. Currently, the inflation rate is set at an average of 5% (South African Reserve Bank, 2012). This rate will be used in the model formulation.

3.4 Biological Factors

3.4.1 Enclosure density

As mentioned in paragraph 3.3.1, a 400ha enclosure will be examined. Information captured on the questionnaire (Appendix A), from the North West intensive rhino farm, designates 20 rhino to a 400ha enclosure.

‘The size of the founder population of white rhino is an important factor when establishing a new population’ (Bothma et al, 2005). It is suggested that the minimum starting herd size should be at least six animals. This herd should

consist of one dominant bull, one sub-adult bull, two adult cows and two sub-adult cows.

3.4.2 Reproduction

White rhino breed well on smaller game ranches, until breeding bull numbers reach saturation level and fighting starts, resulting in mortalities. White rhino do not have a particular mating season. This fact contributes to facilitate the intensive farming of the animal. Gestation period for a white rhino cow is 16 months. However, for model purposes, an inter-calving period of two years will be used (Bothma et al, 2005).

A white rhino cow reaches sexual maturity at the age of seven and can reproduce up to the life expectancy age of 40 years. Through experimental research it has been established that a white rhino cow on average can produce up to 14 calves in her expected lifespan (Bothma et al, 2005).

In an enclosure of 400ha, one adult rhino bull is required for breeding purposes and one sub-adult bull to stimulate breeding. Getting rid of surplus bulls will generate income for the rhino farmer and help with genetic management.

For the calculation of the number of calves born each year, an assumption is made that half of the rhino cows in the analysed herd will be sexually mature. For example, if you have eight rhino cows in year t , the number of sexually mature cows will be four. Each of these four cows can deliver half a calf each year, thus the total number of calves at the end of a year t will be two.

3.4.3 Mortality

The mortality rate of a white rhino calf, in an intensive breeding scheme, is estimated to be 10% (Hume, 2012). This percentage decreases significantly with age and adult white rhino have on average a mere 2% mortality rate (Bothma et al, 2005).

3.5 Chapter Summary

In this chapter it was determined that biological factors and financial factors will contribute to the model formulation. Table 1 summarizes the factors discussed.

Table 1-Summary of input factors for a 400ha enclosure

Year t		
Factors		
Available Land (ha)	400	ha
Enclosure Capacity	20	rhino
Maximum number of calves	10	calves
Infrastructure	547200	ZAR/once off
Starting number of rhino bulls	2	rhino
Starting number of rhino cows	8	rhino
Bull-Rhino Value (Buy)	199794	ZAR/rhino
Cow-Rhino Value (Buy)	199794	ZAR/rhino
Bull-Rhino Value (Sell)	185808.42	ZAR/rhino
Cow-Rhino Value (Sell)	185808.42	ZAR/rhino
Auction Deduction for selling	7.00%	%
Horn Cost	210000	ZAR/kg of feed
Maintenance on Infrastructure	7800	ZAR/annum
Average weight of rhino cow	1600	kg
Average weight of rhino bull	2300	kg
Cost of Feed	3	ZAR/kg of feed
Cow Feed	35040	ZAR/rhino cow/annum
Bull Feed	50370	ZAR/rhino bull/annum
Labour	9900	ZAR/rhino
Insurance	9070	ZAR/rhino
Dehorning Procedure	7000	ZAR/rhino
Veterinary Cost	300	ZAR/rhino
Inflation	5.00%	%
Mortality Rate Calf	10.00%	%

The factors in Table 1 will be used as input to the mathematical model formulated in the next chapter.

4 MODEL FORMULATION

In this chapter a dynamic recursive programming model is used to formulate a suitable production strategy for an intensive white rhino farm. As discussed in the literature review, a dynamic recursive programming model is an outflow of the classic LP model. Dynamic recursive models optimise over the whole period, while explicitly taking into account the interactions across the years. This aids the user of the model to make decisions at every time period. The set, variables, objective function, assumptions and constraints that will be used in the model are set out below.

4.1 Sets

T = set of time periods in years, $t \in \{1, 10\}$

S = set for distinction of white rhino sex $\{1=\text{Bull}, 2=\text{Cow}\}$

4.2 Decision Variables

In any LP the decision variables should completely describe the decisions to be made. Keeping the aim of this project in mind, the decisions to be made includes the following:

$\text{Buy}W_{ts}$ = White rhino bought during time $t \in T$, from sex $s \in S$ (4.1)

SW_{ts} = White rhino sold during time $t \in T$, from sex $s \in S$ (4.2)

Totkg_{ts} = Horn harvested (kg) during time $t \in T$, from sex $s \in S$ (4.3)

$\text{Beg}CW_{ts}$ = Offspring from rhino cows already on farm, during time $t \in T$,
with sex $s \in S$ (4.4)

$\text{Buy}CW_{ts}$ = Offspring from rhino cows bought, during time $t \in T$, with sex $s \in S$ (4.5)

4.2.1 Rhino trade

The farmer will require a clear indication on how to manage the trade process on the farm. The decision variables 4.1 and 4.2, of buying and

selling of white rhino will be the focal point when it comes to optimising the net present value of an intensive white rhino farm. Surplus rhino will be sold, whilst new bloodlines will be bought to promote genetic management of the species.

4.2.2 Rhino horn harvesting

Once the trade in rhino horn has been legalised, harvested horn will be supplied for the escalating demand in Yemen and the Middle East. The quantity of horn, in kilogram, that needs to be harvested from the farm per year should be determined (4.3).

4.2.3 Rhino breeding

The propagation of the species on the farm is essential for the success of the farm. Results from the model would need to give a target quantity of rhino that need to be bred per year (4.4 and 4.5).

4.3 Objective Function

‘In most LP models, there will be a function we wish to maximise or minimise’ (Winston and Venkataramanan, 2003). This function encompasses the objective of the problem. The function incorporates the decision variables and constraints of the model to deliver an optimal result.

In the literature by Qingzhen et al (1991), an optimal production plan for crops and livestock in Chan Qing Country, China was developed. The aim of the production plan was to increase the net profit. The author’s strategy was implemented for the calculation of an optimal production strategy for the intensive white rhino farm. The annual net present value (NPV) of the farm will need to be maximised. The maximum NPV of the farm for time period t is calculated below:

$$f_t = \max_t (R_t - E_t) \left(1 + \frac{i}{100}\right)^n$$

Where:

f_t = The NPV for time period t;

R_t = Total revenue made in time period t from white rhino sold and harvested horn;

E_t = Total expenses for time period t involved in intensively farming with white rhino;

t = Time period in years; and

i = Inflation rate

4.4 Model Assumptions

4.4.1 Land

For the purpose of the model analysis, a single 400ha piece of agricultural land will be looked at. Owing to the unavailability of reliable farmland prices in South Africa, a 400ha area will be assumed available to the farmer without any extra capital expense. This may narrow the analysis down to only include existing farmland owners.

4.4.2 Trade

Owing to the fact that trade will not only take place in terms of live animals, but also in terms of harvested rhino horn, a clear differentiation should be made to set these animals apart. With rhino horn harvesting seen as a fairly new venture, the assumption to put more rhino up for trade than for horn harvesting is made. Thus, 60% of the total population could be utilised for trade, whilst the remaining 40% may be utilised for horn harvesting purposes.

Furthermore, in year 1 no trade of live animals or horn takes place. This assumption is made to give the farmer and the animals a one-year period to become acquainted with the set up.

4.4.3 Inflation

The current inflation rate of 5% is used in the determination of the profit function. For the time period of ten years, this rate is assumed to stay constant.

4.4.4 Capital availability

The model does not take into account interest on loaned money to start the enclosure.

4.4.5 Continuity

The assumption is made that all input factors, biological and financial, remain constant over the analysed period of ten years.

4.5 Constraints

The constraints in the model are factors that have a direct relationship with the model's objective function. The model is subjected to the following constraints set out in the table below.

Table 2-Model constraints

Constraint Equations				
	<u>Sign Convention</u>			<u>Equation</u>
Ha_t	\leq	400	$\forall t \in T$	4.5.1
$BegW_{11}$	$=$	2		4.5.2a
$BegW_{12}$	$=$	8		4.5.2b
$BegW_{t2}$	$=$	$4BegCW_{t1}$	$\forall t \in [2,10]$	4.5.3a
$BegW_{t2}$	$=$	$4BegCW_{t2}$	$\forall t \in [2,10]$	4.5.3b
$BuyW_{t2}$	$=$	$4BuyCW_{t1}$	$\forall t \in [2,10]$	4.5.3c
$BuyW_{t2}$	$=$	$4BuyCW_{t2}$	$\forall t \in [2,10]$	4.5.3d
$Totkg_t$	$=$	$0.4(1BegW_{t1}+0.6BegW_{t2}+BuyW_{t1}+0.6BuyW_{t2})$	$\forall t \in [2,10]$	4.5.4
$\sum_{s=1}^2 SW_{ts}$	$=$	$\sum_{s=1}^2 0.6(BegCW_{ts} + BegW_{ts} + BuyW_{ts} + BuyCW_{ts})$	$\forall t \in [2,10]$	4.5.5
$EndBW_{t1}$	\geq	BW_{01}	$\forall t \in T$	4.5.6a
$EndBW_{t2}$	\geq	BW_{02}	$\forall t \in T$	4.5.6b
$EndW_{ts}$	$=$	$BegW_{t+1,s}$	$\forall t \in T$	4.5.7
$\sum_{s=1}^2 ENBW_{ts}$	$=$	20	$\forall t \in T, s \in S$	4.5.8

Where:

Table 3-Definition of variables

Variables	
Ha_t	: farmland available (ha)
$BegW_{11}$: year 1 starting rhino bull count
$BegW_{12}$: year 1 starting rhino cow count
$BegW_{t2}$: rhino bull count at the beginning of year t
$BegCW_{t1}$: Offspring bull calves from $BegW_{t2}$, in year t
$BegCW_{t2}$: Offspring cow calves from $BegW_{t3}$, in year t
$BuyW_{t2}$: rhino cows bought in year t
$BuyCW_{t1}$: Offspring bull calves from $BuyW_{t2}$, in year t
$BuyCW_{t2}$: Offspring cow calves from $BuyW_{t2}$, in year t
$Totkg_t$: Weight (kg) of harvested rhino horn, in year t
SW_t	: Total number of rhino sold in year t and sex s
$EndBW_{t1}$: rhino bull count at the end of year t
$EndBW_{t2}$: rhino cow count at the end of year t
$EndW_t$: ending rhino count in enclosure

For the purpose of the project, a single 400ha enclosure was optimised. In Table 2-equation 4.5.1, a limitation on available land is set to an area not larger than 400ha.

In year one the starting herd size will be taken as two bulls and eight cows (4.5.2a and 4.5.2b). This herd size stays in line with the optimal relationship of one bull for every four cows. However, from research, only one bull and four cows from the starting herd will be sexually mature, the remaining will be sub-adults.

As previously mentioned, a rhino cow requires a period of two years between subsequent calves. In mathematical terms, a rhino cow is able to deliver half a calf annually. For modelling purposes it is assumed that half of the rhino cows in the herd are sexually mature. Equations 4.5.3a to 4.5.3d state that within year t, half of the rhino cows in the herd will deliver half a calf.

Annually a rhino bull can produce a mean horn mass of 1kg, whilst a rhino cow can produce 0.6kg. Earlier in the report an assumption was made that 40% of the adult rhino in the enclosure will be made available for horn harvesting. Equation 4.5.4 enforces this constraint on the model.

Equation 4.5.5 computes the number of rhino to be sold within a given year, taking into account that only 60% of the rhino can be put up for sale in that year.

To prohibit the model from just selling all the rhino and leaving the farmer with zero rhino, a constraint is added that forces the quantity of rhino at the end of each year to be greater or equal to the rhino at the start of that year (4.5.6a and 4.5.6b).

As a result of the constructed model being a dynamic recursive model, equation 4.5.7 links model result in year t with model results in year $t+1$, $\forall t \in T$.

The 400ha enclosure has a capacity of 20 rhino in total. In Table 4 the sex ratios within the enclosure are set out.

Table 4-400ha enclosure white rhino capacity and sex ratios

White Rhino	Count (rhino)
Bull	2
Cow	8
Calve	10

Finally, equation 4.5.8 restricts the total number of rhino within the enclosure, in year t , from exceeding 20.

4.6 Software

The software used for the purpose of solving the dynamic recursive model is Haverly Systems Linear Programming (HSSLP) package¹. The software is seen as very user friendly and ideal for solving smaller complex linear problems. Unfortunately, the software package has a minor incapability of presenting the outputs as whole numbers.

The software employs a matrix as input (Table 8 in Appendix E). The first row of the matrix contains the objective function, whilst the remaining rows contain the constraints of the model.

¹ Access to the software was made available by Large Scale Linear Programming Solutions

4.7 Model Results

The objective of the model was to calculate a strategic production plan for an intensive white rhino farmer, while maximising the annual NPV. Table 5 summarises the optimal production plan and Figure 6 displays a potential annual NPV value associated with the optimal production strategy for that year. Table 9 and Table 10 in Appendix F give a more detailed view of the software output and potential NPV values. These results were captured from the HSSLP dynamic recursive model.

Table 5-HSSLP model results: production plan

Year t	Beginning of year (BegWts)		Beginning Offspring (BegCWts)		Purchased in year t (BuyWts)		Purchased' Offspring (BuyCWts)		Sell in year t (SWts)		Total offspring in year t (TOTCt)	Harvested Horn (TOTkgt)	Inventory Year Ending (BegWt+1,s)	
	Bull	Cow	Bull	Cow	Bull	Cow	Bull	Cow	Bull	Cow	Calves	kilogram	Bull	Cow
1	2.00	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	8.00
2	2.00	8.00	2.00	2.00	2.49	9.98	2.49	2.49	3.20	8.26	8.09	6.112360	5.34	13.76
3	5.34	13.76	3.00	3.00	0.79	3.15	0.79	0.79	3.72	7.77	7.61	6.508616	6.21	12.95
4	6.21	12.95	3.00	3.00	0.84	3.36	0.84	0.84	4.02	7.49	7.34	6.732798	6.70	12.49
5	6.70	12.49	3.00	3.00	0.87	3.48	0.87	0.87	4.19	7.34	7.19	6.859628	6.98	12.23
6	6.98	12.23	3.00	3.00	0.89	3.55	0.89	0.89	4.28	7.25	7.10	6.931382	7.13	12.08
7	7.13	12.08	3.00	3.00	0.46	1.83	0.46	0.46	4.02	6.39	6.26	6.372991	6.70	10.65
8	6.70	10.65	3.00	3.00	1.00	4.00	1.00	1.00	4.12	6.73	6.59	6.594570	6.87	11.21
9	6.87	11.21	3.00	3.00	1.00	4.00	1.00	1.00	4.24	6.99	6.85	6.799748	7.06	11.65
10	7.06	11.65	3.00	3.00	1.00	4.00	1.00	1.00	4.34	7.19	7.04	6.979045	7.24	11.98
11	7.24	11.98												

From the model outputs in Table 5, it is clear that all the decision variables have annual values allocated to them.

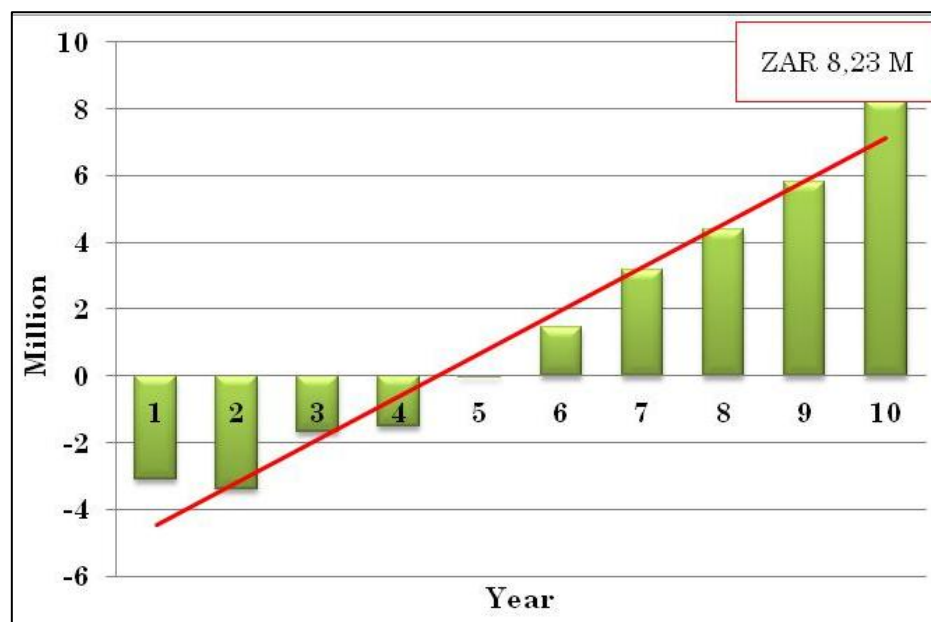


Figure 6- Potential NPV growth before inflation

Figure 6 shows a steady increase in the potential NPV of the analysed enclosure over a ten-year period. In year 1 the assumption was made to not trade with rhino or harvested horn. Trade in rhino and harvested horn starts from year 2. This may explain the further loss in year 2, due to the fact that the dynamic mathematical model tries to fill the enclosure to its capacity of 20. In year 5 the break-even point is reached. Furthermore, between year 7 and year 8 the optimised enclosure has made 100% profit. At the end of year 10 the model gives a potential NPV of ZAR 8, 23M.

Table 6-Capital expenditure in year 1

Income Statement Year 1			
Revenue			
	Unit Cost	Units	
Gross live bull sales	185808.42	0	0
Gross live cow sales	185808.42	0	0
Gross harvested horn sales	210000.00	0	0
			0.00
Expenses			
Infrastructure	-547200.00	1	-547200.00
Maintenance	-7800.00	1	-7800.00
White rhino bull	-199794.00	2	-399588.00
White rhino cow	-199794.00	8	-1598352.00
Rhino bull feed	-50370.00	2	-100740.00
Rhino Cow Feed	-35040.00	8	-280320.00
Rhino Insurance	-9070.00	10	-90700.00
Rhino Vet	-300.00	10	-3000.00
Labour	-9900.00	10	-99000.00
Total Expenses			-3126700.00
Net Operating Income			-3126700.00
Net Income (loss)			-ZAR 3,126,700.00

Table 6 gives a representation of the farms income statement for year 1. The net income loss of ZAR 3,126,700.00 in year 1 denotes the total amount of capital needed to begin this farm, before intensive breeding can start.

To make the assumption that the intensive rhino farm is feasible due to a positive NPV after ten years might be farfetched. In Appendix G, a simple calculation is done to compare a capital investment with an intensive white rhino farm investment. The initial capital expenditure for year 1 (Table 6) is invested for a ten-year period. This calculation gives a future value of ZAR 5,

093064.83, if the current repo rate of 5% is used (South African Reserve Bank, 2012). Comparing this investment output value to the constructed models output value (ZAR 5, 093064.83 against ZAR 8, 237736.84), it is clear that the intensive rhino farm investment yields a much larger return than the bank investment over the ten years.

4.8 Model Validation through Sensitivity Analysis

Sensitivity analysis is defined as the process of altering key model inputs to determine their effect on the outputs (Evans, 2010). In the analysed model, inputs such as the trade price in live rhino and harvested rhino horn are influenced by the economic principle of supply and demand. Damania and Bulte (2006) make it clear that additional supply of wildlife products from intensive farming initiatives decreases the price of the wildlife products. Unfortunately, the price effect of an increase in the supply of rhino horn is difficult to determine, due to unavailability of reliable rhino horn demand data. For this reason, various horn trade price scenarios are investigated and results are given below.

Table 7-Potential NPVs for possible horn price scenarios

Possible Scenario	White rhino price (ZAR)	Rhino horn price (ZAR)	Potential 10year NPV (ZAR M)	10year NPV as a % of set up cost (-ZAR 3,126,700.00)
1	200000	50000	0.261	8%
2	200000	100000	2.82	90%
3	200000	150000	5.59	179%
4	200000	200000	8.47	271%
5	200000	250000	11.37	364%
6	200000	300000	14.37	460%

It is clear from Table 7 that all the proposed scenarios give a positive NPV. However, in scenario 1 the enclosure makes a mere 8% profit after ten years. In scenario 2, the NPV after ten years approaches 100%, which can be seen as a more successful scenario. Scenario 3 through to 6 calculates the 400ha enclosure to make more than 100% back on the initial investment of -ZAR 3,126,700.00.

4.9 Chapter Summary

In this chapter a dynamic recursive LP model was constructed to give a feasible optimal production strategy for an intensive commercial white rhino farm. This

model not only took live rhino trade into consideration, but also incorporated a rhino horn harvesting plan. In addition the model calculated a potential NPV after ten years. The next chapter concludes the dissertation by giving recommendations and looking into future work.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Recommendations and Future Work

The dissertation provided a potential optimal production strategy for a 400ha intensive white rhino enclosure. However, the mathematical model was constructed on constant estimated values. To improve the accuracy of the developed model and certify results, it is recommended that in-depth cost sourcing be done. This will also ensure that the model is fully utilised.

Owing to the fact that this model only investigates the financial feasibility of a 400ha enclosure by calculating an optimal production plan, a business-engineering approach can be performed, in the future, to include a feasible business plan for the farm as a whole. This approach will need to include thorough market research, marketing plan, demand planning, operations and legal requirements of such a potential farm.

In the future the model could also be refined to include annual capital loan repayment for a prospective farmer.

5.2 Conclusions

The aim of this dissertation was to develop a strategic optimal production plan for an intensive white rhino farm, by incorporating a mathematical model. The project analysed a single 400ha enclosure with a maximum capacity of 20 white rhino.

The dynamic recursive model was constructed for a ten-year period, maximising the NPV of such an enclosure. The results conveyed a feasible financial solution over the ten-year period. Compared to a capital investment option, the intensive white rhino farm still delivered a higher NPV than the capital investment. Nevertheless, because the input capital needed for this intensive farm is quite a large amount (ZAR 3, 126700.00) the success of such a farm also depends on the financial state of the prospective farmer.

This model can be viewed as a future endeavour, since it is dependent on the legalisation of the rhino horn trade. However, the model signifies the definite

probability to intensively farm with white rhino successfully and possibly halt the poaching of the beautiful creature.

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Glossary

ADULT RHINO A white rhino is classified as an adult from the age of seven.

ANTERIOR HORN The white rhino horn at the front of the animal's head.

BLACK MARKET An illegal traffic or trade in officially controlled or scarce commodities

BOMA A small type of camp, especially for animals used in eastern and southern Africa.

CITES APPENDIX I Includes species threatened with extinction. Trade in specimens of these species is permitted only in exceptional circumstances.

CITES APPENDIX II Includes species not necessarily threatened with extinction, but in which trade must be controlled in order to avoid utilisation incompatible with their survival.

ENCLOSURE A larger area surrounded by barriers.

GESTATION PERIOD The period of the foetus developing inside the womb, between conception and birth.

INTER-CALVING PERIOD An average period between subsequent calves.

POSTERIOR HORN The white rhino horn sitting more to the back of the animal's head.

SUB ADULT A sub-adult white rhino is classified as being between the ages of three and seven years.

APPENDIX A: QUESTIONNAIRE TO MR. J HUME (6 JUNE 2012)

1. Are rhino farmed intensively or extensively at North West, or are both used?

Intensive

2. Are the rhino kept in a boma or a hectare plus enclosure?

They are kept in camps/enclosures.

3. What is the size of such a boma/enclosure (Ha or m2)?

400 hectares

4. How many rhino per boma/enclosure?

About 20.

5. What is the ideal sex ratio and age of the rhino in such a boma/enclosure?

2 males, one of them a younger bull, about 8 or 9 adult females and the rest being calves.

6. How many water and feeding points does such a boma/enclosure have?

Various

7. Up to what age can one intensively farm with a rhino? Does this differ across sex?

Throughout its life so about 35 to 40 years. Horn growth rate differs between sexes, yes. A male rhino will produce about 1kg of horn a year and a female about 0,6kg per year.

8. After the period for intensive farming has elapsed, what happens to these "old" rhino?

Rhino horn continues to grow throughout the animal's life so there is not really a 'lifespan' or time limit on horn farming.

9. What happens with surplus rhino, young and old?

We keep them.

10. How often does the North West bring in new genetic material?

When necessary

11. With concern to intensive farming, what is the mortality rate of calves?

1 in 10

12. How much horn can be harvested? (I read that 2/3 can be harvested at a time (Rhino Ranching by Dr. JG du Toit?))

One per rhino every 3-4 years. If you are referring to a per day figure, the dehorning process is about a 20-minute procedure, so in an intensive situation, you can dehorn as many rhino as may need dehorning. Up to 16 have been done in one day.

13. I have researched horn growth and a rough growth figure of 1kg/year seems to be the norm. From experience would you agree?

Yes, for males. For females, about 0,6kg/year. One rhino can produce about 6-8 horns in its lifetime

APPENDIX B: AVERAGE RHINO TRADE PRICES (SA Game & Hunt Magazine, 2012, p19)

Tendense van lewende wildverkope 2011

Dr Filippie Cloete
Eenhed vir Omgewingswetenskappe en Bestuur,
Noordwes-Universiteit, Potchefstroom-kampus

Die gemiddelde pryse vir 2011 is verteenwoordigend van 55 amptelike wildveilinge wat gedurende die jaar in die onderskeie provinsies aangebied is. Die pryse weerspieël 'n verteenwoordigende of verwysingsprys vir elke spesie.

Vergeleke met die vorige jare, het wildveilingpryse van die meeste spesies geen merkwaardige fluktuasies getoon nie. Die klein pryverskille, op of af, kan hoofsaaklik toegeskryf word aan die aantal, geslag, ouderdom en samestelling van die lot wat tydens veilinge verkoop is. Byvoorbeeld, die gemiddelde prys vir volwasse elandbulle wat tydens amptelike wildveilinge gedurende 2011 verkoop is, het 'n beraamde R10 904 per dier behaal, wat soortgelyk is aan pryse wat in 2010 behaal is. Die prys van volwasse elandkoeie het egter 'n bietjie gedaal tot R5 598 per dier, met teeltrope en jong bulle wat gemiddelde pryse van R5 343 en R5 000 onderskeidelik per dier behaal het. Gesamentlik het dit gelei tot 'n 6,1%-daling in die gemiddelde prys vir elande vergeleke met 2010 (kyk Tabel 1). 'n Soortgelyke situasie geld vir ander meer algemene spesies, soos blesbokke met 'n 11%-daling, koeoedoes (-6%), waterbok (-18,1%) en bontebokke met 'n 10,4%-daling in gemiddelde prys vergeleke met 2010.

In teenstelling hiermee het veral kleurvariasies van die meer algemene spesies merkwaardige prysfluktuasies (>R1 000) in gemiddelde pryse getoon. Dit sluit onder meer blouwildebees-*splits*, goue gemsbokke, goue blouwildebeeste, wit koeoedoes, asook swart en swartgrug-rooibokke in. Die gemiddelde prys van blouwildebees-*splits* is misleidend en kan toegeskryf word aan die status, bv F1, F2 of F3, van die diere asook die aansienlike pryverskille wat daarmee gepaard gaan. Pryse vir blouwildebees-*splits* het gewissel tussen R2 900 en soveel as R240 000 per dier. Die gemiddelde prys vir blouwildebees-*splits* gedurende 2011 beloop egter 'n geraamde R23 221.

Die aansienlike toename in die prys van goue wildebeeste en swart rooibokke is te danke aan 'n oplewing in die vraag na hierdie diere, met die hoëste aangebied op amptelike wildveilinge wat met 13,4% en 86% onderskeidelik toegeneem het. Ten spyte van die aansienlike toename in aanbod, het die gemiddelde prys van goue blouwildebeeste byna verdubbel en dié van swart rooibokke met ongeveer R27 000 per dier toegeneem. Die gemiddelde prys van swartgrug-rooibokke kan hoofsaaklik toegeskryf word aan die pryse wat gedurende September 2011 op 'n veiling in Limpopo behaal is. By die bepaalde veiling is pryse van R500 000 vir vroulike en R590 000 vir 'n volwasse ram onderskeidelik behaal. Die gemiddelde prys van wit koeoedoes kan toegeskryf word aan 'n volwasse bul wat verkoop is vir R860 000.

Kleurvariasies wat die eerste keer op amptelike wildveilinge



4 Dogers Boertryf

ings verhandel het, sluit in rooi blesbokke en bruin koeoedoes. Altesaam vier rooi blesbokkrame is gedurende 2011 teen 'n gemiddelde prys van R8 500 stuk verhandel, met 'n bruin koeoedobul wat teen R320 000 verkoop is (sien Tabel 1).

Tabel 1: Gemiddelde Wildveilingpryse 2009 tot 2011

Wildspesie	GEMIDDELTE WILDSVEILINGSPRyse		
	2009 45 Veilings R	2010 56 Veilings R	2011 55 Veilings R
Bastergemsbok	62 993	67 178	108 219
Basterhartbees	11 280	12 127	11 832
Blesbok – wit	1 785	1 615	1 294
Blesbok – gewoon	1 328	1 262	1 122
Blesbok – geel	3 418	9 500	8 666
Blesbok – rooi			8 500
Blouwildebees	2 439	2 374	2 907
Blouwildebees – splits			23,221
Bontebok	5 500	4 000	3 583
Bosbok	4 057	2 557	4 123
Buffel – skoon	246 878	325 282	510 225
Buffel – water	27 500	35 000	
Buffel – Oos-Afrika			986 812
Bosvark			400
Dassie			500
Duiker – grysb	1 183	811	2 790
Duiker – blou			10,000
Eland – gewoon	6 879	7 153	6 711
Eland – livingstone	15 191	20 396	39 686
Emoe	1 875	707	400
Gemsbok	4,762	4 757	4 934
Gemsbok – goue			355,000
Goue blouwildebees	197 149	265 312	459 416
Jagluiperd	50 000	67 292	25 000
Kameel	19 578		14 187
Kameelperd	13 647	18 264	10,000
Klipspringer			5 089
Koeoedoe – gewoon	4 894	5 417	860 000
Koeoedoe – wit			320 000
Koeoedoe – bruin			
Kuilkooparentale	1 000		
Lama	1 300		
Lichtensteins hartbees	100 000		140 000
Letsjwe	10 175	10 369	8 625



Piet du Toit Wildbedryf



Die positiewe toename in die gemiddelde veilingpryse vir siektervrybuffels is gedurende 2011 volgehou. Volwasse vroulike diere het egter 'n afname getoon in gemiddelde pryse van R373 898 tot R353 738. Buffelverse het 'n gemiddelde prys van R502 142 per dier gehaal, met 'n gemiddelde prys van R903 571 vir diere wat as deel van 'n teeltroppe aangebied is. Die gemiddelde prys van teeltrope is positief beïnvloed deur die aantal dragtige asook vroulike diere met kalwers wat verkoop is. Die veilingpryse vir teeltrope het gewissel van R175 000 tot R2,6 miljoen per dier. Die gemiddelde veilingprys van volwasse buffelbulle het ook aansienlik toegeneem van R276 725 in 2010 tot R684 932 in 2011. Die toename in die gemiddelde prys van buffelbulle kan deels toegeskryf word aan pryse wat tydens die Thaba Tholo-veiling in Limpopo behaal is, waar 16 bulle teen 'n gemiddelde prys van R1,5 miljoen stuk verkoop is. Tydens dieselfde veiling is 'n nuwe SA-rekord behaal met 'n buffelbul wat vir R18 miljoen verkoop is. Die gemiddelde prys van jong buffelbulle gedurende 2011 beloop R106 740 per dier.

Die gemiddelde prys van swartwitpens het dieselfde tendens as dié van buffels gevolg. Vergeleke met 2010, het die gemiddelde prys van swartwitpens met 29,2% of R34 391 toegeneem tot 'n gemiddelde van R152 122

Wildspesie	GEMIDDELTE WILDSVEILINGSPRyse		
	2009 45 Veilings R	2010 56 Veilings R	2011 55 Veilings R
Leeu – gewoon	28 469		64 025
Njala	7 455	6 979	6 809
Rietbok	4 218	4 650	5 000
Rooibok – gewoon	1 099	1 122	1 160
Rooibok – swart	53 412	102 672	129 809
Rooibok – swartgrug			355 000
Rooibok – splits	6 597		8 000
Rooihartbees	4 409	3 971	4 314
Rooiribbok	1 910	3 097	2 857
Rooikat	2 375		
Sebra – vlakke	5 248	4 550	4 826
Sebra – Hartmann	16 688	12 250	10 127
Sebra – berg	17 750		
Seekoei		43 144	48 125
Saenle	5 511		
Springbok – gewoon	866	980	1 392
Springbok – hartwater	4 065	7 598	8 952
Springbok – swart	2 001	1 535	1 974
Springbok – wit	3 952	3 525	3 825
Springbok – koper	6 406	5 682	5 226
Springbok – Kalahari	1,553		2,486
Steenbok	1 761	5 012	4 438
Swartwildebees	2 435	2 154	2 970
Swartwitpens	121 827	117 731	152 122
Swartwitpens – Zambies			419 167
Sahelgembok (<i>scimitar</i>)			7 550
Talchok – <i>fallow deer</i>	2 500	2 286	4 350
Talchok – <i>red deer</i>			6,600
Vlakvark	1 133	710	1 306
Vaalribbok		2,000	
Vultruis	1 285	1 297	2 619
Waterbok	6 006	6 269	5 130
Wildebeest	1 012		
Witrenoster	220 064	223 099	199 794



Vervolg op bladsy 21

Thabha Thabo



APPENDIX C: REPRESENTATION OF A DEHORNING PROCEDURE

(Rhino Dot Com, 2012)

A dehorning procedure

Some game farmers and private reserve owners have resorted to dehorning their rhinos to protect them from poachers. The dehorning process is painless to the rhino as their horns are composed primarily of keratin and they do not have a bony core. If horns can be removed painlessly from rhino, we have to wonder why these magnificent animals are dying every day to provide it.



1. The rhino is darted with anaesthetic by a vet



2. The sedated rhino is blind-folded to reduce stress levels.



3. The horns are measured for growth point location.



4. The horns are cut off with a reciprocal saw



5. The dehorned rhino. Blood and horn samples are collected



6. The vet administers a drug to wake the rhino up



7. The rhino is awake and back with other rhinos within minutes



8. The horns are measured again, weighed and micro-chipped.

APPENDIX D: DRIEHOEK FEEDS

(Driehoek Feeds, 2012)

ABOUT US

ABOUT US

Manufacturing our products in the heart of the Waterberg, **Driehoek Feeds** has more than 20 years experience in the milling trade. Years of experience, the stringent quality control of raw materials and a proactive attitude to the latest research has seen **Driehoek Feeds** successfully develop a range of products for most animal types which is respected throughout the Limpopo Province.

Together with a committed team of expert nutritionists and experienced staff, **Driehoek Feeds** has become a leader in the Game Feed industry and produces a range of speciality products catering for needs as diverse as those of elephants used for safaris through to the intensive breeding programs of rare species such as sable, roan antelope and buffalo.

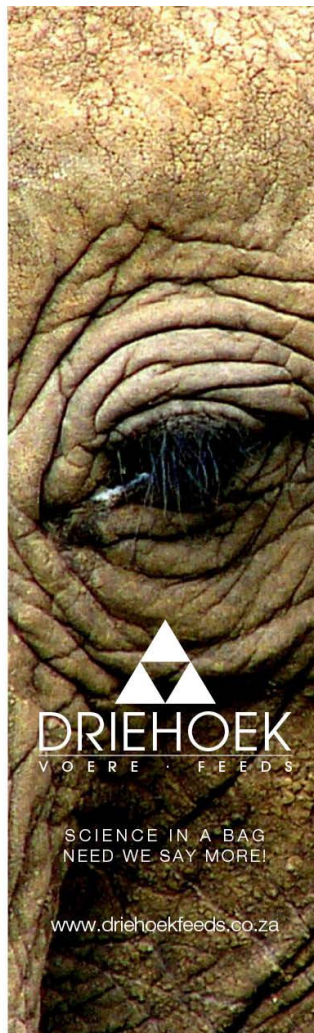
Constantly innovative, we pride ourselves on the continual incorporation of new technology in our feed. Only top quality raw materials are channelled to the Game section of the Feed Mill and we are proud to present a very comprehensive range of scientifically formulated products more natural and wholesome than the market standard.



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		Breeding Muesli	Std Game Cubes	Boma Feed	Game Lick	Elephant Cubes	Lucerne Cubes
Protein	g/kg	150	100	120	150	140	150
Fat	g/kg	25	25	25		25	
Fibre (min)	g/kg	140	140	140		180	200
Fibre (max)	g/kg	200	200	200	80	240	250
Calcium (min)	g/kg	7	6	7	15	6	4.5
Calcium (max)	g/kg	10	8	10	20	8	7
Phosphorus	g/kg	4.5	3	3	10	4	3
Sodium	g/kg	4	2.5	2.5		4	
Magnesium	g/kg	3	2.4	2.6	5	3	
ADF (min)	g/kg					280	
Vitamin A	IU/kg	10000	7000	3500	8000	8000	5000
Vitamin E	mg/kg	50	44	31	40	100	30
B1	mg/kg	5.5	5	4.5		9	
Biotin	mg/kg	0.4		0.3			
Manganese	mg/kg	70	70	62	120	52	
Zinc	mg/kg	82	79	59	150	115	
Organic Zinc	mg/kg	3.3					
Copper	mg/kg	20	20	17	37	35	
Iodine	mg/kg	3.1	3	1.6	5	1.1	
Cobalt	mg/kg	1.2	1.2	0.6	2.5		
Ferrous	mg/kg	182	182	177	190	250	
Selenium	mg/kg	1.1	0.8	0.6	2.25	0.6	
Org.Selen.	mg/kg	0.5	0.2	0.1	1		



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APPENDIX E: MODEL FORMULATION

Table 8- Input matrix for HSSLP software

HAVERLY SYSTEMS INC. SPREADSHEET LP (H/SLLP) Version 2 Copyright @ 1997		BegW t-1,1	BegW t-1,2	BegCW t-1,1	BegCW t-1,2	BuyCW t,1	BuyCW t,2	BuyW t,1	BuyW t,2	EndW t,1	EndW t,2	EndTOT t	TOTKgt	TkgBW t,1	TkgBW t,2	TOTC t	TOTW t,2	TOTW t,1	SW t,1	SW t,2	TOTSW t	Ha t	Feed t,1	Feed t,2	Labour t	Insur t	Dehorn t	Vet t
Row 1	Profit t =	-312670	-312670					-199794	-199794				210000						185808.42	185808.42			-50370	-35040	-9900	-9070	-7000	-300
2	TOTSW t <=																		1	1	-1							
3	BALWM t =	1		0.9		0.9		1		-1									-1									
4	BALWV t =		1		0.9		0.9		1		-1									-1								
5	BALWT t =	1	1	0.9	0.9	0.9	0.9	1	1			-1									-1							
6	BegCW t,1 =		1	-4																								
7	BegCW t,2 =		1		-4																							
8	BuyCW t,1 =						-4		1																			
9	BuyCW t,2 =						-4		1																			
10	TOTC t =			0.9	0.9	0.9	0.9									-1												
11	BWVtWM t =	-4	1																									
12	AWWtWM t =							-4	1																			
13	IEndWM t >=	-1																1										
14	IEndWV t >=		-1														1											
15	TOTKgt =												-1	0.4	0.2													
16	TkgBW t,1 =	1						1						-1														
17	TkgBW t,1 =		1						1						-1													
18	SW t,1 =									-1									1									
19	SW t,2 =										-1									1								
20	Ha t =	20	20	20	20	20	20	20	20										-20	-20		-1						
21	Feed t,1 =									1													-1					
22	Feed t,2 =										1													-1				
23	Labour t =									1	1														-1			
24	Insur t =									1	1															-1		
25	Dehorn t =	1	1					1	1																		-2.5	
26	Vet t =									1	1																	-1

APPENDIX F: MODEL RESULTS

Table 9-HSSLP model output: screen shot

HAVERLY SYSTEMS INC. SPREADSHEET LP (H/SSLP) Version 2 Copyright © 1997				Column Name	BegW11	BegW12	BegCW11	BegCW12	BuyCW11	BuyCW12	BuyW21	BuyW22	EndWM2	EndWV2	EndTOT2	TOTKg2	TkgBW21	TkgBW22	TOTC2	TOTW22	TOTW21	SW21	SW22	TOTSW2	Ha2	Feed21	Feed22	Labour2	Insur2	Dehorn2	Vet2			
Options				OPTIMAL (INTEGER)	Activity																													
Row Name	Sign	RHS	Act-ivity	DJ																														
Upper Bound				2																														
Lower Bound				2																														
Profit		8237736.899	7735.899	-1	-319690	-319690					-199794	-199794				210000								185808.42	185808.42			-50370	-35040	-9900	-9070	-7000	-300	
TOTSW2	<=																							1	1	-1								
BALWM2	=	58686.74			1		0.9		0.9		1		-1											-1										
BALWV2	=	93744.84				1		0.9		0.9		1		-1											-1									
BALWT2	=				1	1	0.9	0.9	0.9	0.9	1	1			-1											-1								
BegCW11	=	17008.64				1		-4																										
BegCW12	=	24896.71				1			-4																									
BuyCW21	=	17008.64							-4			1																						
BuyCW22	=	24896.71							-4			1																						
TOTC2	=							0.9	0.9	0.9	0.9									-1														
BWVtWM2	=	11223.31				-4	1																											
AWWtWM2	=	8672.691									-4	1																						
lEndWM2	>=					-1																			1									
lEndWV2	>=						-1																		1									
TOTKg2	=	10000														-1	0.4	0.24																
TkgBW21	=	84000									1						-1																	
TkgBW22	=	50400										1																						
SW21	=	1905.187											-0.6											1										
SW22	=	66847.08											-0.6												1									
Ha2	=	3739.175			20	20	20	20	20	20	20	20												-20	-20		-1							
Feed21	=	50370											1															-1						
Feed22	=	35040												1																-1				
Labour2	=	9900													1	1																-1		
Insur2	=	9070														1	1																-1	
Dehorn2	=	2800																																-2.5
Vet2	=	300																																-1

Table 10-HSSLP model's NPVs for ten years

Year	NPV before inflation (ZAR M)	NPV after 5% inflation (ZAR M)
1	-3.13	-3.29
2	-3.40	-3.57
3	-1.67	-1.75
4	-1.53	-1.61
5	-0.05	-0.05
6	1.44	1.51
7	3.15	3.31
8	4.40	4.62
9	5.81	6.10
10	8.23	8.64

APPENDIX G: INVESTMENT CALCULATION

F = Final amount

P = Investment amount (ZAR 3, 126700.00)

i = Compound repo-interest rate (5%) (South African Reserve Bank, 2012)

n = time periods

Equation G.1

$$F = P\left(1 + \frac{i}{100}\right)^n$$

$$F = 3,126700.00\left(1 + \frac{5}{100}\right)^{10}$$

$$F = \text{ZAR } 5,093064.83$$