AN ECONOMIC EVALUATION OF CROP ROTATION SYSTEMS UNDER CENTRE PIVOT IRRIGATION IN THE SOUTHERN FREE STATE SUB-AREA

by

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TO STUDY THE PHENOMENON OF DISEASE WITHOUT BOOKS IS TO SAIL AN UNCHARTERED SEA, WHILE TO STUDY BOOKS WITHOUT PATIENTS IS NOT TO GO TO SEA AT ALL.

(SIR WILLIAM OSBURN)

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ABSTRACT

The lack of sufficient and accurate knowledge of the effect of alternative crop rotation systems on economic profitability and financial feasibility for irrigation farming indicates that farmers purchase mechanisation systems and plant successive crops without having determined the effect of these actions on long term farm profitability and feasibility.

The importance of the study is reflected by the large numbers of irrigation farmers and the relatively large number of farmers having a high debt to asset ratio. The study is done in the irrigation area below the P.K. le Roux Dam but can also be applied to other irrigation areas without the need for structural changes.

The objective of this study is to determine the economic profitability and financial feasibility of alternative crop rotation systems in the research area, taking into consideration price, production and financial risks.

The lack of comparable and accurate information on crop yields and gross water requirements over a lengthy period necessitated these values to be simulated. Data on crops, soils and climate are used to validate and calibrate the PUTU crop growth simulation model P9MZAB3 for this area. The BEWAB irrigation scheduling model is used to determine the irrigation scheduling of the crops. The calibrated PUTU model then is used to generate the crop yields and gross water requirements for wheat, late maize, cotton, peanuts, dry beans, lucerne and soyabeans for a period of eleven consecutive years.

Selected farmers in this area provided the data on crops and crop rotation systems. Based on economic, agronomic and practical principles, fourteen alternative crop rotation systems are

developed. For each typical crop rotation system an appropriate mechanisation system, which includes a centre pivot irrigation system, is developed. The crop rotation systems are evaluated to run over a period of ten years. The irrigation systems are used to irrigate an area of sixty hectares with a predominantly sandy soil. Depending on the crop rotation system various land utilisation percentages (degree of double cropping) are considered. The systems are used to irrigate areas with two different pumping heights: +10 m (Sarel Hayward canal) and -15 m (Ramah area). The simulated gross water requirements of the crop rotation systems are calculated and compared for the ten-year period to the available water quota. The results indicate that the maximum water quota of 900 000 m^3 is sufficient in satisfying the gross water requirements of the following crop rotation systems:

45W45LM15P *
30W30S30L
30W30LM30L
30W30S30LM30L
30W30LM30C30L
30W30S30C30L

Price risk is the result of crop prices that change over time. For late maize and wheat price scenarios are determined. By using linear regression analysis on the basis of historical national production levels of these crops, equivalent 1990 adjusted national production levels and prices are calculated. The prices of dry beans and lucerne hay are subject to price variability and determined largely by supply and demand situations. A procedure is followed to generate a distribution of prices for these two crops that takes the price variability into consideration. For soyabeans, cotton and peanuts no

* The number refers to the number of hectares while the symbols are explained as W = Wheat, LM = Late Maize, P = Peanuts, L = Lucerne, S = Soyabeans and C = Cotton

quantifiable price risk is assumed and subsequently predetermined fixed prices are used.

By using an irrigation system cost calculation method the fixed, variable and marginal irrigation system costs are calculated for the two systems with different pumping heights. On the basis of the supplied data on crops, mechanisation costs and determined average crop prices and yields, the crop budgets are developed and the net margins calculated. The crop net margins are the basis on which the different crops are analysed for economic profitability.

For the consideration of production and price risks the net margins of the crops in the budgets are calculated for each year of the ten-year period on the basis of randomly selected crop prices and yields from the respective price and yield distributions. This process is repeated twenty times to obtain a distribution of twenty net margins for ten years for each crop.

The net present value method is used to calculate the economic profitability of the crop rotation systems. By including in the calculation the distributions of the determined net margins the production and price risks are taken into consideration. On the basis of the net present values and ratios of net present values to investment the economic profitability of the crop rotation systems can be evaluated on an equal basis.

The results indicate that crop rotation systems with late maize and/or soyabeans as the main summer crops are the least profitable, while crop rotation systems with lucerne and cotton as the main summer crops are the most profitable.

The results also indicate that crop rotation systems irrigated by the systems with higher pumping heights have a considerably lower economic profitability.

In the financial feasibility analysis the crop rotation systems are analysed for a hypothetical farm for cash deficits for the ten-year period by comparing basically the cash incomes with the cash costs (financial obligations). On the hypothetical farm two sixty-hectare areas are irrigated and only the associated revenues and costs are considered.

In the financial feasibility analysis the financial risks are firstly incorporated by including the distribution of net margins and secondly by using three different debt to asset ratios. The annual cash costs are calculated for each year for the ten-year period and for each debt to asset ratio. The annual cash incomes are calculated from the crop net margins minus the non-cash fixed costs for each year for the ten-year period. A decision rule is implemented to determine when a crop rotation system is feasible.

The results indicate that the debt to asset ratio is the main factor influencing financial feasibility of the crop rotation systems. For a 70/30 debt to asset ratio all crop rotation systems are unfeasible for the irrigation systems with a positive pumping height (+10 m) and unfeasible, except one (30W30S30C30L), for the negative pumping height (-15 m). For a 50/50 debt to asset ratio only five crop rotation systems are feasible for irrigation systems with positive and negative pumping heights (30W30S30L; 30W30S30LM30L; 30W30LM30L; 30W30LM30C30L; 30W30S30C30L). For a 20/80 debt to asset ratio all crop rotations systems except one (60W60LM) are feasible for both pumping heights.

The conclusion is that the debt to asset ratio is more important in obtaining financial feasibility than the choice of the crop rotation system and the given crops.

OPSOMMING

Die gebrek aan voldoende en akkurate kennis van die effek van alternatiewe gewaswisselboustelsels op ekonomiese winsgewendheid en finansiële uitvoerbaarheid vir 'n besproeiingsboerdery toon aan dat boere meganisasiestelsels aankoop en 'n opeenvolging van gewasse plant sonder dat die effek van hierdie aktiwiteite op die lang termyn winsgewendheid en uitvoerbaarheid bepaal word.

Die belangrikheid van die studie word weerspieël deur die groot aantal besproeiingsboere en die relatiewe groot aantal boere wat 'n hoë skuld tot eie kapitaalverhouding het. Die studie is gedoen vir die besproeiingsgebied benede die P.K. le Rouxdam maar is ook van toepassing op ander besproeiingsgebiede sonder dat strukturele veranderinge gemaak te hoef word.

Die doel van hierdie studie is om die ekonomiese winsgewendheid en finansiële uitvoerbaarheid van alternatiewe wisselboustelsels in die navorsingsgebied te bepaal, met inagneming van prys-, produksie- en finansiële risiko.

Die gebrek aan vergelykbare en akkurate inligting oor gewasopbrengste en bruto waterbehoeftes oor 'n langer periode noodsaak dat hierdie waardes gesimuleer moet word. Data oor gewasse, gronde en klimaat is gebruik om die PUTU-gewasgroeisimulasiemodel P9MZAB3 vir die gebied te kalibreer en te valideer. Die gekalibreerde PUTU-model word dan gebruik om die gewasopbrengste en bruto waterbehoeftes van koring, laat mielies, katoen, grondbone, droë bone, sojabone en lusern oor 'n periode van elf opeenvolgende jare te genereer.

Data oor gewasse en wisselboustelsels is verkry van boere wat in die gebied geselekteer is. Gebaseer op ekonomiese, agronomiese en praktiese beweegredes is veertien alternatiewe gewaswisselboustelsels ontwikkel. Vir elke tipiese gewaswisselbou-

stelsel is 'n toepaslike meganisasiestelsel, wat die besproeiingstelsel insluit, ontwikkel. Die gewaswisselboustelsels word geëvalueer oor 'n periode van tien jaar. Die spilpunt-besproeiingstelsels word gebruik om 'n oppervlakte van sestig hektaar op hoofsaaklik sanderige grond te besproei. Afhangende van die gewaswisselboustelsel word verskillende grondbenuttingspersentasies in ag geneem. Die besproeiingstelsels word gebruik om oppervlaktes te besproei met respektiewelik +10 m (Sarel Hayward-kanaal) en -15 m (Ramah-gebied) pomphoogte. Die gesimuleerde bruto waterbehoeftes van die gewaswisselboustelsels word bereken en vergelyk met die beskikbare waterkwota oor 'n tienjaar-periode. Die resultate toon aan dat die maksimum waterkwota van 900 000 m³ voldoende is vir die volgende gewaswisselboustelsels:

45W45LM15P *
30W30S30L
30W30LM30L
30W30S30LM30L
30W30LM30C30L
en 30W30S30C30L

Prysrisiko is die resultaat van gewaspryse wat wissel oor tyd. Vir laat mielies en koring word prys-scenario's bepaal. Deur die gebruik van lineêre regressie-analise, kan op grond van historiese nasionale produksiepeile vir hierdie gewasse gelykwaardige 1990 aangepaste nasionale produksiepeile en -pryse bereken word. Die pryse vir droë bone en lusernhooi is onderhewig aan prysveranderings en word hoofsaaklik bepaal deur vraag- en aanbodtoestande. 'n Prosedure word gevolg om 'n waarskynlikheidsverdeling van pryse vir die twee gewasse te genereer wat voorsiening maak vir prysveranderinge. Vir sojabone, katoen en grondbone word veronderstel dat geen kwantifiseerbare prysrisiko bestaan nie en vaste pryse word dus gebruik.

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* Die getalle verwys na die aantal hektare en die simbole word as volg verduidelik W = Koring, LM = Laat Mielies, P = grondbone, S = Sojabone, C = Katoen en L = Lusern

Deur die gebruik van 'n besproeiingstelselkosteberekeningsmetode word die vaste, veranderlike en marginale besproeiingskoste bereken vir die twee stelsels met verskillende pomphoogtes. Op grond van die gegewe data oor gewasse, meganisasiekoste en beraamde gemiddelde gewaspryse en opbrengste, word die gewasbegrotings opgestel en die netto marges bereken. Die gewas netto marges is die grondslag waarop die verskillende gewasse vir ekonomiese winsgewendheid ontleed word.

Vir die inagneming van produksie- en prysrisiko word die netto marges van die gewasse in die begrotings bereken vir elke jaar van die tienjaar-periode op grond van ewekansig gekose pryse en opbrengste van die respektiewelike prys- en opbrengsverdelings. Hierdie prosedure word twintig maal herhaal om 'n verspreiding te verkry van twintig netto marges vir tien jaar vir elke gewas.

Die netto huidige waarde metode word gebruik om die winsgewendheid van die gewaswisselboustelsels te bereken. Deur in die berekening die verdelings van die bepaalde netto marges in te sluit word die produksie- en prysrisiko in ag geneem. Op grond van die netto huidige waardes en die verhoudings van die gewaswisselboustelsels en die ooreenstemmende beleggings kan die ekonomiese winsgewendheid van die gewaswisselboustelsels op gelyke grondslag geëvalueer word.

Die resultate toon dat gewaswisselboustelsels met laat mielies en/of sojabone as die belangrikste somergewasse die minste winsgewend is, terwyl gewaswisselboustelsels met lusern en katoen as die belangrikste somergewasse die mees winsgewendste is.

Die resultate toon ook dat gewaswisselboustelsels wat besproei word deur die stelsels met hoër pomphoogtes aansienlik minder winsgewend is.

In die finansiële uitvoerbaarheidsontleding word die gewaswisselboustelsels ontleed vir 'n hipotetiese plaas vir kontanttekorte vir die tienjaar-periode deur basies die kontantinkomste te vergelyk met die kontantuitgawes (finansiële verpligtinge). Op die hipotetiese plaas word twee sestighektaar-oppervlaktes besproei en slegs die tersaaklike inkomste en kostes word in ag geneem.

In die finansiële uitvoerbaarheidsontleding word die finansiële risiko's ten eerste in ag geneem deur die verspreiding van die netto marges in te sluit en ten tweede deur drie verskillende skuld tot bate verhoudings te gebruik. Die jaarlikse netto kontantuitgawes word bereken vir elke jaar vir die tienjaar-periode en vir elke skuld tot bate-verhouding. Die netto jaarlikse kontantinkomste word bereken deur van die gewas netto marges die nie-kontant vaste koste af te trek vir elke jaar vir die tienjaar-periode. 'n Besluitnemingsreël word toegepas om te bepaal wanneer 'n gewaswisselboustelsel uitvoerbaar is.

Die resultate toon aan dat die skuld tot bate-verhouding die belangrikste faktor is wat finansiële uitvoerbaarheid beïnvloed. Vir 'n 70/30 skuld tot bate-verhouding is al die gewaswisselboustelsels onuitvoerbaar vir die besproeiingstelsels met 'n positiewe pomphoogte (+10 m) en onuitvoerbaar, uitgesluit een (30W30S30C30L), vir die besproeiingstelsel met 'n negatiewe pomphoogte (-15 m). Vir 'n 50/50 skuld tot bate-verhouding is slegs vyf (30W30S30L, 30W30S30LM30L, 30W30LM30L, 30W30CM30C30L and 30W30S30C30L) gewaswisselboustelsels uitvoerbaar vir besproeiingstelsels met positiewe en negatiewe pomphoogtes. Vir 'n 20/80 skuld tot bate-verhouding is al die gewaswisselboustelsels, uitgesluit een (60W60CM), uitvoerbaar vir beide pomphoogtes.

Die gevolgtrekking is dat die skuld tot bate-verhouding belangriker is as die keuse van die gewaswisselboustelsel vir finansiële uitvoerbaarheid.

CHAPTER 1

INTRODUCTION

1.1 DESCRIPTION OF THE AREA UNDER RESEARCH

1.1.1 Location

The analysis of alternative crop rotation systems under irrigation in the Southern Free State subarea is done in the area of the Vanderkloof State Water Scheme, known as the irrigation area below the P.K. le Roux Dam. The importance of this scheme for centre pivot irrigated crops makes the scheme a good choice for economic analysis of crop rotation systems. The scheme is situated approximately 30 km south of Luckhoff on the north bank of the Orange River and runs from the Rust area just below the P.K. le Roux Dam up to the farm Ramah on the border line between the Cape Province and the Orange Free State. The size of the incorporated irrigation areas entails a total of 4236 hectares (RSA, 1987: 9) and the area is divided into 68 irrigation plots. The irrigation scheme consists of the following two canals:

(a) The right-bank canal or the Vanderkloof canal, a trapesoidal with a capacity of 54 m^3/s which runs from the right canal outlets of the dam over a distance of 13,8 km to the point where the Ramah canal starts. At this point the pump station for the Sarel Hayward canal is situated. The Vanderkloof canal provides water to the Rust area.

(b) The Ramah canal runs from the pump station all along the right-bank of the Orange River up to Sanddraai. This canal provides water to the Bleskop, Baviaanskrans, Kalkplaat and Sanddraai areas. The total length of the canal is 87,6 km with an initial carrying capacity of 9,6 m^3/s. An extension of the Vanderkloof canal system is the Sarel Hayward canal, completed in 1987. This canal provides water from the right-bank canal to the Riet River settlement at Jacobsdal and to irrigation farmers with land along the canal. The canal is situated at a higher level than the right-bank canal and the pump station raises the water level by 47 meters.

1.1.2 Climate

The summers in this area are warm and the winters relatively cold (Kirsten, 1989). Generally night temperatures do not rise before October and therefore summer crops can usually not be planted before October to early December. A too low soil temperature will result in poor germination of crops.

The high summer temperatures, in combination with wind and relative low humidity contribute to the high evaporation and subsequently crop evapotranspiration. The occurrence of occasional heat-waves is responsible for crop damages.

The low annual rainfall is a striking characteristic. The average annual rainfall is 333 mm in the area. Thunderstorms and rain showers are mainly responsible for the rainfall in the summer months, from October till March.

The occurrence of frost, averaging between 111 and 132 days a year influences crop cultivation practices.

Hail usually occurs at the beginning of the summer rainfall season, causing large crop losses and crop insurance is required.

The highest average wind-speeds occur from September to November, during which the prevailing wind direction is north-westerly. Thunder storms together with very strong winds and occasionally whirl winds occur during the summer months and can be responsible for large losses.

1.1.3 Infrastructure

The area is well served with road and rail connections. A national road runs through the irrigation area and connects up with the Kimberley-Cape Town national road at Modder River.

The South-West Transvaal Agricultural Cooperative serves this area with a branch at Modder River and with agricultural information services from Christiana and Barkly-West branches. A branch of the Sentraal Wes Cooperative serves the Luckhoff district. Cotton is processed at Cotton Clark at Modder River. Wine grapes are delivered to the cooperative cellars at Jacobsdal. Wheat, maize, soyabeans and peanuts are delivered to the Hopetown cooperative. Dry beans which are not sold to private traders are also delivered at the Hopetown cooperative. Lucerne is traded on the free market.

1.2 ECONOMIC BACKGROUND

Investment decisions are of the most important decisions which the manager must take (Boehlje and Eidman, 1984: 315).

Mechanised irrigation has accelerated from 1982 in the Sentraal Wes Cooperative service area of the Orange Free State (Van der Walt, 1988: 1). The purchase of capital-intensive mechanised irrigation systems takes place continually.

The crop rotation system practised is one of the most important factors that influence the viability of irrigation farming (Niksch, 1988: 1).

The farmers purchase mechanised irrigation systems and plant a succession of crops without having determined the effect of these actions on long term farm profitability and feasibility (Niksch, 1988: 1).

Research has shown that in the irrigation areas effective crop rotation systems must be practised and that critical crop yields must be obtained in order to achieve long-run profitability.

The economic squeeze effect of lower real crop prices and rising real crop production cost affects the economic profitability of the crops and crop rotation systems.

The financial feasibility of the crop rotation systems is affected by the debt to asset ratio, financing method and absolute debt load.

1.3 MOTIVATION

The importance of the study in the irrigation area below the P.K. le Roux Dam is reflected by the large number of irrigation farmers and the relatively large number of farmers having high debt to asset ratios.

The agronomic crops traditionally cultivated in this area are wheat, maize, peanuts and cotton. On the economic viability of these crops within crop rotation systems little information is available. Some of these crops are subject to overproduction. This implicates the need for alternative crops to be included in crop rotation systems. Also no information on the viability of these crops is available.

Investment and management decisions should only be based on economic profitability and financial feasibility analysis. No accurate economic and financial analysis can be done without taking into account the price, production and financial risks. To determine how the financial risk affects the farmer, the economic and financial analysis must be done on farm level.

1.4 PROBLEM STATEMENT

The problem statement of this study is subsequently subdivided into four problems.

1.4.1 Problem 1

Given different practical crop rotation systems for the research area, how do the yields and gross water requirements of wheat, late maize, cotton, peanuts, soyabeans, dry beans and lucerne under uncertain climatic circumstances differ and to what extent will the water quotas satisfy the gross water requirements of the alternative crop rotation systems?

More specifically the following questions should be answered:

(a) What are the yields and the corresponding gross water requirements of wheat, late maize, cotton, peanuts, soyabeans, dry beans and lucerne over a period of eleven years considering production risks?

(b) What are the total gross water requirements of the alternative crop rotation systems?

(c) To what extent do water quotas satisfy the gross water requirements of the alternative crop rotation system?

1.4.2 Problem 2

How does the economic profitability of the different crops in the crop rotation system differ in the research area? To analyse this problem the following questions should be answered:

(a) To what extent are crop prices subject to price risk?

(b) What are the irrigation variable costs of the different crops?

(c) What are the estimated income and cost for the different crops?

(d) How does the relative economic profitability of the different crops differ?

1.4.3 Problem 3

How does the relative economic profitability of the alternative crop rotation systems differ, considering price and production risks?

1.4.4 Problem 4

How does the financial feasibility of the alternative crop rotation system differ for a hypothetical farm, considering price, production and financial risks?

1.5 MAIN OBJECTIVE

The main objective of this study is to determine the economic profitability and financial feasibility for alternative irrigated crop rotation systems in the Southern Free State area, considering price, production and financial risk.

1.6 RESEARCH PROCEDURE

Due to the lack of comparable and accurate information on crop yields over a lengthy period it was found to be necessary to simulate them. Data on crops, soils and weather are used to validate and calibrate the PUTU crop growth simulation model (P9MZAB3) for the research area. The BEWAB irrigation scheduling model is used to determine the irrigation scheduling of the crops. For a period of eleven consecutive years the calibrated PUTU model is then used to generate a distribution of crop yields and gross water requirements.

Economical and practical aspects and agronomical principles must be considered in the development of alternative crop rotation systems. The crop rotation systems must be developed to run for a fixed period and for a specific soil type. The irrigation systems used (centre pivots) are determined by the irrigation capacity requirements of the crops. The simulated total gross water requirements of the crop rotation systems must be calculated from the gross water requirements of the crops and compared to the available water quota.

In order to incorporate price risk the crop prices must be analysed over time. For late maize and wheat price scenarios are developed. On basis of historical national production levels for these crops the equivalent present national production levels and prices can be calculated. A linear regression procedure is used in this analysis. For lucerne and dry beans a procedure will be followed to generate a distribution of prices that allows for the consideration of price variability. For soyabeans, cotton and peanuts no quantifiable price risk is assumed and for these crops a predetermined fixed price is used.

Fixed, variable and marginal irrigation system costs are calculated for two centre pivot irrigation systems, which differ in regard to pumping height. As the crop rotation systems differ in degree of double cropping, provision must be made for this in the calculation of the fixed irrigation systems cost. The irrigation variable costs are calculated by the multiplication of the marginal factor costs and the gross water requirements. On basis of the supplied data on crops the budgets can be developed for each crop separately. The average values of the determined price distributions, variable irrigation costs and simulated yields are calculated. Using these average values the crop net margins and the ratios of net margins to investments can be calculated.

The net present value method is used to calculate the net present values for the alternative crop rotation systems. For the consideration of production and price risks a distribution of crop net margins must be calculated. A process is followed whereby for each year of the ten-year period net margins are calculated for each crop on basis of randomly selected crop prices and yields from the respective price and yield distributions. These randomly selected prices and yields are entered into the developed budgets in order to obtain the required net margins. For each year of the ten-year period the process is repeated twenty times to provide for production risk. Successively on basis of the obtained multiple annual net margins and the section of the lands planted to the crops concerned the net present values can be calculated for each crop rotation system.

A financial feasibility study on the crop rotation systems need to be analysed for a hypothetical farm of 120 hectares irrigated by two 60 hectares centre pivot irrigation systems. In the financial feasibility analysis the after tax annual cash incomes are compared to the after tax annual cash costs for the crop rotation systems. The crop after tax margins minus the non-cash fixed cost factors and the section of the land planted to the prevailing crops form the basis on which the after tax annual cash incomes are calculated. The annual after tax cash costs are the after tax annual financial obligations that must be met. The obligations result from using debt capital for the financing of the investment in a developed land and mechanisation system. The effect of financial risk associated with financial feasibility is reflected by using different annual after tax cash flows, effected by the randomly selected prices and yields and by using three different debt to asset ratios. On the basis of a decision rule it can be determined when a crop rotation system is feasible for a given debt to asset ratio.

1.7 COMPOSITION OF THE DISSERTATION

The dissertation consists of six chapters. Each chapter is an independent and separate entity but forms a coherent and essential part in obtaining the objectives of the study. The structure of each chapter is as follows: introduction, literature study, research procedure, results and discussion of results, conclusions and recommendations.

The first chapter is the introduction. In this chapter the research is described briefly. The research problems, motivation and objectives are stated. The research procedure and the composition of the study are set out.

In chapter three the gross water requirements and yields of the crops are simulated for eleven years. The gross water requirements are used to calculate the gross water requirements of the developed crop rotation systems. In a final analysis the total gross water requirements are compared to the available water quota over the eleven years.

In Chapter three the crop price distributions are determined, the mechanisation costs are calculated and the crop budgets are developed. On basis of average prices, yields, irrigation costs and production inputs the net margins in the budgets are calculated and analysed.

In Chapter four the economic profitability of the crop rotation systems is determined by calculating the net present value of the crop rotation systems, considering price and production risks.

In Chapter five the financial feasibility of the crop rotation systems is determined and analysed, considering price, production and financial risk.

In the last chapter a summary of the complete dissertation is given.

CHAPTER 2

ANALYSIS OF THE YIELDS AND GROSS WATER REQUIREMENTS OF ALTERNATIVE CROP ROTATION SYSTEMS SUBJECT TO SPECIFIED WATER QUOTAS

2.1 INTRODUCTION

The yield per hectare and the crop price are the two most critical factors which influence the profitability of crop production (Oosthuizen, 1983: 66). Irrigation has long been recognised as a means of increasing yields and profits by reducing the risk of low crop yields (Boggess, 1983).

One of the most important factors that can be controlled and that influences crop yields is a timely and adequate availability of water (Hughes and Metcalfe, 1972: 81). The use of sophisticated irrigation systems, such as the centre pivot system, enables the farmer, subject to the constraints of the specific irrigation system, to regulate the quantity and the timing of the water applied. The farmer is therefore able to irrigate according to an irrigation scheduling strategy, developed specifically according to the needs of the specific crops. The management of the irrigation water can only be effective when the irrigation system is adapted to the application requirements of the scheduling strategy followed (Bennie, Coetzee, Van Antwerpen, Van Rensburg and Burger, 1988: 63) or vice versa. In principle, the irrigation systems are designed to meet the average daily water consumption requirements during the period of peak consumption of the crops.

Information on yields and yield/water consumption relations for the crops over a number of past years cannot always be obtained or made available. The development of dynamic crop growth computer simulation models can largely overcome this lack of accurate information. The climatic conditions are, besides the application of water, the main factor influencing crop yields. The yields for the crops concerned are estimated as a function of water application, rainfall, soil characteristics and weather conditions. It is assumed that the weather conditions that have prevailed over a number of years in the recent past will continue unchanged over the coming years. Yields achieved from the crops can then be regarded as representative for future crop yields with other factors considered as constant.

The crop rotation system practised is one of the most important factors which influences the viability of irrigation farming (Meiring, 1989).

The following main and subproblems are experienced:

Given different practical crop rotation systems for the research area, how do the yields and the gross water requirements differ for wheat, late maize, cotton, peanuts, soyabeans, dry beans and lucerne under uncertain climatical conditions and to what extent will the water quotas satisfy the gross water requirements of the alternative crop rotation systems?

More specifically, the following questions are analysed:

(a) What are the yields and the gross water requirements of wheat, late maize, cotton, peanuts, soyabeans, dry beans and lucerne over a period of eleven consecutive years considering production risks?

(b) What are the total gross water requirements of the alternative crop rotation systems?

(c) To what extent do the water quotas satisfy the gross water requirements of the alternative crop rotation systems?

The following objectives in this chapter are pursued:

(a) To simulate yields of wheat, late maize, cotton, peanuts, soyabeans, dry beans and lucerne and corresponding gross water requirements;

(b) To determine the gross water requirements of the alternative crop rotation systems; and

(c) To compare the gross water requirements of the alternative crop rotation systems with the available water quotas.

2.2 REVIEW OF LITERATURE

2.2.1 Development and functioning of the PUTU crop growth model

The problem of a lack of actual adequate and accurate data on crop yields and crop water requirements necessitated the use of crop growth simulation models. The development of the crop growth irrigation simulation model PUTU has made it possible to generate simulated crop water yield and water requirement relations.

The PUTU model was originally developed by De Jager (1974) and De Jager and King (1974). The early model was limited to simulating maize yields only, but has been adapted for wheat by De Jager, Botha and Van Vuuren (1981). The later version PUTU9-87 simulation model was developed by De Jager, Van Zyl, Bristow and Van Rooyen (1982) and De Jager, Van Zyl, Kelbe and Singels (1987) to schedule irrigation water for wheat in the Vaalharts State Water Scheme and UOFS campus.

Botes (1990) described the functioning of the PUTU model and calibrated the PUTU9-87 model for simulation of wheat yields in the irrigation areas below the P.K. le Roux Dam. The calibration was done by comparing the simulated yields with experimental data collected in this area. The seasonal change in soil water content levels was simultaneously checked.

Meiring (1989) used the calibrated PUTU9-87 model to simulate wheat yields in the irrigation area below the P.K. le Roux Dam. The PUTU12-8 model, developed by De Jager, Mottram and Singels (1986) for simulation of dryland-yields for maize, and adjusted by De Jager and Hensley (1988) and De Jager (1989), was calibrated and used by Meiring (1989) to simulate maize-yields under irrigation in this area. Meiring (1989) used the PUTU9-86 model to simulate cotton-yields under irrigation in this area.

All PUTU models require the same set of inputs. The models differ in the method in which the specific soil and crop characteristics are calculated.

The following inputs are required:

(a) Climatological data (climatological data files):

Maximum and minimum temperature (°C), evapotranspiration (mm) and duration of sunshine (hr) on a daily basis.

(b) Soil data (irrigation scheduling and carry-over files):

Clay percentage, gross soil density, soil water content at planting of each layer, the soil depth and profile available water capacity.

(c) Plant data (crop factor and carry-over files):

Crop factors, yield response factors, planting density (plants/ha or kg/ha) and planting dates (Julian day).

(d) Irrigation data (irrigation scheduling files):

Quantity and scheduling of irrigation water applied.

For this research the PUTU P9MZAB3 has been used. This model, developed by De Jager (1990), is an improvement on previous models as it can simulate multiple crop yields. The model is a direct successor to the original PUTU P9MZAB2 model and differs in so far that output is given in a form that directly meets the yield/water consumption research requirements. Output is given as environmental seasonal potential yield (%) with totals for the season (mm); deep percolation (Dp); evaporation from soil surface (ETs); evaporation from crop surface (Etc); total rainfall (Rf); total irrigation applied (Ir); and difference between initial and final profile water content (PWC). Total evapotranspiration (ET) equals evaporation from the crop (ETc) and the soil (ETs). The following equation (2.1) indicates the relation between these variables:

$$ETs + ETc + Dp = Rf + Ir + PWC \qquad (2.1)$$

The total water consumed and that which is lost through deep percolation in the soil equals the total water supplied in the form of rainfall, irrigation and difference in the soil profile water content. The difference in profile soil water content indicates the amount of extra water that is withdrawn from the soil in addition to the maintenance of a constant water status of the soil profile. For the simulation of yields and the gross water requirements, modelling is started with a full soil profile water content. The relationship between crop yields and water supplied can be determined when crop water requirements and crop water deficits on the one hand, and maximum and actual crop yields on the other hand can be quantified. Water deficits in crops and the resulting water stress on the plant, have an effect on crop evaporation and crop yield (Doorenbos and Kassam, 1979). Water stress in the plant can be quantified by the rate of actual evapotranspiration (ETa) in relation to the rate of maximum evapotranspiration (ETm). ETm refers to a condition when water is adequate for unrestricted growth and development. The following equation (2.2) indicates the effect of water stress in the relation between relative yield decrease (actual yield/maximum yield, Ya/Ym) and relative evaporation deficit given by the yield response factor (ky):

$$(1 - Ya/Ym) = ky\ (1 - ETa/ETm) \qquad (2.2)$$

The ky-values (yield response factor) represent the yield reaction to moisture stress and are an indication of the sensitivity of the plant to moisture stress.

Climate is one of the most important factors determining the crop water requirements required for unrestricted optimum growth and yield (Niksch, 1988). The level of ET is directly related to the evaporative demand of the air. This demand can be expressed as the reference evapotranspiration (ETo) which predicts the effect of climate on the level of crop evapotranspiration. The Priestly-Taylor equation is used in PUTU to calculate ETo. Empirically-determined crop coefficients (kc) are used to relate ETo to the maximum crop evapotranspiration (ETm) when water supply fully meets the water requirements of the crop. The value of kc varies with the crop, the development stage of the crop and, to some extent, with wind speed and humidity. The crop coefficients value increases from a low value at the time of crop emergence to a maximum value when the crop reaches full development and declines as the crop reaches maturity. For a given climate, crop and crop development stage, the maximum evapotranspiration (ETm) in mm/day is given by the following equation (2.3):

$$ETm = kc \times ETo \qquad (2.3)$$

2.2.2 Calibration and evaluation of crop growth models

The objective of calibration of a model is to simulate satisfactorily accurate yields and water requirements and can be pursued having established confidence in the verification of the model on a basis of model predictions. Within the calibration process it may be necessary to return to further refinement of the model within the basic cycle as the predictions may reveal further deficiencies (Brockington, 1979: 121). Calibration involves the adaptation of the subroutines of a model for specific alternative, planned circumstances or behaviour, but still directly in line with the objective of the model. With calibration a procedure is followed in determining the similarity of generated simulated data with historical data. The judgement of this process in determining a degree of confidence in the model is subjective in nature in the case where output and input do not conform exactly. Through the process of calibration of a model, the model can be adapted to accommodate alternative situations or systems on which historical data are not available. The model is run in precisely the same set of conditions as in a case where real data are available. Persons with expert knowledge on the subject, or the user having obtained information from appropriate literature, can assess the results subjectively. Statistical tests can be used to analyse these results more "objectively" (Dent and Blackie, 1979).

The crop growth models need to be validated against observed data over different climatic areas and for different crops, before the model can be used with a degree of confidence (Dent, Schulze and Angus, 1988: 65). The model must go through a formal validation process to achieve this level of confidence. During the validation process the model is tested, modified and assessed continuously over time. The formal validation process starts with searching for internal consistency (verification); this is achieved by running the model with the given input data and in the prescribed exogenous conditions (Dent *et al.*, 1979: 95). The output from the model is generated so that the model can be assessed on its functioning. The assessment process includes two types of judgements (Dent *et al.*, 1979: 16):

(a) The model is not different from the real existing system to a degree that it will detract values or results exactly in line with the purpose of the design of the model.

(b) The model is accepted as being adequate in its output and behaviour. The last judgement is of subjective nature but not without value and is still being relevant.

Statistical tests, being less "subjective", can be used to determine whether the model behaviour and output are different from actual process behaviour to some stated level of significance (Dent *et al.*, 1979). A graphic display of input and output is the most favoured method of presenting the data. Positive results of these statistical tests can contribute to the confidence that the user has in the model, or can form the basis on which the model will achieve an acceptable level of significance by means of a series of assessments and subsequent modifications over time.

Sensitivity analysis is a procedure to be carried out on the completed, and at least partly validated, model which involves exploring the operation and the output of the model (Dent *et al.*, 1979: 17). In successive runs of the model under identical environmental conditions, the value of the parameter may be changed (Brockington, 1979: 121). A resultant modification of the output or behaviour will be analysed to determine whether or not the changed parameter values have a measurable consequence. A sensitive parameter is a parameter which causes a significant change.

2.2.3 Application, development and functioning of the crop irrigation scheduling model

One of the main factors in the simulation of crops under irrigation in the crop growth simulation models, is the specific irrigation schedule followed.

In recent years several studies of De Jager *et al.*, (1982) and De Jager *et al.*, (1987), Bennie *et al.*, (1988), Streutker (1983) and Botes (1990) were undertaken, dealing with irrigation scheduling. For this research project it has been decided that the irrigation scheduling model, BEWAB, from Bennie *et al.*, (1988) is to be used. The objective of this model is to forecast the soil water shortage in an attempt to prevent over-irrigation or plant water stress.

In irrigation scheduling management the available soil water profile is essentially used as the basis for estimating the application and the timing of the amount of water. Growth of crops under irrigation is stimulated by moderate quantities of soil moisture and retarded by either excessive or deficient amounts. This implies that crops should be grown in a soil maintained at an optimal soil water level for maximum yield (Bennie *et al.*, 1988: 1).

A basic principle of irrigation scheduling for all irrigation systems is that the plant accessible soil water reservoir is managed and not plant water stress or atmospheric demand (Bennie *et al.*, 1988: 1). The occurrence of plant water stress then indicates a too low level of the soil water reservoir. Climatological circumstances and the atmospheric evaporation demand influence, in addition, the rate at which the level of the soil water reservoir will decrease. Given the constant volume of the soil water reservoir the objectives of economic efficient management of "optimum" crop yields with the minimum of water consumption can be pursued. Hensley and De Jager (1982) defined this reservoir as the profile available water capacity. The profile available water capacity is the difference between the wet limit (field water capacity) and the bottom or dry limit of the plant accessible water (Bennie *et al.*, 1988: 2). These limits are of a dynamic nature and differ among soils.

The design of the irrigation systems is determined by a combination of crop water requirements, soil structure, water application efficiency, size of irrigated area and climatic conditions. For deep soils with higher profile available water capacity than shallower soils, the storage capacity of the soils accordingly lowers the design capacity requirements of the irrigation system. The successful utilisation of irrigation systems, designed according to the minimum application requirements, is based on the principle that the reserve design application capacity of the system, when the system application capacity exceeds the daily crop water requirements, is used to gradually increase the profile available water capacity of the soil and therefore has adequate water available to meet the peak water consumption requirements later in the growing season (Bennie *et al.*, 1988: 63). The management of these irrigation systems necessitates a well-adapted irrigation scheduling program.

The BEWAB program provides four different scheduling strategies or irrigation management strategies for each crop (Bennie *et al.*, 1988). Option (a) is the complete crop water requirement replenishment during the period of peak water consumption. According to this option the water status of the soil profile will remain constant from the beginning till the end of the growing season. Options (b), (c) and (d) represent the partial replenishment of crop water requirements during peak water consumption, and the profile at planting time is wet, partially wet and dry. For these options, the growing season is concluded with a dry soil. In these options provision is made for rainfall by selecting a reserved rain storage capacity. The actual rainfall during the growing season is then considered as irrigation and subtracted from the irrigation requirement up to the maximum of its water storage capacity, as specified by the scheduling strategy. In option (a) the quantity of rain is subtracted from the irrigation requirement up to the maximum of this requirement. Rain in excess of this requirement is wasted.

In this research option (a) is followed in order to completely satisfy the water requirements of the crops and make maximum use of any rainfall.

The BEWAB program requires as input the different crops and their planting dates, the crop yield targets, information on the soil characteristics and the required irrigation cycle. Soil information is required to determine the profile available water capacity of the soil. The required irrigation cycle indicates the number of days between succeeding irrigation applications, and this number is variable. The longer the cycle, the higher the irrigation application quantity per cycle and the fewer the number of irrigations per growth season. In practice, a cycle is chosen which will strike a balance between high evaporation losses with low and frequent applications and soil run-off with high and less-frequent applications. The final infiltration rate of the soil and the application rate capacity of the irrigation system limit the maximum irrigation quantity per application (Meiring, 1989: 96). The application quantity per cycle is regulated by the control of the speed with which the irrigation system moves. The output of the BEWAB-program is in the form of a water application schedule, stated in days after planting and minimum effective irrigation requirement per cycle. In addition it states the minimum required irrigation system capacity.

2.2.4 Review of crop rotation studies

2.2.4.1 Aspects of crop rotation systems

In irrigation areas where winter and summer crops succeed each other continuously for years, the rate at which the soil is depleted is, in comparison, much faster than with dryland crop cultivation, where only one crop per year is planted (Hughes and Metcalfe, 1972: 216). The double crops under irrigation annually remove large quantities of nutrients and, in addition, continued irrigation depletes the soil from considerable quantities of soluble nutrients. If this type of overcropping is continued for an extended period, several plant diseases, insect pests and weeds will increase and theoretically result in systematically lower annual crop yields. This type of farming is detrimental to the soils and must be prevented as far as possible. On the other hand, a planned rotation of cultivated crops, forms the basis of a healthier crop rotation system and promotes long-run income stability.

Crop rotation can be defined as the practice of cultivating different crops during different seasons on the same land in a planned succession with the objective to improve productivity (Niksch, 1988). The original rotation-idea comprises the following four principles:

(a) The length of time before the same crop can be planted on the same land. According to experts in the planning of the crop rotation system, it is necessary that the length of survival of disease-causing organisms should be considered. Equally, crops or groups, of crops, which are susceptible to the same diseases, or act as host-plants, must be considered. Experts are of the opinion that peanuts and dry beans can only be planted on the same land once every fourth year, or with a longer period in between. In practice it is found that the crops wheat, maize, cotton and soyabeans can be planted successfully on the same land every year.

(b) Rest to recover. The rest-period can be either in the form of a fallow-time period or a grass-legume crop.

(c) Supplementation of organic material. With relatively constant cropping it is impossible to maintain the organic material of the soil, regardless of the amount of organic material ploughed in under (Hughes and Metcalfe, 1972).

(d) Rest-harvests with legumes. In the original rotation idea, legumes fulfil a prominent function. Initially, when sowing legumes, the seed of the legumes is inoculated with nitrogen-fixating nodular bacteria. This promotes the fixing of atmospheric nitrogen in a form which the small plant can absorb and use for its own requirements.

Tests conducted in Indiana, USA have shown that crop yields can economically be maintained regardless of the rotation system followed, providing the soil contains a legume at least once every 5 years and providing the crops are reasonably well fertilized (Hughes and Metcalfe, 1972). This practice allows the farmer a wide range in the selection of a crop rotation system best suited to his soil and climate.

From results of cropping tests conducted in Ohio, USA, it has been deducted that soils become less productive when mono-cropping is practised continuously (Hughes and Metcalfe, 1972). It has also been observed that the crop immediately preceding can have either a detrimental or a beneficial effect on crops following.

In the planning phase of crop rotation systems, the interaction of the soil and the crops must be considered first. In addition to the mentioned principles of crop rotation systems, the effect of the specific crop on the soil and on the cultivation requirements must be understood. This necessitates crops to be classified according to their different influences on the soil on which they are cultivated. The agronomical crops are classified as follows:

(a) Organic material producing crops: these crops improve the organic material and physical condition of the soil.

(b) Organic material depleting crops: these crops deplete the soil of organic material.

(c) Crops fixing nitrogen: perennial and annual legumes can fix atmospheric nitrogen into a form which the crop can utilise.

(d) Strong feeding crops: crops able to withdraw moisture and nutrients from a relatively large soil area.

(e) Fine feeding crops: crops with relatively delicate root systems, which utilise a relatively smaller soil contact area and require a better prepared soil.

(f) Deep and shallow rooted crops: strong feeding crops with a deeper root system and fine feeding crops with a shallow root system.

2.2.4.2 Economic principles of crop rotation

The economics of crop rotation is affected by the inter-relations between the different crops. The effect on crop yields and the use of resources must be considered. The economic effects of changing a crop in existing crop rotation systems are five-fold (Barnard and Nix, 1979: 272):

(a) The gross margin of the break crop;

(b) The effect on the variable costs of the existing crops (costs can be reduced for subsequent crops);

(c) The beneficial effect on the yields of the following crops;

(d) The effect on the fixed cost structure of the farm.

2.2.4.3 Economic implications of researched crop rotation systems

Niksch (1988: 2) has analysed several crop rotation systems in the Riet River irrigation area. The following crop rotation system realised the highest profitability and satisfied the requirements for maintaining critical yields in the long run:

- maize 36 ha, cotton 15 ha, wheat 45 ha, potatoes 9 ha. The critical yields to be achieved for these crops in this rotation system are the following:

- maize 7,5 ton/ha, wheat 5,5 ton/ha, cotton 2,8 ton/ha, potatoes 27 ton/ha.

This crop rotation system gives a land utilisation percentage of 175 per cent on an annual basis. Niksch emphasised that it is unrealistic to go for a long-run 200 percent land utilisation.

Van der Walt (1988: 47) advocates a crop rotation system with a 175 % land utilisation for farmers with potato and peanut machinery. Each section represents 15 hectares, a quarter of the area under irrigation. In winter wheat is planted on three quarters with the remaining quarter lying fallow. In summer all sections are planted with peanuts and potatoes each on one section and late maize on the remaining two sections. If the farmer does not have the required peanut machinery, this crop can be replaced with cotton. Potatoes can, if necessary, be replaced by late maize.

Meiring (1989) has evaluated the economic profitability and the financial feasibility of alternative centre pivot irrigation systems for one crop rotation system of wheat, maize and cotton in the irrigation area below the P.K. le Roux Dam. With this specific crop rotation system the crops are planted on full circles. Price and production risks were incorporated in the analysis of economic profitability. The financial feasibility of the systems was analysed by considering the various financing methods available. The results indicated that the given crop rotation system, irrigated by different typical irrigation systems, is economically profitable, but not necessarily financially feasible.

De Klerk (1986) investigated various crop rotation systems under dry land conditions in the north-eastern Free State. A crop rotation system of potatoes-wheat-maize-maize has proved to be the most acceptable in the long-run in terms of profitability and risk, given the simulation model that was used as well as product prices.

2.2.4.4 Planning the crop rotation system

Having understood the principles of crop rotation systems and having knowledge of the effects of crops on each other and of the crop-soil relationships, thought can be given to the development of the planning of crop rotation systems. The following factors should be considered and incorporated in the planning process:

Climate; crops thriving in the areas; size and potential of the soil; occurrence of diseases; system design, capacity and management; relative prices of crop products; availability of labour; financial risk and capital requirements; markets; availability of implements; and availability of water.

- As discussed in the introductory chapter, the climate allows for a large variety of crops, but at the same time it is responsible for the crop yield variations over the years. It must be considered that within the area large climatic differences do occur, which affect the crop yields.

- The following cash crops are grown in the research area: wheat, peas, lucerne, maize, sweet maize, late maize, cotton, peanuts, potatoes, dry beans and soyabeans (RSA, 1987). The crop rotation systems are developed from the following crops: the annual winter crop, wheat, the annual summer crops, late maize, peanuts, cotton, dry beans, soyabeans and the perennial crop lucerne. These crops were identified during meetings with local farmers on the basis of their economic importance and the size of area planted with these crops.

- Size and potential of the available land. The soil in the research area mainly consists of Hutton and Oakleaf soil forms, varying in clay percentage from 5 to 20 percent. Meiring (1989) has shown that the clay percentage of the soil has irrigation cost implications. This research is concentrated on sandy soils with a water infiltration of minimum 40 mm per hour and a water holding capacity of 100 mm. The soils have an unrestricted depth of 1,2 m.

- The occurrence of diseases can restrict crop rotation systems. The effect of these diseases is dealt with for each crop in the crop rotation systems further on in this chapter.

- The crops planted are irrigated by different irrigation systems. Centre pivot systems predominate, but handlines and wheelmoves are used too.

- In practice the prices obtained for the crops are the main factors that motivate farmers in the short-run to plant the crops. The cyclical trends in crop prices, aggravated by irregular supply factors and inelastic demand conditions emphasise the need for planning crops and crop rotation systems on a long term basis. For given circumstances the long-term crop prices should determine the extent and intensity of crop plantings. As prices are subject to risk in the long run, the planning of crop and crop rotation systems must incorporate price risks.

- The availability, knowledge and experience of permanent and seasonal labour can restrict the implementation of certain crop rotation systems. Crops such as peanuts and cotton are very labour-intensive. Crop rotation systems with these crops included can restrict the size of the area planted with these crops. The present trend of higher labour wages without a corresponding increase in labour productivity is another factor to be considered in restricting labour-intensive crop rotation systems. The use of the automated irrigation systems reduces labour dependence in the irrigation of the crops, especially of importance where high irrigation water volumes to larger land sizes must be applied.

- Crops are capital-intensive in their production with the largest part of the required capital to be committed early in the season. Capital is usually made available in the form of short-term production credit accounts from commercial banks and local cooperatives. Adverse crop yields or price trends can restrict short-term profitability and negatively influence credit availability and cash-flow. The overall poor condition of agriculture and the monetary policy of the government restrict the flow of funds with relatively low interest rates to the agricultural sector.

- The long-term success of crop production depends on the marketing thereof. Only those crops must be produced for which the prices are relatively favourable and marketing costs are relatively low.

- Each crop rotation system requires a specific mechanisation system. A complete mechanisation system is essential in maintaining large-scale and long-term crop production. Each crop and crop rotation system require a specific combination of implements in a mechanisation system. The present high purchase costs and running costs necessitate the machinery to be financed over the length of their lifespan. The mechanisation system has a fixed and variable cost factor-maximum use of the system minimises system unit costs. In line with the objective to maximise profits and maintain financial feasibility, the farmer must find a balance between mechanisation needs and mechanisation costs. With the present poor financial situation of the farmers and the high purchase and running costs an uncontrolled acquisition of the mechanisation system for a planned crop rotation system cannot be justified. Crop rotation systems should be planned that maximise use of presently available implements.

- The water quotas are fixed at a given quantity of water per hectare per year. The farmers pay a fixed price in the form of a tariff for the actual quantity of water used. The present water quota in this area is determined at 11 000 cubic meter per listed hectare. This equalises to 1 100 mm/ha/yr. The majority of the sections are listed for 60 hectares which means an annual quota of 660 000 m^3 per section. The water tariff is determined at R200,00 /ha/yr or R0,01818/m^3. An additional 400 mm water per listed hectare is available against the maximum tariff. Water quotas are limited to be supplied within a year and cannot be carried over to the next year. Preplanning can make it possible to irrigate the summer crops from two different quotas.

2.2.4.5 Specific aspects of crop rotation systems

2.2.4.5.1 Wheat

Research has shown that in a crop rotation system where wheat is rotated with legumes (Kotze, 1983) the long-term effect is more profitable than in a no-legume wheat system. This type of crop rotation system generally results in higher soil fertility, less weeds and less diseases. The intensive soil cultivation can be eliminated and nitrogen fertilisation after legumes can be curtailed considerably. Wheat usually is the only winter crop available. Due to the relatively low temperatures in the winter, initial water consumption and evaporation are low. From an economical point of view it is recommended to plant full circles of wheat and have a rotating section laying fallow in summer.

2.2.4.5.2 Soyabeans

Soyabeans fit well in a crop rotation system which includes wheat. These rotation systems are selected for the following reasons: Firstly, soyabeans fix nitrogen for own needs and have a residual nitrogen benefit for the succeeding crop; secondly, soyabeans can utilise the residual fertilizer of the preceding crop well because nutrient requirements and rooting depth differ; thirdly, soyabeans and wheat can be planted with the same planter and can be harvested with the same harvester to maximise equipment utilisation. In discussions with farmers, it appears that they experience germination problems when the crop is planted early in December. By selecting the right cultivar, this problem can largely be overcome. The choice of the cultivar can do little about the extreme susceptibility of soya beans to hail damage. In comparison with dry beans, soyabeans have a lower gross margin. The low cost and relatively low gross margin of the crop, in comparison with other mid-summer planted crops, planted for cash flow reasons, can justify its planting.

2.2.4.5.3 Cotton

From a disease point of view, cotton does not always fit in a crop rotation system with crops such as peanuts and potatoes. Optimally it is best suited in a crop rotation system with wheat and maize. Cotton is a perennial crop and more than one economic harvest can be obtained in succeeding seasons. The high susceptibility to diseases has made this practice undesirable. In discussions with farmers, the farmers mentioned the extreme susceptibility of the crop to hail damage, wind damage and they experienced germination problems due to cold in the lower-lying parts in the research area. In a crop rotation system with cotton, long fallow periods must necessarily be included, as the crop is planted in the spring. Mainly on the basis of gross margins and growth periods of the different crops, the farmer must decide whether the inclusion of cotton justifies the long fallow period.

2.2.4.5.4 Peanuts

A well-planned crop rotation system can assure good peanut yields of high quality and restrict the occurrence of diseases. The peanut, as it is a legume, is able to provide most of its own nitrogen requirements by the activity of the nodular bacteria on the peanut roots, which fix atmospheric nitrogen and make it available to the plant. In addition the crop has a residual nitrogen effect on the next crop. A crop rotation system where peanuts are included, is restricted to soils with a clay percentage lower than 18 percent. Peanuts are reasonably sensitive to other crops and the following must be considered: firstly, best production is achieved in a crop rotation system with wheat and maize and prevent a crop rotation system with cotton, as this can induce seedling diseases; secondly, do not plant the crop after another legume to prevent eelworm infestation built-up, or plant on the same soil previously planted with peanuts. As peanuts are planted in early summer, it necessarily excludes a previous wheat crop. New cultivars of peanuts are being developed, which can be planted later in the season, but practical results have not yet been available. The gross margin of the crop must justify the resulting long fallow periods. For practical reasons the size of the crop plantings is limited to a quarter section.

2.2.4.5.5 Lucerne

Lucerne is an extremely advantageous crop for inclusion in a rotational system, as yields obtained with succeeding non-leguminous crops are particularly high. Lucerne increases the fertility of the soil by the ability to fix atmospheric nitrogen and improves the soil structure. Lucerne under irrigation can remain economically productive in a crop rotation system for four years. A shortcoming of lucerne, in comparison with cash crops, is the high initial establishment cost and the high water consumption. The high initial establishment costs are more than compensated for by the relatively large cash flow and cash flow distribution. The dual nature of lucerne as a cash crop in the form of the sale of hay and seed and as grazing for livestock reduces risk and uncertainty. For practical reasons, on the one hand the size of the crop plantings must be restricted, on the other hand, the cost of extra implements must be recovered. A decision was made to restrict the size to 30 hectares.

2.2.4.5.6 Late maize

Maize fits in well in a crop rotation system with other crops (Koekemoer, 1988). It is a particularly good antipode against root diseases in wheat. When late maize is planted in a crop rotation system, it is cultivated as a catch-crop after a winter crop of wheat and in that case short-growth cultivars must be planted. The choice of the herbicides for the maize must be adjusted to the planned next crop. Maize does not have specific crop rotation requirements and can be planted year after year. The variable market prices of the past few years have induced farmers to evaluate the maize plantings relatively to alternative summer cash crops.

2.2.4.5.7 Dry beans

Dry beans can replace soyabeans or late maize in crop rotation systems. As the beans are a legume, they can, by means of the nodular bacteria on the plant roots, fix nitrogen from the atmosphere and therefore are partially self-sufficient regarding nitrogen. The next crop profits from the residual nitrogen in the soil after the dry beans have been harvested. Dry beans are very susceptible to eelworm infestations. The built-up of infestations must be controlled either by a specific crop rotation system or chemically. Dry beans, wheat and soyabeans can be harvested contractually. The sensitivity of the crop to hail stress and demand restricts the size of the area planted with the crop to 30 hectares.

2.3 PROCEDURE

2.3.1 Application procedure for calibration and validation of the PUTU model

2.3.1.1 Introduction

The basic PUTU P9MZAB model was calibrated successfully for the Vaalharts irrigation area for wheat and maize on yields and water requirements (De Jager *et al.*, 1987). The complete data available on soils, climate, crops and irrigation (Bennie *et al.*, 1988) form the basis on which the calibration of the PUTU P9MZAB3 model on water requirements/yields relations for wheat, cotton, late maize and peanuts in the irrigation area below the P.K. le Roux Dam is done by the researcher. This model is validated by the researcher for lucerne, soyabeans and dry beans for the area.

The calibration process of the PUTU P9MZAB3 model started with the gathering of relevant and correct historical data. A decision was made to use published results of research tests (Bennie *et al.*, 1988). A complete description of these tests, complete data on yields, cumulative water consumption and initial soil water level and its change in the soil during the crop's growth period is used as the motivation for selecting these data.

2.3.1.2 Compilation of the subfiles

The first step in the calibration process is to compile crop factor, carry-over, irrigation and weather files for the crops on basis of the available complete data. It was decided to use the test results for the irrigation areas of both below Ramah and Sandvet in order to extend the data base. For wheat 7, peanuts 5, late maize 8 and cotton 3 complete data sets are available.

In the compilation of the crop factor files, specific attention must be given to enter the actual planting dates and the length of the specific crops growth season correctly.

Bennie *et al.*, (1988) do not indicate the dates at which the crops merge into the next crop stage. Doorenbos and Kassam, (1979) give in their report an interval of the average length of each crop stage for all the crops. In practice the length of the growing season is variable and depends partly on climatic conditions and cultivars. From the figures on the length of the crop stages in the above-mentioned report a ratio could be calculated between the length of the crop growth till flowering and the length of the crop growth from after flowering till the completion of maturation. The ratios are as follows: late maize 0,560-0,565; wheat 0,70-0,75; peanuts 0,73-0,76; cotton 0,60-0,65; potatoes 0,76-0,80; soyabeans 0,55-0,58 and dry beans 0,57-0,60. For lucerne this ratio is not used as the crop is cut several times during the flowering stage and no maturity or grain stage is entered. Initially an average crop factor from the crop factor intervals and an average crop response factor from the crop response factor intervals are obtained from the report as used in the crop factor files.

2.3.1.3 Calibration procedure of the model

Initially during the calibration procedure the model with the existing average crop factors and crop response factors is evaluated by comparing the water requirements and yield results with the actual test water requirements and yield results.

The simulated output concerning yield is expressed in percentages of a maximum yield and a target yield with which the simulated percentage is multiplied had to be determined. The target yield is formulated on the basis of average yields for each crop which the farmers achieved consensus on and the crop yield ranges for which the model is calibrated.

An effort is made to overcome the differences in these results, by means of a trial and error process by subsequently changing the average crop factors and crop response factors. The changes in the crop factors and crop response factors are made with the objective to optimise the results for all four crops simultaneously. The standard according to which the results are evaluated is of statistical nature where the regression of the simulated crop water requirements (SET) is measured and compared to the regression of the actual experimental water requirements (MET). The regression of the simulated crop yields (SY) is measured and compared to the regression of the actual experimental yields (MY). With the optimum determined crop factor and crop response factors the resulting crop files could be developed.

Given the above-mentioned optimum-determined crop response factors and crop factors, a statistical analysis of the regression lines between MET and SET and between MY and SY for wheat, late maize, peanuts and cotton is calculated and shown in Table 2.1. The following R^2 values are obtained for the relation between MET and SET: cotton 98 %, late maize 74 %, peanuts 96 % and wheat 47 %. The following R^2 values are obtained for the relation between MY and SY: cotton 96 %, late maize 38 %, peanuts 19 % and wheat 2 %. The R^2 value results of the four crops are considered satisfactory when taken into consideration that all four crops are simulated with the same model. The below average R^2 values for wheat can be explained by the fact that only wheat is a winter crop while the other crops are summer crops. The PUTU model is more accurate in simulating summer crops than winter crops. No satisfactory explanation could be given for this by dr. Singels, the developer of the model.

2.3.1.4 Validation procedure of the model

The crop factors and crop response factors which are used to obtain the "optimum" results are used for validation of the model and simulation of yields and water requirements.

For those crops for which no data was available on water requirements and yield relations, the supposition is made that if the P9MZAB model is calibrated satisfactorily for Vaalharts, Ramah and Sandvet irrigation areas for wheat, late maize, cotton and peanuts, the same model can be used with a certain degree of satisfaction for lucerne, soyabeans and dry beans. On basis of information on crop stages, crop growth length, crop factors and crop response factors from the Doorenbos report (Doorenbos and Kassam, 1979) the corresponding crop factor and crop response factor files could be compiled. The target yields and water consumption figures for these crops are used as a guidance for result evaluation. On the basis of experience obtained in the calibration of the crops for which data are available the crop response factors and crop factors could limitedly be adapted. The results obtained for these crops are however not as accurate as for the crops for which complete data are available.

Table 2.1 The equations and the corresponding R^2 values for the actual measured gross water requirements (MET) to the simulated gross water requirements (SET) and the actual measured yield (MY) to the simulated yield (SY) for cotton, late maize, peanuts and wheat in the irrigation area below the P.K. le Roux Dam

Crops	Equations	R^2
Cotton	MET = - 195 x SET + 1,163	0,979
Late maize	MET = - 375 x SET + 1,500	0,737
Peanuts	MET = - 173 x SET + 1,194	0,960
Wheat	MET = - 181 x SET + 4,100	0,470
Cotton	MY = - 75 x SY + 1,013	0,957
Late maize	MY = - 151 x SY + 2,857	0,380
Peanuts	MY = - 223 x SY + 1,538	0,187
Wheat	MY = - 150 x SY + 20,000	0,023

In Table 2.2 and Table 2.3 the yield response factors and the crop factors for the corresponding crop growth stages for the crops are given. For lucerne all the crop growth stages cannot be applied and are consequently adapted to the crop's growth characteristics.

Table 2.2 Yield response factors (ky) for the corresponding crop growth stages for alternative crops in the irrigation area below the P.K. le Roux Dam

Crops	Crop growth stages *							
	1	2	3	4	5	6	7	8
Wheat	0	0,10	0,10	0,10	0,25	0,45	0,0	0
Late maize	0	0,05	0,10	0,15	0,90	0,20	0,2	0
Cotton	0	0,20	0,25	0,30	0,65	0,55	0,0	0
Lucerne (E)	0	0,10	0,10	0,40	0,70	0,10	0,1	0
Lucerne (P)	0	0,10	0,10	0,30	0,70	0,10	0,1	0
Soyabeans	0	0,10	0,10	0,20	0,50	0,30	0,0	0
Dry beans	0	0,10	0,10	0,20	0,50	0,20	0,0	0
Peanuts	0	0,00	0,05	0,20	0,60	0,60	0,2	0

Table 2.3 Crop factors for the corresponding crop growth stages for alternative crops in the irrigation area below the P.K. le Roux Dam

Crops	Crop growth stages *							
	1	2	3	4	5	6	7	8
Wheat	0	0,3	0,75	1,10	1,20	1,00	0,65	0,2
Late maize	0	0,3	0,40	0,90	1,10	0,90	0,60	0,6
Cotton	0	0,3	0,40	0,90	1,10	1,10	0,75	0,2
Lucerne (E)	0	0,4	0,40	0,80	0,80	0,40	0,40	0,4
Lucerne (P)	0	0,5	0,50	0,80	0,80	0,50	0,50	0,5
Soyabeans	0	0,3	0,40	0,75	1,10	0,75	0,45	0,0
Dry beans	0	0,3	0,40	0,70	1,05	0,65	0,30	0,2
Peanuts	0	0,3	0,50	0,70	1,00	0,70	0,60	0,2

*- Crop growth stages explained as follows:
1-Sowing, 2-Establishment, 3-Development, 4-Mid season, 5- Flowering, 6-Grain filling, 7-Riping and 8-Resting.

- Lucerne (P) is lucerne under full production and Lucerne (E) is established lucerne.

In the actual simulation of the crop yields and corresponding water consumption figures over the past eleven years, only the optimum determined crop factor files are retained and used. The other three subfiles: irrigation, carry-over and weather files are constructed according to the specific requirements, applicable to the concerned area.

2.3.2 Application procedure for BEWAB

The required input data for the BEWAB program for the compilation of the irrigation files are obtained mainly from group discussions with the farmers and research reports (Meiring, 1989). The soils are predominantly of a sandy texture with a profile available water capacity of 100 mm. The irrigation cycle for these soils is determined at four days, based on minimising water run-off (Meiring, 1989: 96).

In the discussions the farmers were asked to achieve consensus on maximum, minimum and average crop yields over a period of ten years. The average crop yields are used largely as the target yields in the BEWAB program. The compilation of the irrigation files has been developed according to the irrigation scheduling of crops, determined by BEWAB for wheat, maize, peanuts, cotton and soyabeans. BEWAB has so far not been adapted for dry beans and lucerne. The compilation of irrigation files for these crops has been developed according to a simulated irrigation scheduling based on BEWAB or based on information supplied by the farmers. The scheduled water requirements, in turn, largely determine the required irrigation system capacity and a centre pivot system with a capacity of 12 mm per day has been found to be the minimum capacity requirements. It must be mentioned that the water schedule program is in net values and must be converted to gross values by the division of the application efficiency factor 0,85 (Meiring, 1989: 97).

2.3.3 Application procedure for PUTU

Besides the above-mentioned crop factor and irrigation files the carry-over files and the weather files still needed to be compiled. The farmers provided the information for the compilation of the carry-over files. Information is required of the planting dates and length of growth season and the soil depth and soil clay percentages. For practical reasons the soil is filled up to the full water profile level at the start of the growth season. Data on target yields, planting dates and length of growth season are given in Table 2.4.

Files with climatic data have been obtained from Glen in unprocessed form for the P.K. le Roux area. The files state complete weather data on minimum and maximum temperatures, rainfall, evaporation and sunshine duration on a daily basis for eleven years from 1978 up to 1989. Adjustments needed to be made to the format of the files to make them PUTU acceptable.

Having compiled all subfiles, the model was run repeatedly for each crop and each year. The crop yields and water requirements of the crop simulations are determined for each of the twelve or eleven succeeding years from 1978/1979 till 1989.

Table 2.4 Target crop yields (kg/ha), planting dates and length of growth season (days) for crops in the irrigation area below the P.K. le Roux Dam

Crops	Target crop Yields (kg/ha)	Planting dates	Length growth season (days)
Wheat	7 000	15/07	152
Late maize	9 000	15/12	151
Cotton	4 000	15/10	180
Peanuts	3 500	15/10	163
Soyabeans	3 000	15/12	140
Dry beans	2 250	15/12	112
Lucerne	23 000	15/03	365

2.3.4 Development of alternative crop rotation systems

2.3.4.1 Theoretically- and scientifically- developed crop rotation systems

The objective is to develop alternative crop rotation systems, with which the farmers in the research area can identify themselves. The Department of Agricultural Economics (Den Braanker, 1990) in cooperation with the Department of Agronomy at the University of the Orange Free State has developed scientifically based crop rotation systems for irrigation for this area, but it was decided to take into consideration certain limiting factors. No practical useful rotation systems could be developed without first consulting the farmers concerned.

To achieve the objective of developing practical useful rotation systems, meetings were arranged with farmers residing in the Ramah area. In the initial phase of the meetings with the farmers, the discussion was centered at obtaining the farmers' opinion on the proposed rotation systems. The farmers were shown the following six crop rotation systems for a 60 ha centre pivot irrigation system and a 150 per cent land utilisation:

Crop rotation systems on sandy and clay soils:

1. Wheat 60 ha, potatoes 30 ha, dry beans 30 ha
2. Wheat 60 ha, dry beans 30 ha, late maize 30 ha
3. Wheat 30 ha, dry beans 30 ha, potatoes 30 ha, lucerne 30 ha

Crop rotation systems on sandy soils:

4. Wheat 30 ha, dry beans 30 ha, peanuts 30 ha, cotton 30 ha, potatoes 30 ha
5. Wheat 30 ha, potatoes 30 ha, late maize 30 ha, peanuts 30 ha, cotton 30 ha

6. Wheat 30 ha, late maize 30 ha, dry beans 30 ha, peanuts 30 ha, cotton 30 ha

In addition crop rotation systems developed by Professor Bennie of the Department of Agronomy were shown. These crop rotation systems were also developed for a 60 ha centre pivot irrigation system and for different land utilisation percentages:

1. Wheat 40 ha, cotton 20 ha, late maize 20 ha, peanuts 20 ha
2. Wheat 40 ha, cotton 20 ha, peanuts 20 ha
3. Wheat 40 ha, cotton 20 ha, peanuts 20 ha, soyabeans 20 ha
4. Wheat 30 ha, lucerne 15 ha, peanuts 15 ha, cotton 15 ha, late maize 15 ha
5. Wheat 30 ha, cotton 30 ha, peanuts 30 ha
6. Wheat 60 ha, cotton 60 ha

Having been shown these crop rotation systems, the farmers were asked to comment on them. In general the farmers experienced no or few problems with these rotation systems, concerning the technical and agronomical aspects thereof.

2.3.4.2 Practical aspects of crop rotation systems

Considering the practical feasibility of the systems, the farmers expressed criticism on the long fallow periods. The long fallow periods were included to satisfy the principal requirements of crop rotation systems and to decrease the possibility of the occurrence of long-run management problems. The farmers defended their point of view on short or no fallow periods as follows: Due to their present financial position and the agricultural economical situation, they felt they were forced to plant the crops in close succession, irrespective of crop rotation principles, to achieve high land utilisation percentages on the short run. The present prices obtained for the various crops were another strong factor determining which crops would be planted and the extent of these crop plantings.

After having shown the farmers the proposed crop rotation systems and having obtained their critism on them, the farmers were asked what crop rotation systems they used themselves. It became clear that in consideration of the above-mentioned factors, the farmers did not use typical crop rotation systems. Rather, crop prices, machinery and labour restrictions and the mentioned economical and financial factors for each farmer individually determined how the irrigation area was utilised by the crops annually. Still, what appears was that the crops wheat, late maize and cotton were the predominant crops in the crop rotation systems used. Farmers try "new" crops if the prices thereof seem good and leave these crops in the next years if too many cultivation, labour, marketing or management problems are experienced.

In addition to the mentioned information obtained from the farmers, a need was felt to contact local extension officers. The practical knowledge and experience of these persons proved to be valuable and guided the development of the final crop rotation systems.

The objective of the development of crop rotation systems is not to select and develop systems that maximise long-run profits, but to develop systems that make it possible to analyse clearly the effect of crop changes within crop rotation systems on economic profitability and financial feasibility. Simple and uncomplicated crop rotation systems are favoured. The analysis is to be done over a ten-year period.

2.3.4.3 Crop rotation systems, crops, land utilisation percentages and mechanisation systems

Fourteen alternative crop rotation systems are developed on the basis of all the information obtained. The crop rotation systems are shown and the land utilisation percentages are indicated.

1. 60W60S : Wheat 60 ha, soyabeans 60 ha
   Land utilisation : 200 %

2. 60W60LM : Wheat 60 ha, late maize 60 ha
   Land utilisation : 200 %

3. 60W60LM60S : Wheat 60 ha, late maize 60 ha, soyabeans 60 ha
   Land utilisation : 200 %

In practice it is found that a continued crop rotation of wheat followed by late maize or soyabeans every year is and can be used.

4. 60W45LM15D : Wheat 60 ha, late maize 45 ha, dry beans 15 ha
   Land utilisation : 200 %

5. 45W45LM15P : Wheat 45 ha, late maize 45 ha, peanuts 15 ha
   Land utilisation : 175 %

In the two previous crop rotation systems, the effect of partially substituting late maize with either dry beans or peanuts can be evaluated.

6. 60W60LM60C Wheat 60 ha, late maize 60 ha, cotton 60 ha
   Land utilisation : 150 %

7. 60W60S60C : Wheat 60 ha, soyabeans 60 ha, cotton 60 ha
   Land utilisation : 150 %

In the two previous crop rotation systems the effect of cotton in crop rotation systems of wheat with either late maize or soyabeans can be evaluated.

8. 60W45LM15D60C : Wheat 60 ha, late maize 45 ha, dry beans 15 ha, cotton 60 ha
   Land utilisation : 150 %

9. 45W45LM15P60C : Wheat 45 ha, late maize 45 ha, peanuts 15 ha, cotton 60 ha
   Land utilisation : 137,5 %

In the previous two crop rotation systems the effect of cotton in the crop rotation systems with late maize partially substituted by dry beans or peanuts can be evaluated.

10. 30W30S30L : Wheat 30 ha, soyabeans 30 ha, lucerne 30 ha
    Land utilisation : 200 %

11. 30W30LM30L : Wheat 30 ha, late maize 30 ha, lucerne 30 ha
    Land utilisation : 200 %

12. 30W30S30LM30L : Wheat 30 ha, soyabeans 30 ha, late maize 30 ha, lucerne 30 ha
    Land utilisation : 200 %

In the three previous crop rotation systems the effect of lucerne in crop rotation systems of wheat, and with either late maize or soyabeans can be evaluated.

13. 30W30LM30C30L : Wheat 30 ha, late maize 30 ha, cotton 30 ha, lucerne 30 ha
    Land utilisation : 175 %

14. 30W30S30C30L : Wheat 30 ha, soyabeans 30 ha, cotton 30 ha, lucerne 30 ha
    Land utilisation : 175 %

In the two previous crop rotation systems the effect of lucerne in crop rotation systems of wheat and cotton with either late maize or soyabeans can be evaluated.

The required mechanisation system for each crop rotation system is given in Table 2.5.

2.3.4.4 Crop cultivation procedures

2.3.4.4.1 Wheat

The procedure starts with preparing the soil for wheat planting. The previous crop residue is slashed, after which the soil is disced and ploughed. Fertilizer is spread and incorporated into the soil with another disc operation. The final seedbed is prepared with the field cultivator after which the wheat is planted with the planter in early July. Weeds are controlled by the application of herbicides by sprayer. Insecticides are applied by contractual aerial spraying to control pests. Harvest and transport of the crop are done on contract in late November or early December. The remaining residue is either burned or baled.

Table 2.5 Mechanisation systems for the alternative crop rotation systems in the irrigation area below the P.K. le Roux Dam, 1990

Crop rotation* system	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Tractor 35 kw	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Tractor 52 kw	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Tractor 71 kw	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Offset (disc)	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hay baler	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ploughs 3 furrow	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ploughs 4 furrow	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Fertilizer spreader	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Slasher	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Field cultivator	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Wheat planter	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sprayer	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Trailer	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Maize planter	0	1	1	1	1	1	1	1	1	1	1	1	1	1
Subsoil chisel plough	0	1	1	1	1	1	1	1	1	1	1	1	1	1
Mower	0	0	0	1	0	0	0	1	0	1	1	1	1	1
Dry bean picker	0	0	0	1	0	0	0	1	0	0	0	0	0	0
Peanut digger	0	0	0	0	1	0	0	0	1	0	0	0	0	0
Peanut picker	0	0	0	0	1	0	0	0	1	0	0	0	0	0
Row-crop cultivator	0	0	0	0	0	1	1	1	1	0	0	0	1	1
Hay rake	0	0	0	0	0	0	0	0	0	1	1	1	1	1

* Crop rotaion systems:

1= 60W60S, 2= 60W60LM, 3= 60W60LM60S, 4= 60W45LM15D, 5= 45W45LM15P, 6= 60W60LM60C, 7= 60W60S60C, 8= 60W45LM15D60C, 9= 45W45LM15P60C, 10= 30W30S30L, 11= 30W30LM30L, 12= 30W30S30LM30L, 13= 30W30LM30C30L, 14= 30W30S30C30L

2.3.4.4.2 Soyabeans

Due to the little time available before the next crop, soyabeans must be planted in middle December and the soil must be prepared quickly. Ploughing is a relatively time consuming cultivation process and both ploughs must therefore be used. The final seedbed is prepared with the field cultivator, after which the seed is planted. Herbicides and Rhizobium inoculation vaccine are applied through the irrigation system to control weeds and to inoculate the seed. Insecticides are applied by contractual aerial spraying to control pests. Harvest and transport of the soyabeans are by contract in April. The residue of the soyabeans is baled and removed.

2.3.4.4.3 Late Maize

Late maize requires few machinery operations. Two weeks after the harvest of the previous wheat crop the residue is burned and the late maize can be planted middle December without a previous soil cultivation. After the emergence of the maize the rows in between the maize are ripped with the subsoil chisel plough. The irrigation system is used to apply the fertilizer. A sprayer is used to apply herbicides and insecticides. The crop is harvested and transported on contract in April.

2.3.4.4.4 Cotton

Cotton requires numerous operations. The residue of the previous crop is slashed and ploughed into the soil. Weeds are controlled by the application of herbicides with the sprayer. The final seed bed is prepared with a single disc and field cultivator operations. The cotton seed is planted middle October with the maize planter. The irrigation system is used to apply the fertilizer. Weeds are again controlled by a mechanical hoe operation with the row-crop cultivator. The rows in between the cotton are ripped with the subsoil cultivator. Insects are controlled twice by the application of insecticides with the sprayer. Another hoe operation is required, this time manually. The crop is harvested mechanically by contractors in April. Contractors also transport the crop.

2.3.4.4.5 Dry beans

The previous crop residue is burned and ploughed into the soil. The seedbed is prepared with the field cultivator, after which the seed is planted with the maize planter in middle December. The irrigation system is used to apply the inoculation vaccine Rhizobium to the seed after planting. Herbicides to control and prevent weeds are also applied through the irrigation system. The system is also used to apply the fertilizer. Pests are controlled by insecticide application by a single contractual aerial spraying. When the crop is ready for harvesting in April, it is cut with a mower and at the same time placed into rows, after which the crop is picked up and picked with the dry bean picker. The dry beans are transported contractually.

2.3.4.4.6 Peanuts

Peanuts require relatively many operations. The previous crop residue is slashed and incorporated into the soil with a disc and plough operation. A possible hard subsoil layer is removed with a rip action using the subsoil chisel plough. The final seedbed is prepared with the field cultivator. In middle October the seed is planted using the modified maize planter. Pests are controlled by the application of insecticides by using the sprayer. When the peanuts are ready for harvesting, usually in April, the peanuts are dug up using the peanut digger. The plants are placed into heaps by seasonal labourers. The plants are then picked mechanically using the peanut picker. The peanuts are finally transported contractually to the Christiana Cooperative for contractual shelling and grading. The residual hay is baled and sold.

2.3.4.4.7 Lucerne

The lucerne seedbed must be prepared well before planting. The previous crop residue is slashed after which the soil is ploughed once, ripped once with the subsoil chisel plough and finally prepared with the field cultivator. The seed is planted with the modified maize planter in March. The Rhizobium vaccine to inoculate the seed is applied through the irrigation system. Lucerne is cut in its flowering stage, six times per season, from September till late March. The crop is cut with the mower, left to dry, raked once or twice with the hay rake, then baled with the baler and transported to the shed or immediately transported by contractors to the cooperative. The same procedure is then repeated six times per season.

2.3.4.5 Analysis of water requirements

The water quotas are made available annually to the farmers for the year from March 1st to February 28th. All the crops, except lucerne and wheat, do not grow within this tax-year period, therefore in the allocation of the water to the crops in the crop rotation system, distinction must be made from which quotas the crops are irrigated. The calculation is based on the distinction of total gross water requirements before and after the end of the tax year for the simulated crop yields for the period of eleven years.

The farmers received a standard quota of 11 000 m^3 water per ha for the tax year. The area irrigated by the centre pivot irrigation system covers 60 ha. Initially a total of 660 000 m^3 water is available per tax year per irrigated area. Additional water can be purchased when available to a maximum of 4 000 m^3 water per ha. A maximum quota of 900 000 m^3 is then available per tax year per irrigated area. The gross water requirements of the crop rotation systems are determined by firstly calculating for each crop the separate total crop gross water requirements by multiplication of the gross water requirements of the crops with the size of area irrigated of the specific crop for each crop rotation system, and secondly, by adding the separate total crop gross water requirements for each crop rotation system. The following equation (2.4) is used:

$$GWRCRS_t = \Sigma(GWRC_{at} \times AS_a) \quad (2.4)$$

where:

$GWRCRS_t$ = gross water requirements of the crop rotation system in year t

$GWRC_{at}$ = gross water requirements of crop a in year t

AS_a = size of land section for crop a

a = crops planted 1 to 4

t = year 1 to 10

The gross water requirements of the crop rotation systems are then compared with the maximum water quotas. The following equations are used (2.5).

$$DSs_t = WQs - GWRCRS_t \quad (2.5)$$

$$DSm_t = WQm - GWRCRS_t \quad (2.6)$$

where:

DSs_t = deficit or surplus of gross water from standard quota in year t

DSm_t = deficit or surplus of gross water from maximum quota in year t

WQs = standard available water quota

WQm = maximum available water quota

$GWRCRS_t$ = gross water requirements of the crop rotation system in year t

2.4 RESULTS AND DISCUSSION OF RESULTS

2.4.1 Crop yields and gross irrigation water requirements

The simulated gross water requirements and yields for wheat, late maize, peanut, cotton, dry bean, soyabeans, lucerne (establishment) and lucerne (full production) for eleven succeeding years are shown in Tables 2.6 and 2.7.

Table 2.6 Simulated gross water requirements and yields for wheat, late maize, peanuts and cotton from 1978/79 to 1989/90 per hectare in the irrigation area below the P.K. le Roux Dam

	WHEAT		LATE MAIZE	
Year	Gross water requirements (mm)	Yield (Kg)	Gross water requirements (mm)	Yield (Kg)
1978/79	819,6	6 720	718,7	8 730
1979/80	735,8	6 650	727,6	8 550
1980/81	746,9	6 650	641,6	8 550
1981/82	773,0	6 790	688,7	8 550
1982/83	761,6	6 510	836,2	8 460
1983/84	781,0	6 790	774,1	8 460
1984/85	745,1	6 650	695,6	8 550
1985/86	783,2	6 440	734,5	8 550
1986/87	786,8	6 580	718,6	8 550
1987/88	710,4	6 790	569,9	8 640
1988/89	716,1	6 790	575,1	8 730
1989/90	762,0	6 790	000,0	0 000
Average	760,100	6 679,000	698,20	8 588,000
St.dev.	31,320	121,100	79,20	84,080
CF.var.	4,120	1,813	11,34	0,979
	PEANUTS		COTTON	
1978/79	1 025,00	3 360	1 196	3 760
1979/80	979,60	3 185	1 145	3 600
1980/81	886,90	3 465	1 039	3 840
1981/82	985,00	3 150	1 063	3 520
1982/83	1 102,70	2 905	1 261	3 440
1983/84	996,70	3 010	1 132	3 440
1984/85	994,00	3 395	1 147	3 800
1985/86	986,90	3 080	1 155	3 520
1986/87	1 057,20	3 325	1 181	3 720
1987/88	849,50	3 395	851	3 840
1988/89	812,70	3 290	951	3 800
Average	970,500	3 230,000	1 102,30	3 661,000
St.dev.	89,220	180,000	117,90	160,400
CF.var.	8,987	5,573	10,74	4,389

Table 2.7 Simulated gross water requirements and yields for dry beans, soyabeans, lucerne establishment and full production from 1978/79 to 1988/89 per hectare in the irrigation area below the P.K. le Roux Dam

	DRY BEANS		SOYABEANS	
Year	Gross water requirements (mm)	Yield (Kg)	Gross water requirements (mm)	Yield (Kg)
1978/79	541,6	2 138	647,5	2 820
1979/80	506,8	2 003	632,9	2 670
1980/81	468,9	2 003	593,6	2 670
1981/82	549,1	2 025	632,2	2 700
1982/83	602,1	1 980	741,2	2 640
1983/84	572,7	2 025	678,9	2 730
1984/85	497,5	2 047	628,8	2 700
1985/86	642,8	2 047	660,1	2 750
1986/87	528,4	2 003	653,9	2 670
1987/88	421,1	2 070	504,5	2 730
1988/89	428,7	2 115	521,1	2 820
Average	514,500	2 040,000	627,90	2 715,000
St.dev.	68,730	49,350	67,36	59,800
CF.var.	13,360	2,419	10,73	2,202
	LUCERNE (FULL PRODUCTION)		LUCERNE (ESTABLISHMENT)	
1978/79	1 397	21 850	1 317	21 390
1979/80	1 243	20 930	1 206	20 240
1980/81	1 265	21 850	1 220	21 390
1981/82	1 285	21 390	1 256	20 930
1982/83	1 307	20 930	1 312	20 240
1983/84	1 310	21 160	1 285	20 470
1984/85	1 254	19 780	1 248	19 320
1985/86	1 341	21 620	1 313	20 930
1986/87	1 377	21 620	1 346	20 930
1987/88	1 026	21 850	1 002	20 390
1988/89	1 327	21 850	1 130	21 620
Average	1 285,000	21 350,000	1 239,000	20 805,00
St.dev.	98,600	632,540	100,160	685,100
CF.var.	7,673	2,962	8,084	3,293

The following average yields and gross water requirements are obtained:

Wheat	760 mm/ha,	6 679 kg/ha
Late maize	698 mm/ha,	8 588 kg/ha
Peanuts	971 mm/ha,	3 230 kg/ha
Cotton	1 102 mm/ha,	3 661 kg/ha
Dry beans	515 mm/ha,	2 040 kg/ha
Soyabeans	628 mm/ha,	2 715 kg/ha
Lucerne (full production)	1 285 mm/ha,	21 350 kg/ha
Lucerne (establishment)	1 239 mm/ha,	20 805 kg/ha.

The variation between the gross water requirements of the crops within the years is caused by the changing weather conditions, particularly rainfall. The high rainfall for the 1987/1988 season can clearly be deducted from the low gross water requirements for that season. Wheat requires relatively high gross water requirements due to low or no rainfall during the winter.

For all the crops the value of the coefficient of variation of the gross water requirements is consistently higher than the value of the coefficient of variation of the yields. This result conforms with results obtained in the research by Botes (1990) and Meiring (1989). The PUTU model is primarily an irrigation model, where the growth of the crop is mainly influenced by the timing and the quantity of rainfall and irrigation. The following order of crops indicate the ranking order of gross water requirements from the highest to the lowest: lucerne, cotton, peanuts, wheat, late maize, soyabeans and dry beans. On the basis of these gross water requirements the irrigation variable costs are calculated.

2.4.2 Comparison of the total gross water requirements of the alternative crop rotation systems with the available water quotas

The total gross water requirements of the crop rotation systems are subtracted from the standard (660 000 m^3) and maximum available water quota (900 000 m^3) to determine the gross water surplus or deficit for each crop rotation system. In Table 2.8 the results on the number of deficit years for either the standard and maximum quota are summarised. In the annexure in Tables 2.9 to 2.15 for each crop rotation system the total gross water requirements, total water surplus or deficit for the maximum quota and water surplus or deficit for the maximum quota per hectare for eleven years are shown. The following are two-year crop rotation systems: 60W60LM60S, 60W60lM60C, 60W60S60C, 60W45LM15D60C, 45W45LM15P60C, 30W30S30LM30L, 30W30LM30C30L and 30W30S30C30L. Systems 60W60S, 60W60LM, 60W45LM15D, 45W45LM15P, 30W30S30L and 30W30LM30L are one-year crop rotation systems.

The results indicate that only crop rotation systems 45W45LM15P, 30W30S30L, 30W30LM30L, 30W30S30LM30L, 30W30S30C30L and 30W30LM30C30L can meet the gross water requirements for all the years from the maximum quota. For no crop rotation systems the standard water quota is sufficient. For crop rotation systems including cotton the second year requires less water due to the relatively long fallow period before cotton is planted and therefore, in the second year, the water requirements can be met from the standard quota, but not in the first year. It is significant to note that in spite of the high water requirements of lucerne, this crop is included in all the crop rotation systems for which the gross water requirements can be met. The absolute water requirements are high for the crop relative to other crops but in relation to the length in months the water requirements for lucerne are relatively low. The land utilisation percentages of these crop rotation systems vary from between 137,5 and 200 percent and therefore the land utilisation percentage as such is not an indication of whether the gross water requirements can be met. The number of hectares planted, the gross water requirements and the relative distribution of water during the growth season are the main factors determing whether the gross water requirements can be met.

Table 2.8 Number of deficit years for standard and maximum quota for the crop rotation systems in the irrigation area below the P.K. le Roux Dam

No	Crop rotation system	Number of deficit years for standard quota		Number of deficit years for maximum quota	
		year 1	year 2	year 1	year 2
1.	60W60S	11	11	1	1
2.	60W60LM	11	11	5	5
3.	60W60LM60S	11	11	5	1
4.	60W45LM15D	11	11	2	1
5.	45W45LM15P	11	11	0	0
6.	60W60LM60C	10	11	2	0
7.	60W60S60C	11	6	3	0
8.	60W45LM15D60C	11	4	4	0
9.	45W45LM15P60C	11	6	8	0
10.	30W30S30L	11	11	0	0
11.	30W0LM30L	11	11	0	0
12.	30W30S30LM30L	11	11	0	0
13.	30W30LM30C30L	9	10	0	0
14.	30W30S30C30L	9	10	0	0

2.5 SUMMARY

In order to consider the effect of production risk on crop yields and crop gross water requirements accurate and comparable data over a period of time for the irrigation area below the P.K. le Roux Dam are required. The lack of these data necessitated them to must be simulated.

The PUTU P9MZAB3 model is calibrated and evaluated on the basis of available crop, soil and weather data for the research area. Subsequently the calibrated model is used in combination with a predetermined irrigation schedule (BEWAB) to generate yields and gross water requirements for the following crops for a period of eleven consecutive years: wheat, late maize, cotton, peanuts, soyabeans, dry beans and lucerne.

The crop rotation systems practised is one of the most important factors influencing the viability of irrigation farming. The lack of adequate information on crop rotation systems necessitated the development of these systems. According to economical, practical and agronomical factors, fourteen typical crop rotation systems are developed that run over a period of ten years. The systems are developed for 60 hectares under irrigation by centre pivots on predominantly sandy soils in the irrigation area below the P.K. le Roux Dam. For each crop rotation system a corresponding mechanisation system is developed.

For the alternative crop rotation systems the corresponding gross water requirements are estimated on basis of simulated crop gross water requirements over the period of eleven consecutive years. In a final analysis the simulated gross water requirements for each crop rotation system for the eleven years are compared to the annual available standard and maximum water quota.

The results indicate that only six crop rotation systems (numbers 5, 10, 11, 12, 13 and 14) can meet their gross water requirements for all the years from the maximum quota and that for no crop rotation system the standard water quota is sufficient.

2.6 RECOMMENDATIONS

The crops used in the crop rotation systems, are only crops selected on basis of their economic importance and their use by the farmers. More crops, such as potatoes, peas and sweet maize can be included in future research.

The proposed crop rotation systems do not comprise all the possible system combinations that can be devised on the basis of the available crops. If more crops are available, more extensive research is possible.

This research is limited to the irrigation area below the P.K. le Roux Dam. Research should be extended to other important South African irrigation areas.

ANNEXURE

Tables 2.9 to 2.15 show for the 14 crop rotation systems from 1978/79 to 1988/89 the total water requirements, total water or deficit and water surplus or deficit per hectare.

Table 2.9 Total water requirements, total water surplus or deficit and water surplus or deficit per hectare from 1978/79 to 1988/89 for the crop rotation systems 60W60LM and 60W60S in the area below the P.K. le Roux Dam

	* TWR[1]	SD[1]	SD/HA[1]	TWR[2]	SD[2]	SD/HA[2]
CROP ROTATION SYSTEM 60W60LM (m^3)						
1978/79	880270	19730	328	880270	19730	328
1979/80	821350	78650	1310	821350	78650	1310
1980/81	810790	89210	1486	810790	89210	1486
1981/82	842830	57170	952	842830	57170	952
1982/83	901960	-1960	-32	901960	-1960	-32
1983/84	880170	19830	330	880170	19830	330
1984/85	824340	75660	1261	824340	75660	1261
1985/86	863920	36080	601	863920	36080	601
1986/87	864400	35600	593	864400	35600	593
1987/88	728970	171030	2850	728970	171030	1850
1988/89	741490	158510	2641	741490	158510	2641
CROP ROTATION SYSTEM 60W60S (m^3)						
1978/79	922980	-22980	-383	922980	-22980	-383
1979/80	878180	21820	363	878180	21820	363
1980/81	840870	59130	985	840870	59130	985
1981/82	872400	27600	460	872400	27600	460
1982/83	958990	-58990	-983	958990	-58990	-983
1983/84	938900	-38900	-648	938900	-38900	-648
1984/85	864440	35560	592	864440	35560	592
1985/86	901970	-1970	-32	901970	-1970	-32
1986/87	903220	-3220	-53	903220	-3220	-53
1987/88	770630	129370	2156	770630	129370	2156
1988/89	788790	111210	1853	788790	111210	1853

* - TWR is the total gross water requirements for the crop rotation systems per 60 hectares
- SD is the gross water surplus (+) or deficit (-) when subtracting the total gross water requirements from the available maximum water quota for 60 hectares
- SD/ha is the gross water surplus (+) or deficit (-) when subtracting the total gross water requirements from the available maximum water quota per hectare
- $Year_1$ refers to the first year and $year_2$ to the second year of the crop rotation systems

Table 2.10 Total water requirements, total water surplus or deficit and water surplus or deficit per hectare from 1978/79 to 1988/89 for the crop rotation systems 60W60LM and 60W60LM60C in the irrigation area below the P.K. le Roux Dam

	* TWR[1]	SD[1]	SD/HA[1]	TWR[2]	SD[2]	SD/HA[2]
CROP ROTATION SYSTEM 60W60LM (m^3)						
1978/79	914290	-14290	-238	888950	11050	184
1979/80	879590	20410	340	819940	80060	1334
1980/81	842070	57930	965	809590	90410	1506
1981/82	883710	16290	271	831520	68480	1141
1982/83	960400	-60400	-1006	900550	-550	-9
1983/84	943140	-43140	-7185	875940	24060	401
1984/85	865000	35000	583	823780	76220	1270
1985/86	922230	-22230	-370	843670	56330	9388
1986/87	903220	-3220	-53	864400	35600	593
1987/88	770700	129300	2155	728900	171030	2851
1988/89	784760	115240	1920	745520	154480	2574
CROP ROTATION SYSTEM 60W60LM60C (m^3)						
1978/79	932650	-32650	-544	709000	191000	3183
1979/80	844130	55870	931	702340	197660	3294
1980/81	817280	82720	1378	648350	251650	4194
1981/82	835400	64600	1076	675100	224900	3748
1982/83	927510	-27510	-458	791500	108500	1808
1983/84	899300	7000	116	717310	182690	3044
1984/85	858370	41630	693	694300	205700	3428
1985/86	884170	15830	263	693760	206240	3437
1986/87	896090	3910	65	714130	185870	3097
1987/88	681190	218810	3646	591310	308609	5144
1988/89	757780	142220	2370	601610	298390	4973

* - TWR is the total gross water requirements for the crop rotation systems per 60 hectares
- SD is the gross water surplus (+) or deficit (-) when subtracting the total gross water requirements from the available maximum water quota for 60 hectares
- SD/ha is the gross water surplus (+) or deficit (-) when subtracting the total gross water requirements from the available maximum water quota per hectare
- $Year_1$ refers to the first year and $year_2$ to the second year of the crop rotation systems

Table 2.11 Total water requirements, total water surplus or deficit and water surplus or deficit per hectare from 1978/79 to 1988/89 for the crop rotation systems 60W60S60C and 60W45LM15D in the irrigation area below the P.K. le Roux Dam

	* TWR[1]	SD[1]	SD/HA[1]	TWR[2]	SD[2]	SD/HA[2]
CROP ROTATION SYSTEM 60W60S60C (m^3)						
1978/79	924000	-24000	-400	675000	225000	3750
1979/80	845520	54480	908	644100	255900	4265
1980/81	818520	81480	1358	617090	282910	4715
1981/82	846780	53220	887	634260	265740	4429
1982/83	928920	-28920	-482	733080	166920	2782
1983/84	903480	-3480	-58	654360	245640	4094
1984/85	858900	41100	685	653640	246360	4106
1985/86	881700	18300	305	635460	264540	4409
1986/87	896100	3900	65	675360	224640	3744
1987/88	681240	218760	3646	549600	350400	5840
1988/89	753720	146280	2438	558360	341640	5694
CROP ROTATION SYSTEM 60W45LM15D (m^3)						
1978/79	897120	2880	48	897120	2880	48
1979/80	845050	54950	915	845050	54950	915
1980/81	814640	85360	1422	814640	85360	1422
1981/82	852690	47310	788	852690	47310	788
1982/83	923870	-23870	-397	923870	-23870	-397
1983/84	907450	-7450	-124	907450	-7450	-124
1984/85	834710	65290	1088	834710	65290	1088
1985/86	873490	26510	441	873490	26510	441
1986/87	874700	25300	421	874700	25300	421
1987/88	747690	152310	2538	747690	152310	2538
1988/89	763530	136470	2274	763530	136470	2274

* - TWR is the total gross water requirements for the crop rotation systems per 60 hectares
- SD is the gross water surplus (+) or deficit (-) when subtracting the total gross water requirements from the available maximum water quota for 60 hectares
- SD/ha is the gross water surplus (+) or deficit (-) when subtracting the total gross water requirements from the available maximum water quota per hectare
- $Year_1$ refers to the first year and $year_2$ to the second year of the crop rotation systems

Table 2.12 Total water requirements, total water surplus or deficit and water surplus or deficit per hectare from 1978/79 to 1988/89 for the crop rotation systems 45W45LM15P and 60W45LM15D60C in the irrigation area below the P.K. le Roux Dam

	* TWR^{1}	SD^{1}	SD/HA^{1}	TWR^{2}	SD^{2}	SD/HA^{2}
CROP ROTATION SYSTEM 45W45LM15P (m^3)						
1978/79	846040	53960	899	846040	53960	899
1979/80	804170	95830	1597	804170	95830	1597
1980/81	764310	135690	2261	764310	135690	2261
1981/82	801980	98020	1633	801980	98020	1633
1982/83	885970	-14030	233	885970	14030	233
1983/84	870690	293100	4885	870690	293100	4885
1984/85	797320	102680	1711	797320	102680	1711
1985/86	824520	75480	1258	824520	75480	1258
1986/87	835550	64450	1074	835550	64450	1074
1987/88	699590	200410	3340	699590	200410	3340
1988/89	714270	185730	3095	714270	185730	3095
CROP ROTATION SYSTEM 60W45LM15D60C (m^3)						
1978/79	942310	-42310	-705	673520	226480	3774
1979/80	858340	41660	694	659510	240490	4008
1980/81	825980	74020	1233	613420	286580	4776
1981/82	847760	52240	870	643030	256970	4282
1982/83	937220	-37220	-620	746670	153330	2555
1983/84	908300	-8300	-138	676860	223140	3719
1984/85	885110	14890	248	637830	262170	4369
1985/86	896280	3720	62	653160	246840	4114
1986/87	904210	-4210	-70	677490	222510	3708
1987/88	690020	209980	3499	559540	340460	5674
1988/89	775180	124820	2080	558960	341040	5684

* - TWR is the total gross water requirements for the crop rotation systems per 60 hectares
- SD is the gross water surplus (+) or deficit (-) when subtracting the total gross water requirements from the available maximum water quota for 60 hectares
- SD/ha is the gross water surplus (+) or deficit (-) when subtracting the total gross water requirements from the available maximum water quota per hectare
- Year$_1$ refers to the first year and year$_2$ to the second year of the crop rotation systems

Table 2.13 Total water requirements, total water surplus or deficit and water surplus or deficit per hectare from 1978/79 to 1988/89 for the crop rotation systems 45W45LM15P60C and 30W30S30L in the irrigation area below the P.K. le Roux Dam

	* TWR[1]	SD[1]	SD/HA[1]	TWR[2]	SD[2]	SD/HA[2]
CROP ROTATION SYSTEM 45W45LM15P60C (m^3)						
1978/78	1008180	-108180	-1803	679520	220480	3674
1979/80	917520	-17520	-292	665340	234660	3911
1980/81	892330	7670	127	610510	289490	4824
1981/82	905780	-5780	-96	650180	249820	4163
1982/83	1007540	-107540	-1792	752760	147240	2454
1983/84	982110	-82110	-1368	683650	216350	3605
1984/85	936460	-36460	-607	660860	239140	3985
1985/86	956320	-56320	-938	659740	240260	4004
1986/87	976580	-76580	-1276	683990	216010	3600
1987/88	752680	147320	2455	555340	344660	5744
1988/89	825330	74670	1244	567180	332820	5547
CROP ROTATION SYSTEM 30W30S30L (m^3)						
1978/79	848580	51420	857	859560	40440	674
1979/80	775680	124320	2072	787200	112800	1880
1980/81	774180	125820	2097	785310	114690	1911
1981/82	798750	101250	1687	808380	91620	1527
1982/83	845330	54670	911	844880	55120	918
1983/84	818290	81710	1361	826270	73730	1228
1984/85	786390	113610	1893	789540	110460	1841
1985/86	825950	74050	1234	835070	64930	1082
1986/87	839360	60640	1010	848960	51140	852
1987/88	665650	234350	3905	673330	226670	3777
1988/89	710220	189780	3163	770640	129360	2156

* - TWR is the total gross water requirements for the crop rotation systems per 60 hectares
- SD is the gross water surplus (+) or deficit (-) when subtracting the total gross water requirements from the available maximum water quota for 60 hectares
- SD/ha is the gross water surplus (+) or deficit (-) when subtracting the total gross water requirements from the available maximum water quota per hectare
- $Year_1$ refers to the first year and $year_2$ to the second year of the crop rotation systems

Table 2.14 Total water requirements, total water surplus or deficit and water surplus or deficit per hectare from 1978/79 to 1988/89 for the crop rotation systems 30W30LM30L and 30W30S30LM30L in the irrigation area below the P.K. le Roux Dam

	* TWR[1]	SD[1]	SD/HA[1]	TWR[2]	SD[2]	SD/HA[2]
CROP ROTATION SYSTEM 30W30LM30L (m^3)						
1978/79	869940	30060	501	880920	19080	318
1979/80	804100	95900	1598	815620	84830	1406
1980/81	789220	110780	1846	800350	99650	1660
1981/82	813540	86460	1441	823170	76830	1280
1982/83	873840	26160	436	873390	26610	443
1983/84	847660	52340	872	855640	44360	739
1984/85	806440	93560	1559	809590	90410	1506
1985/86	844970	55030	917	854090	45910	765
1986/87	858770	41230	687	868370	31630	527
1987/88	686480	213520	3558	694160	205840	3430
1988/89	733780	166220	2770	794290	105710	1763
CROP ROTATION SYSTEM 30W30S30LM30L (m^3)						
1978/79	852920	47080	784	876570	23430	390
1979/80	774980	125020	2083	816320	83680	1394
1980/81	773580	126420	2107	800950	99050	1650
1981/82	793100	106900	1781	828820	71180	1186
1982/83	844620	55380	923	874100	25900	431
1983/84	816180	83820	1397	857760	42240	704
1984/85	786110	113890	1898	809870	90130	1502
1985/86	815820	84180	1403	864220	35780	596
1986/87	839360	60640	1010	868370	31630	527
1987/88	665620	234380	3906	694200	205800	3430
1988/89	712240	187760	3129	792280	107720	1795

* - TWR is the total gross water requirements for the crop rotation systems per 60 hectares
- SD is the gross water surplus (+) or deficit (-) when subtracting the total gross water requirements from the available maximum water quota for 60 hectares
- SD/ha is the gross water surplus (+) or deficit (-) when subtracting the total gross water requirements from the available maximum water quota per hectare
- $Year_1$ refers to the first year and $year_2$ to the second year of the crop rotation systems

Table 2.15 Total water requirements, total water surplus or deficit and water surplus or deficit per hectare from 1978/79 to 1988/89 for the crop rotation systems 30W30LM30C30L and 30W30S30C30L in the irrigation area below the P.K. le Roux Dam

	* TWR[1]	SD[1]	SD/HA[1]	TWR[2]	SD[2]	SD/HA[2]
CROP ROTATION SYSTEM 30W30LM30C30L (m^3)						
1978/79	762970	137030	2283	885750	14250	237
1979/80	716180	183820	3063	798590	101410	1690
1980/81	692960	207040	3450	788560	111440	1857
1981/82	714890	185110	3085	804670	95330	1588
1982/83	790100	109900	1831	857650	42350	705
1983/84	736860	163140	2719	835840	64160	1069
1984/85	721370	178630	2977	806550	93450	1557
1985/86	740870	159130	2652	845190	54810	913
1986/87	764220	135780	2263	864800	35200	586
1987/88	596820	303180	5053	649440	205560	4176
1988/89	640280	259720	4328	778790	121210	2020
CROP ROTATION SYSTEM 30W30S30C30L (m^3)						
1978/79	745960	154040	2567	881410	18590	309
1979/80	687060	212940	3549	799300	100700	1678
1980/81	677320	222680	3711	789160	110840	1847
1981/82	694450	205550	3425	810320	89680	1494
1982/83	760870	139130	2318	858360	41640	694
1983/84	705380	194620	3243	837960	62040	1034
1984/85	701104	198896	3314	806830	93170	1552
1985/86	711720	188280	3138	855320	44680	744
1986/87	744810	155190	2586	864800	35200	586
1987/88	575960	324040	5400	649480	205520	4175
1988/89	618650	281350	4689	776770	123230	2053

* - TWR is the total gross water requirements for the crop rotation systems per 60 hectares
- SD is the gross water surplus (+) or deficit (-) when subtracting the total gross water requirements from the available maximum water quota for 60 hectares
- SD/ha is the gross water surplus (+) or deficit (-) when subtracting the total gross water requirements from the available maximum water quota per hectare
- Year$_1$ refers to the first year and year$_2$ to the second year of the crop rotation systems

CHAPTER 3

ESTIMATION OF CROP PRICES AND COSTS ASSOCIATED WITH IRRIGATED CROPS IN THE AREA BELOW THE P.K. LE ROUX DAM

3.1 INTRODUCTION

Predominantly three factors are important in crop production, which determine the viability of the agricultural investment: crop prices, crop yields and crop production costs. Crop prices and yields are subject to price and production risk respectively. In the preceding chapter the production risk associated with yields was dealt with. The price risk associated with the crops must be estimated next. With regard to production cost two types of costs can be considered: the costs associated with the mechanisation system, including the irrigation system, and the costs directly associated with the crops.

On the basis of the obtained prices, yields and costs the enterprise budgets of the alternative crops in the crop rotation systems can be developed and the gross margins calculated.

The questions that will be addressed in this chapter are the following:

(a) To what extent are crop prices subject to price risk?

(b) What are the irrigation variable costs of the different crops?

(c) What are the enterprise budgets for the different crops?

(d) How does the relative economic profitability of the different crops differ?

3.2 LITERATURE STUDY

3.2.1 Price risks

The research of Gill (1984: 9) indicated that the factors leading to unpredictable shifts in the supply and demand of inputs and outputs are sources of price risk. Prices are important as they are the factors that coordinate the decisions regarding the choice of crops. The effect of price risk must successively be incorporated in economic investment analyses.

Previous studies on economic irrigation analyses incorporating the variability in crop prices were effectively dealt with by Gill (1984), Bosch (1984) and Meiring (1989). Gill considered the price variability by evaluating the irrigation investment by randomly attaching historical prices to simulated yields. Bosch has chosen prices at random from a probability distribution of projected prices. Meiring adjusted historical national crop yields by regression analysis to present crop yields. In his dissertation the prices for wheat, late maize and cotton are determined. The wheat and late maize prices, according to the respective crop price scenarios were attached to the adjusted national production. For cotton, a crop for which a relatively fixed price was determined irrespective of national crop yield levels, a single price was used. For each crop to each price-yield combination a separate number is attached. Subsequently, random numbers were used to select price-yield combinations at random.

The control boards, being responsible for the marketing of crops, have the power under the Marketing Act to influence prices to a certain extent. Therefore the exercise of this power and the degree of influence exerted on prices can have a direct effect on production. For wheat, late maize, cotton, dry beans, peanuts, soyabeans and lucerne a summary is given on how these prices are determined.

3.2.1.1 Wheat price

The Wheat Board is responsible for the marketing of wheat in South Africa. At present wheat is being marketed according to the one-channel system. The system implies that farmers on the one hand are compelled to market the wheat according to the Board's regulations, on the other hand, they are ensured of a single fixed price for each wheat grade. In the alternative markets, the export market and the feeding-grain market, lower prices are realised in comparison with the domestic human consumption market. The sum of the net realisation in all markets represents the amount due to the farmers and which must be distributed according to the total delivered wheat production. Before planting time the Wheat Board makes an estimate of the implications of the various market factors on wheat prices. The size of the total production cannot be predicted before planting time and therefore estimates are made on the basis of specific production levels. The results are published and made available to farmers in the form of price scenarios and represent the crop's price risk. It must be determined on basis of historical national production what the wheat price distribution is for national production adjusted to 1990 levels. The net producer's prices for A1-wheat is given in Table 3.1 (Wheat Board, 1990).

Table 3.1 Net producer's prices for A1-wheat per ton for the 1990 growth season

Crop Yield (million tons)	Net producer's price (R)
2,30	450
2,50	440
2,75	425
3,00	410
3,25	400
3,50	395

3.2.1.2 Maize price

The present operation of the maize marketing scheme is based on the single-channel-fixed-price scheme but incorporates aspects of the single-pool-schemes. The Maize Board markets the maize according to the principle of market segmentation. By means of this principle an attempt is made to maximize long-term income from each market segment. To realise this objective the Board aims at market expansion rather than at raising the maize selling price. The maize market can be divided into separate markets and the marketing actions of the Board will differ with regard to each of these market segments. The market realisation from each market segment can then be considered to be pooled, according to which the producer's price reflects the result of the total market revenues. The present price procedure is as follows:

(a) During July/August of every year, the Maize Board announces a price scenario, indicating producer prices for certain crop yields, based on market factors.

(b) On May 1st the delivery price is announced, again based on present market factors. This delivery price must be regarded as an advance price, to which, through the running of the market season, an additional payment and/or final payment is made to the producers from available market revenues.

(c) The selling prices and conditions of maize for the different market segments are determined by the Maize Board according to the present market characteristics and factors of each of the market segments.

The following market factors influencing the producer price can be mentioned: size of the crop, price movements on the international market, exchange rate, size of the internal market, marketing costs and the influence of state aid in the form of subsidies. From the above-mentioned factors it can be deduced that maize is subject to a considerable price risk. It must be determined on the basis of historical national production what the maize price distribution is for the national production adjusted to 1990 levels. Table 3.2 shows the price scenario of expected net producer prices.

Table 3.2 Price scenario of expected net producer prices for possible national production levels for the 1990/91 maize marketing season

Crop yields (million tons)	Net producers price (ton) (R)
6	261
7	239
8	222
9	209
10	198
11	189
12	182

3.2.1.3 Lucerne price

Lucerne products are marketed in two ways as lucerne hay in bales or as lucerne seed. The marketing of lucerne seed is regulated on the basis of an obligatory single-channel-pool scheme. The marketing of lucerne hay is not regulated and its price is subject to price risk. The lucerne hay price distribution must be determined on the basis of historical national production for the national production adjusted to 1990 levels.

3.2.1.4 Dry bean price

The Dry Beans Scheme is administered by the Dry Bean Control Board. The Board exercises control chiefly over those varieties of dried beans which are mainly purchased for household use. The control measures apply throughout South Africa. Basically, the supply and demand of dry beans determine the average price obtained by the farmers. Only in times of surplus production, the Scheme operates mainly to stabilise producer prices. This is achieved by guaranteeing minimum prices (floor prices) at which the Board is prepared to purchase dry beans from any producers who are unable to obtain guaranteed or better prices in the trade. In spite of the floor prices dry beans are subject to considerable price risk. The dry bean price distribution for the national production adjusted to 1990 levels must be determined on the basis of historical national production.

3.2.1.5 Cotton price

In South Africa the demand for cotton production has usually exceeded the supply resulting in relatively high prices. On the international markets cotton supplies have been the lowest ever this year in relation to cotton consumption. Subsequently the present world price has increased to R5,12/kg for cotton fibre. The South African Cotton Board has a supervision and price regulation function regarding the marketing of cotton. The Board determines the local price according to a formula which is based on the world price. This calculated price then is the price that the cotton ginners are advised to pay to the farmers. The current calculated formula price is determined at R4,82/kg for cotton fibre. This high price was not acceptable to the cotton ginners due to the high price increase (37 %) in comparison with prices of last year. In consequence the ginners collectively decided to pay farmers an advance price of R1,20/kg for picked cotton, which represents only a 6,7 per cent price increase. The price ratio between picked cotton and seed cotton is normally consistent and determined at 0,3. In this study as in the study of Meiring (1989: 104) a fixed cotton picking price of R1,20 is used.

3.2.1.6 Soyabean and peanut prices

An increase of 30 per cent in the demand for soyabeans has been experienced in the last season. The increase can be attributed to the high protein value of soyabeans for animal food. At present the Oilseeds Board is, by means of advertising, attempting to overcome the resistance of using soyabeans for human consumption. The use of soyabeans is promoted by processing the bean into a form which is acceptable to the general public. Due to the demand exceeding the supply presently, the production of soyabeans entails no big price risk for producers.

The Oilseeds Board is investigating a more efficiently segmented peanut market, causing a shift from traditional table and crushing grades. The table market is to be divided into various market qualities, which means an expansion of the segments in the table market. This policy promotes a higher price for the producers. Besides the domestic market, the Oilseeds Board is contracted to market a part of the table peanuts overseas. The high quality peanut marketed there ensures a consistent high demand. Especially for the better grades the production of peanuts entails only slight price risks for the producers.

Oilseeds are marketed according to a one-channelpool system and within this system an advance price is paid to producers that respectively amounts to 93 %, 87 % and 95 % of the calculated net value of oilseeds for table peanuts, crushing peanuts and soyabeans. Foreign prices are accomplished by negotiation with buyers and agents for maximisation of revenue for pool accounts.

The provisional advance price indications for oilseeds which will be harvested during 1990 are as follows (Oilseeds Board, 1990):

3.2.1.6.1 Peanuts

The 1990/91 advance price is determined at R1 525 per ton for choice table peanuts, R1 340 per ton for standard table peanuts, R1 118 per ton for diverse table peanuts and the advance price of R671 per ton for crushed peanuts.

3.2.1.6.2 Soyabeans

Advance prices for soyabeans for crops of up to 200 000 tons is determined at R625 per ton for grade SB12 (eating market) and R585 per ton for grade SB2 (crushing material).

Due to the determined fixed prices, peanuts and soyabeans are assumed to have no price risk. These provisional prices are subsequently used in the research.

3.2.2 Irrigation system costs

The costs of the irrigation systems can be divided into ownership (fixed) costs and operating (variable) costs. Fixed costs are those costs which are constant irrespective of the size or intensity of the production level, such as depreciation, interest and insurance. The variable costs vary with the changes in the production level, such as electricity, labour, water and repair and maintenance costs. Marginal factor costs are calculated on basis of the variable cost and are used in the determination of the profit maximizing quantity of variable production units and can be defined as the cost of the last variable production unit (Boehlje and Eidman, 1984: 101).

Meiring (1989) developed a procedure for estimating annual costs of centre pivot irrigation systems. The same procedure is used to estimate the fixed, variable and marginal costs of the irrigation systems with respectively +10 m (IS+10) and -15 m (IS-15) pumping heights.

3.2.3 Crop budgets

A crop budget can be defined according to Boehlje and Eidman, (1984: 86) as a projection of the expected average annual costs and income of crops. The crop budget includes an estimate of the physical resources required and products produced, their price and the total value of each resource required and product per unit for some future period of time.

Boehlje and Eidman (1984) distinguish between long-run and short-run enterprise budgets. In the long-run budgets costs are included that do not change in the short run. These costs consist mainly of ownership costs of machinery such as depreciation, rent, licenses and insurance. Existing budgets (COMBUDS) of crops for the research area are of short-run nature and cannot be used as the analysis is extended over a ten-year period. Therefore, budgets are compiled directly on the basis of information supplied by farmers with long-run costs incorporated.

Meiring (1989) used the APLAND budget generator to generate budgets for wheat, late maize and cotton. The mechanisation costs are calculated simultaneously in the generation process. The same model is used to develop the budgets for the mentioned crops and to calculate the respective gross margins.

3.3 PROCEDURE

3.3.1 Estimation of crop prices

3.3.1.1 Wheat price

Meiring (1989) used a procedure to determine the adjusted 1989 national production levels for wheat and maize. In imitation the same procedure is used but updated to 1990. Historical size of areas planted and the size of total wheat production levels are known for the years 1955/56 to 1988/89 (RSA, 1990). The following three factors can be held responsible for the variability in wheat national production levels of the past years: weather circumstances, technological progress and size of the area planted.

(a) Weather circumstances influence the size of the area planted and production per hectare. This variation is unpredictable and no trend can be detected.

(b) The technological progress such as improved cultivars, is reflected in an increase of the annual production per hectare. Considering the available historical wheat data a trend could be detected that reflects this increase. The TSP computer program is used to determine the regression line of this trend. The following linear regression equation is obtained:

$$Y = 0{,}407 + 0{,}0276X$$

with Y = yield per hectare in tons
X = time in years with 1955=1.

The t-value of the regression coefficient of 0,0276 tons is 8,967, which is significantly higher than $t_{33;0,001}$. The technological progress can be concluded to have increased the annual production with 0,0276 tons per hectare.

(c) The annual area planted to wheat is, apart from weather influence, also influenced by the crop's relative profitability. A trend that reflects the change in the annual area planted, can be detected from the historic wheat data. The use of the TSP program resulted in the following linear regression equation:

$$A = 1225{,}48 + 23933X$$

with A = total area planted to wheat in hectare
X = time in years with 1955=1.

The t-value of the regression coefficient of 23 933 hectares is 7,353 which is significantly higher than $t_{33;0,001}$. The change in the area planted to wheat can be concluded to have increased annually by 23 933 hectares.

Historic yields per hectare and historic area planted are adjusted to 1990 figures by multiplying the specific number of years with the respective annual increase in yield per hectare and the annual increase in area planted. To obtain the adjusted national production levels for each year the adjusted figures are multiplied, after which a price is allocated to each adjusted production level by using the price scenarios.

3.3.1.2 Maize price

The same procedure used by Meiring for the calculation of adjusted yield levels for maize, is used, but updated.

(a) Weather circumstances influence the size of the area planted and production per hectare. This variation is unpredictable and no trend can be detected.

(b) The technological progress increases the annual production per hectare. Taking into consideration the historic maize data available from 1955 (RSA, 1990) a trend could be detected that reflects this annual increase. The following linear regression equation is obtained:

$$Y = 1,049 + 0,0364X$$

with Y = yield per hectare in tons

X = time in years with 1955=1.

The t-value of the regression coefficient 0,0364 tons is 4,131 which is significantly higher than $t_{33;0,001}$. The technological progress can be concluded to have increased annual production with 0,0364 tons per hectare.

(c) The annual size of the area planted to maize, apart from the weather influence, is also influenced by the crop's relative profitability. A trend reflecting the change in the annual area planted, can be detected from the historical maize data. The use of the TSP program resulted in the following linear regression equation:

$$A = 4100,94 + 3919X$$

with A = total area planted to maize in hectares
X = time in years with 1955=1.

The t-value of the regression coefficient of 7 514 hectares is 0,649, which becomes only significantly at $t_{33;0,521}$. The change in the number of hectares over the past 33 years therefore is not an annual increase of 7 514 hectares.

Historic yields per hectare planted to maize are adjusted to 1990 figures. The adjusted yields are the specific number of years multiplied by the respective annual yield increase per hectare. Due to the insignificance of maize to annual increase in the number of hectares planted, no adjustment to 1990 figures need to be made. To obtain the adjusted total national production levels for each year, the adjusted figures are multiplied by the applicable number of years. By using the price scenarios, a price is allocated to each adjusted national production level.

3.3.1.3 Dry bean price

A procedure developed by Gill (1984: 52) is used to generate a distribution of dry bean prices that allows for the consideration of the price variability. This method is used due to the inherent strong price variability. Data on price indices of intermediate agricultural goods and dry bean prices, (RSA, 1990) available from 1959 up to 1990, are used as a basis to calculate 1990-adjusted prices. The procedure begins with an expected price of R1 346,10 per ton (Dry Bean Board, 1990). The national average dry bean prices for the years 1959-1990 were inflated to 1990 levels using the S.A. index of prices paid by producers for agricultural intermediate goods. The difference between the average of the inflated price series of R1 883,93 and the expected price of R1 346,10 was subtracted from the prices in the inflated series (R1 883,93 - R1 346,10 = R537,83). The result is an adjusted price distribution with an average of R1 346,10. Deviations from the average were reduced so that no price falls below the minimum of the inflated price series. The deviations were reduced by the same percentage, 28,1 %. This value is determined as follows:

(a) The largest deviation from the inflated dry bean price series is R210,30 (R1 346,10 - R1 135,80 = R210,30).

(b) The largest deviation of the price series after reduction to gain the average of R1 346,10 is R748,30 (R1 346,10 - R597,80 = R748,30).

(c) Each deviation is reduced by 28,1% (R210,30/R748,30 = 0,281) so that each price equals or exceeds the R1 135,00 minimum price of the inflated series.

(d) The result is a distribution, inflated to 1990 values with an average of R1 346,10, but with reduced variation.

3.3.1.4 Lucerne hay price

The same procedure used for the distribution of dry bean prices is followed to generate a distribution of lucerne hay prices. Data on price indices of intermediate agricultural goods and lucerne hay prices (RSA, 1990), available from 1959 up to 1990, are used as a basis to calculate 1990 adjusted prices. The procedure begins with an expected price of R200,00 per ton (Lucerne Board, 1990). The national average lucerne hay prices for the years 1959-1990 were inflated to 1990 levels using the S.A. index of prices paid by producers for agricultural intermediate goods. The difference between the mean of the inflated price series of R210,13 and the expected price of R200,00 was subtracted from the prices in the inflated series. The result is an adjusted price distribution with a mean of R200,00. This price distribution was adjusted to eliminate all prices that fell below the lowest price observed (R170,70) for this 32-year period. Each deviation from the mean was reduced by the same percentage (74,3 %), with the desired mean of R200,00 and the lower end of the distribution maintained within the range observed for the 1959-1990 inflated prices.

3.3.2 Estimating irrigation system costs

3.3.2.1 Technical factors

Meiring (1989) determined the following technical coefficients on the basis of which the cost calculations were done for 18 different prototype centre pivot systems.

The water application efficiency of the system is required to calculate the pumping rate. Application losses are compensated for by larger quantities of water pumped with corresponding cost implications. An application efficiency percentage of 85 is used.

Depreciation of the system-components is largely influenced by their lifespan and the salvage values. The lifespan and salvage value of the different components are shown in Table 3.3.

The coefficients used for the estimation of the repair and maintenance costs of the different components are shown in Table 3.4.

Table 3.3 Lifespan and salvage value as percentages of the initial purchase price of the different components of the centre pivot system*

Component	Lifespan (years)	Salvage value %
Centrifugal pump	15	15
Submersible pump	10	5
Electric motor	15	20
Switch	15	20
Cables	20	15
Asbescement pipe	20	30
PVC pipe	20	25
Steel pipe	15	20
Aluminium pipe	10	15
Centre pivot	15	25

*Source: Meiring, 1989

Table 3.4 Estimates of the repair and maintenance costs as percentages of the initial purchase price of the different components of the centre pivot system, 1990*

Component	Repair and maintenance costs
Electric motor	1,0 % of purchase price/year
Centrifugal pump	2,0 % of purchase price/1000 hours
Submersible pump	2,5 % of purchase price/1000 hours
Centre pivot	5,0 % of purchase price/year
Pipes (subsoil)	0,5 % of purchase price/year

*Source: Meiring, 1989

The wages of permanent labourers on farms are usually considered as fixed costs, the labour costs with centre pivot irrigation are variable as these costs can be allocated to a separate farm enterprise. The labour requirements for a 60 hectare system is 35 minutes for every 24 hours that the system operates (Meiring, 1989).

3.3.2.2 Centre pivot system characteristics

Two of the 18 designed typical irrigation systems are selected on the basis of their characteristics. The basic centre pivot system is an eight-tower system irrigating 60 hectares. From the pump to the irrigation system the water is pumped through a 490 m asbestos cement pipe. The capacity of the system is determined at 300 m^3 water per hour giving 12 mm water application per day. This basic system is operated at two different pumping heights. A pumping height of -15 m (IS-15) is used for systems in the area below the Ramah canal and +10 m (IS+10) for systems along the Sarel Hayward canal. The systems require respectively a 37 KW motor and a 60 KW motor.

An irrigation firm was contacted for the latest purchase prices of the different components of the system. Escom provided the 1990 electricity tariffs. The water tariffs were obtained from the Department of Water Affairs. The nominal interest rate and the inflation rate were determined at respectively 21 % and 16 % (First National Bank, 1991).

3.3.2.3 Cost calculation method

In the following sections the cost calculation method is used to calculate the various costs of the centre pivot irrigation systems with the two different pumping heights, respectively +10 m (IS+10) and -15 m (IS-15).

The method consists of four parts of which Part 1 provides general data (Meiring, 1989: 25-29). System (IS+10) is (A) and system (IS-15) is (B).

PART 1	System A	System B
	(R)	(R)
INITIAL CAPITAL INVESTMENT		
Centrifugal pumps	12 850,00	6 425,00
2 * 30 Kw motors + 2 switches	17 253,00	
1 * 37 Kw motor + 1 switch		10 509,00
Pipes and connections (above ground)	9 831,00	7 808,00
Pipes and connections (below ground)	36 979,00	
Electric cables	11 458,00	
Centre pivot system	197 467,00	
PART 2		
ANNUAL FIXED COSTS		
Total capital investment	285 838,00	270 646,00
Interest and depreciation:		
Centrifugal pump	1 086,84	543,42
Motors + switches	1 417,14	863,22
Electric cables	810,46	810,46
Pipes and connections (above ground)	808,51	641,34
Pipes and connections (below ground)	2 435,32	2 435,32
Centre pivot	15 738,10	15 738,10
Total annual interest and depreciation	22 296,37	21 031,86
Annual insurance:		
Fire and storm damage	1 990,87	1 869,34
Fixed annual electricity costs	1 110,24	1 110,24
Total annual fixed costs	25 397,48	24 011,44
PART 3		
OPERATING COSTS OF THE SYSTEM		
Planned water pumped	660 000 m^{s3}/y	660 000 m^3/y
Hours pumped per year	2 200 hours	2 200 hours
Annual electricity consumption:		
Annual high tariff quantity	12 000 kWh	12 000 kWh
Consumption for pumping of water	132 000 kWh	81 400 kWh
Consumption for driving of system:	2 909 kWh	2 909 kWh
Total consumption per year	134 909 kWh	84 309 kWh
Consumption per hour	61,32 kWh	38,32 kWh
High tariff electricity:		
Water pumped with high tariff	58 708 m^3	93 946 m^3
Total costs of high tariff	2 132,76	2 132,76
Costs per cubic meter applied	0,03633	0,02270
Low tariff electricity:		
Water pumped with low tariff	601 292 m^3	566 054 m^3
Total costs of low tariff	12 638,73	7 435,53
Costs per cubic meter applied	0,02101	0,01313
Total electricity costs	14 771,49	9 568,29

	System A (R)	System B (R)
Water purchases:		
Tariff 1:		
Quantity purchased	660 000 m^3	660 000 m^3
Total water costs	12 000,00	12 000,00
Costs per cubic meter applied	0,01818	0,01818
Tariff 2:		
Quantity purchased	variable	variable
Total water costs	variable	variable
Costs per cubic meter applied		
< 15000 m^3/ha/y	0,01818	0,01818
> 15000 m^3/ha/y	0,03418	0,03418
Total water costs (< 15000 m^3/ha/y)	12 000,00	12 000,00
Labour costs:		
Required labour hours per year	53 hours/y	53 hours/y
Labour costs per cubic meter water	0,00010	0,00010
Total irrigation labour costs per year	53,00	53,00
Repair and maintenance costs:		
Pumps	565,40	282,70
Motors + switches	172,53	105,09
Pipes (below ground)	184,90	184,90
Centre pivot and pipes (above ground)	10 364,90	10 263,75
Total repair and maintenance costs	11 287,73	10 836,44
Costs per cubic meter water applied	0,017103	0,016419

PART 4

SUMMARY OF IRRIGATION COSTS

Annual costs for planned water application:

	System A (R)	System B (R)
Fixed costs:		
Total ownership costs	25 397,48	24 011,44
Variable costs:		
Total electricity costs	14 771,49	9 568,29
Total water costs	12 000,00	12 000,00
Total labour costs	53,00	53,00
Total repair and maintenance costs	11 287,73	10 836,44
Total variable costs	38 112,22	32 457,73
Total costs per year	63 509,70	56 469,17
Allocation of costs:		
Fixed costs per hectare crop cultivation		
137,5 % land utilisation (82,5 ha)	307,84	
150 % land utilisation (90 ha)	282,19	
175 % land utilisation (105 ha)	241,88	
200 % land utilisation (120 ha)	211,65	
137,5 % land utilisation (82,5 ha)		291,04
150 % land utilisation (90 ha)		266,79
175 % land utilisation (105 ha)		228,68
200 % land utilisation (120 ha)		200,10

	System A (R)	System B (R)
Labour costs per m^3 water pumped	0,00010	0,00010
Repair costs per m^3 water pumped	0,017103	0,016419
Electricity costs per m^3 water:		
High tariff	0,03633	0,02270
Low tariff	0,02101	0,01313
Water costs per m^3 water pumped:		
Tariff 1	0,01818	0,01818

Only when a water shortage is experienced tariff 2 is applicable

By summation of the separate marginal costs per m^3 water, the total marginal cost is calculated. Two marginal costs are calculated on the basis of the existing two different electricity tariffs. In Table 3.5 the quantity of water that can be applied at respectively the high and low electricity tariffs is shown for both the +10 m (IS+10) and the -15 m (IS-15) pumping heights.

Table 3.5 Quantity of water that can be applied at respectively high and low electricity tariffs for irrigation systems with pumping heights of +10 m (IS+10) and -15 m (IS-15) in the irrigation area below the P.K. le Roux Dam

Irrigation system	Water application at high electricity tariffs		Water application at low electricity tariffs	
m	m^3/ha	c/mm/ha	m^3/ha	c/mm/ha
IS+10	0 - 58 708	71,71	58 708 - 660 000	56,39
IS-15	0 - 93 946	57,50	93 946 - 660 000	47,83

3.3.3 Estimating crop budgets

On the basis of the discussions held with the farmers residing in the research area during 1989 and 1990, information on the cultivation and production cost aspects for the concerned crops was obtained.

The information was obtained systematically by following a previously compiled questionnaire. In addition, an overhead projector and a tape recorder were used for effective communication. The information required first concerned the soil type, soil depth and planting date, planting density and crop yields - information which was required for the compilation of the irrigation and carry-over files, referred to in the previous chapter. The questionnaire continues with requiring information on production inputs needed, the month in which they are needed, the specific input trade name, quantity used and quantity unit. Next the producers were asked to achieve consensus on the specific crop cultivation program, specifying the specific cultivation, the month, the number of cultivations, the KW requirements of the tractor used, the size and type of the implement used and the total number of labourers used, distinguishing between permanent and seasonal labour.

For each crop the Apland EBMCH1 machine cost generator is used to compile a separate crop mechanisation file. The purchase costs of the tractors and implements are obtained from the Cost Guide for Machinery (RSA, 1990). The information obtained on the crop cultivation and production inputs and services were entered in the EBCRP1 crop enterprise budget generator. All production input costs are the latest prices (December 1990), which were obtained by contacting the specific input/service suppliers. The EBCRP1 required information on the machine costs for the crop cultivations, specified into per hour machine ownership and operating costs.

In the crop budgets, distinction is made between ownership and operating costs. The operating costs are variable with respect to the crop yields and prices. The crop yields determine the contract harvest and transport costs. The irrigation costs associated with the crop yield are equally variable. The ownership cost of the irrigation system is a fixed cost but varies depending on the land utilisation percentage.

For the static analysis of the relative economic profitability of the different crops the respective crop budgets are developed and the net margins calculated for the average prices taken from the respective price distributions and respective average yields and corresponding average gross water requirements. A marginal irrigation cost of R0,56 mm/ha is used as the crops are used in a combination of crops in a crop rotation system and large quantities of water are applied. The static analysis is done for the irrigation system with a pumping height of +10 m (IS+10) with a 150 land utilisation percentage.

3.4 RESULTS AND DISCUSSION OF RESULTS

3.4.1 Crop prices

3.4.1.1 Cotton, peanut and soyabean prices

Irrespective of the size of the total cotton yield the producers are paid an advance price of R1 200,00 per ton. The advance price for table peanuts is determined at R1 525,00 per ton for the choice grade, R1 340,00 per ton for the standard grade, R1 118,00 per ton for the diverse grade and the price determined for crushing peanuts is R671,00 per ton. The advance price for soyabeans is determined at R625,00 per ton for grade SB1 and R585,00 per ton for grade SB2.

3.4.1.2 Wheat Price

Adjusted total wheat national production levels and corresponding expected producer prices for the period from 1955 to 1989 is given in Table 3.6.

3.4.1.3 Maize Price

Adjusted total maize national production levels and corresponding expected producer prices for the period 1955 to 1989 is given in Table 3.7.

3.4.1.4 Lucerne Price

Indices for agricultural goods, historical, adjusted, reduced value and reduced deviation prices for lucerne hay per ton for the period 1959 to 1990 are shown in Table 3.8.

3.4.1.5 Dry bean Price

Indices for agricultural goods, historical, adjusted, reduced value and reduced deviation prices for dry beans per ton for the period 1959 to 1990 are shown in Table 3.9.

Table 3.6 National production levels for wheat from 1955 to 1989 adjusted to 1989 with corresponding expected producer prices

Year	Adjusted national production (ton)	Producer prices (R)
1955	3 274 296	395
1956	3 341 354	395
1957	3 177 922	400
1958	2 698 838	425
1959	2 855 073	425
1960	2 843 995	425
1961	2 984 778	410
1962	2 631 353	425
1963	2 870 195	410
1964	2 955 136	410
1965	2 297 807	450
1966	1 958 851	450
1967	2 708 839	425
1968	2 975 825	410
1969	3 039 058	400
1970	3 073 730	400
1971	3 342 185	395
1972	3 336 740	395
1973	3 389 603	395
1974	2 917 820	410
1975	3 053 110	400
1976	3 517 365	395
1977	2 960 930	410
1978	2 671 438	425
1979	3 034 044	400
1980	2 203 811	450
1981	3 121 290	400
1982	3 148 907	400
1983	2 320 708	440
1984	2 151 789	450
1985	2 073 454	450
1986	2 660 939	425
1987	3 425 964	395
1988	3 736 715	395
1989	2 806 816	410
Average		414,14
Standard deviation		19,077
Coefficient of variance		4,606

Table 3.7 National production levels for maize from 1955 to 1989 adjusted to 1989 with corresponding expected producer prices

Year	Adjusted national production (ton)	Producer prices (R)
1955/56	7 868 498	222
1956/57	8 315 808	209
1957/58	7 532 360	222
1958/59	7 955 582	222
1959/60	8 763 247	209
1960/61	9 489 939	198
1961/62	9 587 735	198
1962/63	9 932 229	198
1963/64	7 843 792	222
1964/65	7 755 633	222
1965/66	8 712 286	209
1966/67	13 476 516	182
1967/68	8 972 089	209
1968/69	8 532 715	222
1969/70	8 647 995	208
1970/71	10 881 296	189
1971/72	12 315 735	182
1972/73	5 962 918	261
1973/74	13 473 797	182
1974/75	10 783 812	189
1975/76	9 624 477	198
1976/77	10 900 702	189
1977/78	11 874 305	182
1978/79	9 986 739	198
1979/80	12 388 580	182
1980/81	16 039 570	182
1981/82	9 792 632	198
1982/83	5 195 372	261
1983/84	5 480 094	261
1984/85	8 961 491	209
1985/86	8 850 768	209
1986/87	6 938 915	239
1987/88	6 817 830	239
1988/89	12 060 887	182
Average		210,000
Standard deviation		22,880
Coefficient of variation		10,895

Table 3.8 Calculation of prices for lucerne hay per ton from 1959 to 1990

Year	Historic prices (R)	Intermediate agricultural goods price indices	Adjusted 1990 prices (R)	Prices reduced values (R)	Prices reduced deviations (R)
1959	15,38	51,6	223,90	213,77	210,22
1960	15,38	51,6	220,00	209,87	207,33
1961	15,38	50,9	222,51	212,38	209,19
1962	15,38	51,9	218,43	208,30	206,10
1963	15,38	52,2	216,22	206,09	204,52
1964	15,87	52,5	219,56	209,43	207,00
1965	16,87	52,4	230,19	220,06	214,90
1966	17,87	54,2	238,55	228,42	221,11
1967	15,65	54,9	207,44	197,31	197,99
1968	18,41	53,7	242,18	232,05	223,80
1969	19,29	54,2	249,51	239,38	229,25
1970	18,41	55,2	231,67	221,54	216,00
1971	19,77	58,8	235,98	225,85	219,20
1972	22,88	63,0	219,42	209,29	206,90
1973	25,18	69,2	252,48	242,35	231,46
1974	26,47	82,4	224,36	214,23	210,57
1975	30,24	100,0	210,44	200,21	200,15
1976	33,00	113,7	198,65	188,52	191,47
1977	34,07	128,1	181,96	171,83	179,07
1978	39,84	144,6	187,46	177,83	183,13
1979	51,27	180,5	200,25	190.02	192,60
1980	63,78	214,9	203,88	193,45	195,13
1981	80,91	237,3	232,47	222,34	216,55
1982	87,82	275,0	227,10	216,97	212,60
1983	115,92	312,1	261,40	251,09	237,97
1984	110,41	326,7	232,70	222,57	216,76
1985	113,93	385,3	201,69	191,55	193,71
1986	115,07	445,0	170,70	160,57	170,70
1987	145,07	466,2	196,95	186,82	190,17
1988	167,00	522,5	200,30	190,17	192,69
1989	195,00	628,1	190,00	179,87	185,04
1990	200,00	728,6	200,00	187,87	190,98
Average			210,13	200,00	200,00

Table 3.9 Calculation of prices for dry beans per ton from 1959 to 1990

Year	Historic prices (R)	Intermediate agricultural goods price indices	Adjusted 1990 prices (R)	Prices reduced values (R)	Prices reduced deviations (R)
1959	127,33	51,6	1 549	1 011	1 253
1960	107,33	51,6	1 306	768	1 184
1961	131,22	50,9	1 619	1 081	1 272
1962	159,44	51,9	1 929	1 391	1 359
1963	174,33	52,2	2 097	1 559	1 406
1964	207,55	52,5	2 483	1 945	1 514
1965	238,22	52,4	2 855	2 317	1 619
1966	163,22	54,2	1 891	1 353	1 348
1967	139,78	54,9	1 599	1 061	1 266
1968	196,67	53,7	2 300	1 762	1 463
1969	186,89	54,2	2 165	1 627	1 425
1970	208,99	55,2	2 378	1 840	1 485
1971	183,89	58,8	1 964	1 426	1 368
1972	235,99	63,0	2 354	1 814	1 477
1973	274,66	69,2	2 493	1 955	1 517
1974	350,33	82,4	2 900	2 362	1 631
1975	479,22	100,0	3 009	2 471	1 662
1976	449,99	113,7	2 485	1 947	1 515
1977	231,66	128,1	1 135	597	1 135
1978	381,33	144,6	1 656	1 118	1 285
1979	536,11	180,5	1 865	1 327	1 340
1980	640,89	214,9	1 873	1 335	1 343
1981	507,11	237,3	1 342	804	1 193
1982	869,99	275,0	1 987	1 449	1 375
1983	787,78	312,1	1 585	1 047	1 262
1984	695,78	326,7	1 337	799	1 192
1985	734,89	385,3	1 197	659	1 153
1986	847,99	445,0	1 196	658	1 152
1987	1020,44	466,2	1 496	958	1 237
1988	1071,89	522,5	1 444	906	1 222
1989	1208,89	628,1	1 453	915	1 225
1990	1346,10	728,6	1 346	808	1 195
Average			1 883,93	1 346,10	1 346

3.4.2 Irrigation system cost

The total annual fixed costs per hectare and the total annual fixed costs per hectare for variable land utilisations expressed in percentages and in hectares for two irrigation systems (IS+10) and (IS-15) are shown in Table 3.10.

Table 3.10 Total annual fixed costs and annual fixed costs per hectare for alternative land utilisation percentages for irrigation systems with pumping heights of +10 m (IS+10) and -15 m (IS-15) in the irrigation area below the P.K. le Roux Dam, 1991

Land utilisation		Annual fixed costs		Annual fixed costs per hectare	
percentage	hectare	IS+10 (R)	IS-15 (R)	IS+10 (R)	IS-15 (R)
137,5	87,5	25 397	24 011	307,80	291,04
150,0	90,0	25 397	24 011	282,19	266,78
175,0	105,0	25 397	24 011	241,88	228,68
200,0	120,0	25 397	24 011	211,65	200,11

On the basis of simulated water requirements per crop per year (Table 2.5 - 2.8) the irrigation variable costs can be calculated. These costs depend on the water requirements and on the variable irrigation cost per m^3 water applied with the two different electricity tariff costs accounted for (Table 3.5). For system (IS+10) the first 58 708 m^3 water is pumped with the high electricity tariff and the remaining quantity of water for each year and each crop is pumped with the lower tariff. For system (IS-15) the first 9 3946 m^3 water is pumped with the high electricity tariff and the remaining quantity of water is pumped with the lower tariff. In the following four tables (Tables 3.11 - 3.14) the irrigation variable costs are shown.

Table 3.11 Irrigation variable costs per year for wheat, soyabeans, late maize and dry beans from 1978/79 to 1988/89 for the irrigation system with +10 m pumping height (IS+10) in the irrigation area below the P.K. le Roux Dam

Year	Wheat (R)	Soyabeans (R)	Late maize (R)	Dry beans (R)
1978/79	477,38	365,40	405,44	307,88
1979/80	430,02	356,94	410,51	285,89
1980/81	442,99	334,39	362,58	263,90
1981/82	450,88	356,38	384,57	310,14
1982/83	444,68	417,84	471,42	339,46
1983/84	455,95	386,27	440,96	323,11
1984/85	435,09	354,69	392,47	280,82
1985/86	449,19	377,24	413,33	306,19
1986/87	458,77	368,79	405,44	297,70
1987/88	415,35	284,76	323,67	237,40
1988/89	444,68	292,10	336,64	241,91
Average	409,54	225,60	395,18	290,40

Table 3.12 Irrigation variable costs per year for peanuts, cotton, lucerne (E) and lucerne (F) from 1978/79 to 1988/89 for the irrigation system with +10 m pumping height (IS+10) in the irrigation area below the P.K. le Roux Dam

Year	Peanuts (R)	Cotton (R)	Lucerne (E) (R)	Lucerne (F) (R)
1978/79	577,99	690,54	768,03	788,33
1979/80	546,98	655,01	686,26	707,69
1980/81	502,43	602,00	693,03	713,89
1981/82	555,44	614,97	709,38	727,43
1982/83	627,05	729,45	741,52	740,40
1983/84	625,92	651,63	711,07	725,73
1984/85	559,95	661,78	703,18	709,38
1985/86	556,56	650,50	740,40	757,88
1986/87	594,35	679,26	765,21	783,25
1987/88	457,32	486,97	566,15	580,81
1988/89	461,27	551,25	638,33	751,67
Average	551,38	633,94	702,05	726,04

Table 3.13 Irrigation variable costs per year for wheat, soyabeans, late maize and dry beans from 1978/79 to 1988/89 for the irrigation system with -15 m pumping height (IS-15) in the irrigation area below the P.K. le Roux Dam

Year	Wheat (R)	Soyabeans (R)	Late maize (R)	Dry beans (R)
1978/79	407,34	309,93	343,89	261,15
1979/80	367,16	302,76	348,20	242,49
1980/81	378,17	283,63	307,54	223,84
1981/82	384,86	302,28	326,20	263,06
1982/83	379,60	354,42	399,85	287,93
1983/84	389,17	327,63	374,03	274,06
1984/85	371,47	300,85	332,89	238,19
1985/86	383,43	319,98	350,59	259,71
1986/87	391,56	312,80	343,89	252,54
1987/88	354,73	241,54	274,54	201,36
1988/89	379,60	247,75	285,54	205,19
Average	380,64	300,32	335,19	246,32

Table 3.14 Irrigation variable costs per year for peanuts, cotton, lucerne (E) and lucerne (F) from 1978/79 to 1988/89 for the irrigation system with -15 m pumping height (IS-15) in the irrigation area below the P.K. le Roux Dam

Year	Peanuts (R)	Cotton (R)	Lucerne (E) (R)	Lucerne (F) (R)
1978/79	490,25	588,14	651,44	668,66
1979/80	463,95	558,01	582,09	600,26
1980/81	426,16	513,05	587,83	605,52
1981/82	471,12	524,05	601,70	617,00
1982/83	531,86	621,14	628,96	628,00
1983/84	530,91	555,14	603,13	615,57
1984/85	474,95	563,75	596,44	601,70
1985/86	472,08	554,18	628,00	642,83
1986/87	504,12	578,57	649,05	664,35
1987/88	387,90	415,47	480,21	492,64
1988/89	391,24	470,00	541,43	637,57
Average	467,68	540,14	595,48	615,82

The tendency in the irrigation variable costs reflects the same tendency as obtained with the gross water requirements of the crops, as these requirements are multiplied with the constant irrigation variable costs in c/mm/ha. Dry beans have the lowest costs and lucerne under full production have the highest costs.

3.4.3 Crop budgets

In Tables 3.15 to 3.22 the crop budgets are shown. A summary of the net returns above the costs shown (net margin), gross receipts, total operating costs and a ratio of the gross receipts to the total operating costs is calculated for the alternative crops and shown in Table 3.23.

From the table the following conclusions can be drawn:

Soyabeans and late maize have relatively low gross receipts and low ratios which in turn have largely contributed to the negative net margins. The relatively low total operating costs of these crops cannot compensate for the relatively low gross receipts. Cotton has the highest net margin due to the high gross receipts, which more than compensates for the relatively high total operating costs. Peanuts and lucerne (F) have relatively high net margins due to the relatively highest gross receipts and ratios. Wheat has a relatively low net margin due to relatively high total operating costs and low gross receipts.

Table 3.15 Crop budget for 1991 for wheat under centre pivot irrigation in the area below the P.K. le Roux Dam

Item	Unit	price/unit	quantity	value/unit
Gross receipts:				
Wheat	t	414,14	6,679	2766,04
Total (1)				2766,04
Operating costs:				
Wheatseed: SST66	t	1,22	120,00	146,40
Fertilizer: M.A.P. (33)+75%Zn	t	1080,00	0,15	162,00
U.A.N.	t	555,00	0,52	285,83
Herbicide: Buctril	l	49,40	1,00	49,40
M.C.P.A.	l	10,00	0,50	5,06
Pest control: Metasystox	l	29,29	0,40	11,72
Folidol	l	21,45	0,65	13,94
Contract harvest	t	35,00	6,679	233,76
Contract aerial spraying	ha	25,00	1,00	25,00
Contract transport (50 km)	t	20,00	6,679	133,58
Insurance: hail	t	31,22	6,00	187,32
Diesel fuel: harvest	l	1,09	9,70	10,57
Fuel, lubrication and repairs	ha	258,72	1,00	258,72
Labour, field operations	h	1,00	6,73	6,73
Interest: operating expenses	R	0,21	486,98	102,27
Irrigation costs	ha	0,56	760,10	425,66
Total operating cost (2)				2057,96
Income above operating cost (1)-(2)				708,08
Ownership costs:				
Machinery and implements	ha	98,39	1,00	98,39
Irrigation system	ha	282,19	1,00	282,19
Total ownership costs (3)				380,58
Total costs shown (2)+(3)				2438,54
Net returns above costs shown (1)-(2)-(3)				327,50

Table 3.16 Crop budget for 1991 for peanuts under centre pivot irrigation in the area below the P.K. le Roux Dam

Item	Unit	price/unit	quantity	value/unit
Gross receipts:				
Table peanuts	t	1525,00	2,260	3446,50
Table peanuts	t	1118,00	0,646	722,23
Crushed peanuts	t	671,00	0,323	216,73
Peanut hay	t	125,00	3,000	375,00
Total (1)				4760,46
Operating costs:				
Peanut seed:	kg	1,58	80,00	126,40
Rhizobium vaccine	box	3,95	1,60	6,32
Fertilizer: U.A.N.	t	555,00	0,02	11,10
Gypsium	t	129,61	0,70	90,73
Bailing wire	roll	95,75	0,14	14,41
Seasonal labour	ha	1,00	400,00	400,00
Pest control: Metasystox	l	29,29	0,40	11,72
Bravo	l	25,22	4,00	100,88
Contract shelling	t	47,00	3,23	151,81
Contract transport (325 km)	t	20,00	3,23	64,60
Peanut bags	bag	0,60	65,00	39,00
Fuel, lubrication and repairs	ha	498,36	1,00	498,36
Labour, field operations	h	1,00	22,44	22,44
Interest: operating expenses	R	0,21	311,12	65,33
Irrigation costs	ha	0,56	970,00	543,20
Total operating cost (2)				2146,22
Income above operating cost (1)-(2)				2614,14
Ownership costs:				
Machinery and implements	ha	206,65	1,00	206,65
Irrigation system	ha	282,19	1,00	282,19
Total ownership costs (3)				488,84
Total costs shown (2)+(3)				3086,72
Net returns above costs shown (1)-(2)-(3)				1673,74

Table 3.17 Crop budget for 1991 for cotton under centre pivot irrigation in the irrigation area below the P.K. le Roux Dam

Item	Unit	price/unit	quantity	value/unit
Gross receipts:				
Seed cotton	t	1200,00	3,661	4393,20
Total (1)				4393,20
Operating costs:				
Cotton seed: Acala 1517-20	kg	2,26	20,00	45,20
Fertilizer: M.A.P. (33)+Zn	t	1080,00	0,15	162,00
U.A.N.	t	555,00	0,325	180,38
Herbicide: Treflan	l	20,36	1,00	20,36
Pest control: Folimat	l	75,43	0,20	15,09
Thiodin	l	21,24	7,50	159,33
Defoliation: Hargade	l	56,20	2,00	112,40
Contract aerial spraying	ha	24,00	1,00	24,00
Insurance: hail	t	89,76	3,00	269,28
Hoe cultivation (by hand)	md	6,00	10,00	60,00
Contract harvest	ha	600,00	1,00	600,00
Diesel fuel: harvest	l	1,09	28,00	30,52
Contract transport (50)	t	20,00	3,661	73,22
Fuel, lubrication and repairs	ha	260,58	1,00	260,58
Labour, field operations	h	1,00	7,77	7,78
Interest: operating expenses	r	0,21	616,48	129,45
Irrigation costs	ha	0,56	1102,03	617,14
Total operating costs (2)				2766,72
Income above operating costs (1)-(2)				1592,87
Ownership costs:				
Machinery and implements	ha	93,47	1,00	93,47
Irrigation system	ha	282,19	1,00	282,19
Total ownership costs (3)				375,66
Total costs shown (2)+(3)				1968,53
Net returns above costs shown (1)-(2)-(3)				2424,67

Table 3.18 Crop budget for 1991 for late maize under centre pivot irrigation in the irrigation area below the P.K. le Roux Dam

Item	Unit	price/unit	quantity	value/unit
Gross receipts:				
Late maize	t	210,00	8,588	1803,48
Total (1)				1803,48
Operating costs:				
Maize seed: PNR 394	kg	3,60	20,00	72,00
Fertilizer: M.A.P. (33)+Zn	t	1080,00	0,10	108,00
U.A.N.	t	555,00	0,65	360,75
Herbicide: Bladex+	l	17,20	1,50	25,80
M.C.P.A.	l	10,11	1,00	10,11
Buctril	l	49,40	0,50	24,70
Pest control: Thiodin	l	21,24	1,00	21,24
Fastac	l	203,63	0,20	40,73
Insurance: hail	ha	7,25	7,00	50,75
Contract harvest	t	35,00	8,588	300,58
Contract transport (50 km)	t	20,00	8,588	171,76
Diesel fuel: harvest	l	1,09	8,83	9,62
Fuel, lubrication and repairs	ha	61,94	1,00	61,94
Labour, field operations	h	1,00	2,46	2,46
Interest: operating expenses	r	0,21	214,02	44,95
Irrigation costs	ha	0,56	698,20	390,88
Total operating costs (2)				1696,27
Income above operating costs (1)-(2)				107,21
Ownership costs:				
Machinery and implements	ha	26,70	1,00	26,70
Irrigation system	ha	282,19	1,00	282,19
Total ownership costs (3)				308,89
Total costs shown (2)+(3)				2005,16
Net returns above costs shown (1)-(2)-(3)				-201,68

Table 3.19 Crop budget for 1991 for dry beans under centre pivot irrigation in the irrigation area below the P.K. le Roux Dam

Item	Unit	price/unit	quantity	value/unit
Gross receipts:				
Dry beans (grade 3)	t	1346,00	2,04	2745,84
Total (1)				2745,84
Operating costs:				
Dry bean seed: Wartberg	kg	4,00	100,00	400,00
Rhizobium vaccine	box	3,95	2,00	7,90
Herbicide: Treflon	l	20,36	2,00	40,72
Seasonal labour	h	1,00	20,00	20,00
Contract aerial spraying	ha	25,00	1,00	25,00
Fertilizer: U.A.N.	t	555,00	0,27	149,85
KNO3	t	1344,00	0,05	67,20
Insecticide: Bravo	l	25,22	3,00	75,66
Fastac	l	203,63	0,87	178,18
Bladbuff	l	9,70	0,88	8,54
Dry bean bags	bag	1,75	28,00	49,00
Contract transport (50 km)	t	20,00	2,04	40,80
Fuel, lubrication and repairs	ha	255,15	1,00	255,15
Labour, field operations	h	1,00	17,63	17,63
Interest: operating expenses	r	0,21	51,66	10,85
Irrigation costs	ha	0,56	514,50	288,12
Total operating costs (2)				1634,60
Income above operating costs (1)-(2)				1111,24
Ownership costs:				
Machinery and implements	ha	105,34	1,00	105,34
Irrigation system	ha	282,19	1,00	282,19
Total ownership costs (3)				387,53
Total costs shown (2)+(3)				1494,21
Net returns above costs shown (1)-(2)-(3)				1251,63

Table 3.20 Crop budget for 1991 for soyabeans under centre pivot irrigation in the irrigation area below the P.K. le Roux Dam

Item	Unit	price/unit	quantity	value/unit
Gross receipts:				
Soyabeans	t	625,00	2,715	1696,87
Total (1)				1696,87
Operating costs:				
Soyabean seed: Asgrow 5308	kg	2,40	135,00	324,00
Rhizobium vaccine	box	3,95	3,00	11,85
Baling wire	rl	95,75	0,37	35,91
Herbicide: Samcor	l	121,40	1,00	121,40
Lasso	l	15,85	0,50	7,93
Pest control: Parathion	l	19,31	2,00	38,62
Contract aerial spraying	ha	25,00	1,00	25,00
Contract harvest	t	35,00	2,715	95,03
Contract transport (50 km)	t	20,00	2,715	54,30
Diesel fuel: harvest	l	1,09	9,70	10,57
Fuel, lubrication and repairs	ha	215,07	1,00	215,08
Labour, field operations	h	1,00	7,86	7,86
Interest: operating expenses	r	0,21	513,51	107,84
Irrigation costs	ha	0,56	627,90	351,62
Total operating costs (2)				1407,01
Income above operating costs (1)-(2)				289,87
Ownership costs:				
Machinery and implements	ha	101,51	1,00	101,51
Irrigation system	ha	282,19	1,00	282,19
Total ownership costs (3)				383,70
Total costs shown (2)+(3)				1790,71
Net returns above cost shown (1)-(2)-(3)				-93,84

Table 3.21 Crop budget for 1991 for lucerne (establishment) under centre pivot irrigation in the irrigation area below the P.K. le Roux Dam

Item	Unit	price/unit	quantity	value/unit
Gross receipts:				
Lucerne hay	t	200,00	20,80	4161,00
Total (1)				4161,00
Operating costs:				
Lucerne seed: Diamant	kg	19,80	30,00	594,00
Rhizobium vaccine	box	3,95	3,00	11,85
Baling wire	rl	95,75	2,00	191,50
Transport (50 km)	t	20,00	20,80	416,10
Fuel, lubrication and repairs	ha	749,54	1,00	749,54
Labour, field operations	h	1,00	6,91	6,91
Interest: operating expenses	r	0,21	31,47	6,61
Irrigation costs	ha	0,56	1239,00	693,84
Total operating costs (2)				2670,35
Income above operating costs (1)-(2)				1490,64
Ownership costs:				
Machinery and implements	ha	88,04	1,00	88,04
Irrigation system	ha	211,65	1,00	211,65
Total ownership costs (3)				299,69
Total costs shown (2)+(3)				2970,04
Net returns above costs shown (1)-(2)-(3)				1190,95

Table 3.22 Crop budget for 1991 for lucerne (full production) under centre pivot irrigation in the irrigation area below the P.K. le Roux Dam

Item	Unit	price/unit	quantity	value/unit
Gross receipts:				
Lucerne hay	t	200,00	21,35	4270,00
Total (1)				4270,00
Operating costs:				
Baling wire	rl	95,75	2,00	191,50
Transport (50 km)	t	20,00	21,35	427,00
Fuel, lubrication and repairs	ha	617,28	1,00	617,28
Labour, field operations	h	1,00	36,82	36,82
Interest: operating expenses	r	0,21	355,16	74,58
Irrigation costs	ha	0,56	1285,00	719,60
Total operating costs (2)				2066,78
Income above operating costs (1)-(2)				2203,22
Ownership costs:				
Machinery and implements	ha	325,52	1,00	325,52
Irrigation system	ha	211,65	1,00	211,65
Total ownership costs (3)				537,17
Total costs shown (2)+(3)				2603,95
Net returns above cost shown (1)-(2)-(3)				1666,05

Table 3.23 Net margins, operating costs and the ratio of the gross receipts to the total operating costs for the alternative crops in the irrigation area below the P.K. le Roux Dam

Crop	Net margins (R)	Total operating costs (R)	Total receipts (R)	Gross receipts/ Total operating costs (R)
Peanuts	1673,74	2146,22	4760,46	2,218
Lucerne (F)	1666,05	2066,78	4270,00	2,066
Dry beans	1251,63	1634,60	2745,84	1,680
Cotton	2424,67	2766,72	4393,20	1,580
Lucerne (E)	1190,95	2670,35	4161,00	1,550
Wheat	327,50	2438,54	2766,04	1,344
Soyabeans	-93,84	1407,01	1696,87	1,206
Late maize	-210,27	1696,77	1794,89	1,058

3.5 CONCLUSIONS

From the given simulated yields, gross water requirements and price distributions of the crops, the average of these values is calculated. The average values are subsequently incorporated in the corresponding crop budgets and a single gross margin is calculated. These net margins of the crops indicate a wide distribution from negative net margins for late maize of -R210,27 to a relatively high gross margin of R2 424,67 for cotton.

3.6 RECOMMENDATIONS

The calculation of the fixed cost of the mechanisation system, excluding the irrigation system, is based on the assumption that the cost per hour, that the implement is operating, is the division of the total fixed cost by the assumed lifespan in hours. This assumption can be improved upon.

The development of these long-term budgets can be extended to other irrigation areas.

The gross margins of the budgets are largely dependent on the prices and yields and the need for accuracy cannot be over-emphasised.

CHAPTER 4

ECONOMIC PROFITABILITY ANALYSIS OF THE CROP ROTATION SYSTEMS SUBJECT TO PRICE AND PRODUCTION RISKS

4.1 INTRODUCTION

The success of using crop rotation systems depends on the economic profitability of the crops cultivated within the crop rotation systems. The economic analysis of crop rotation systems is therefore a crucial task in the farm enterprise planning process. Boehlje and Eidman (1983: 316) define the purpose of the economic profitability analysis as a determination of whether investment projects, in this case the crop rotation systems, contribute to the long-run profits of the farm enterprise.

By means of capital budgeting procedures the costs and benefits associated with the crop rotation systems can economically be evaluated over time.

In the previous chapters price and yield distributions have been determined and on the basis of the average of these yields and prices, budgets have been developed and the static net margins for the crops could be calculated. The next step is the use of the these distributions for the calculation of the profitability of the crop rotation systems.

The problem is defined as: How does the relative economic profitability of the alternative crop rotation systems differ, considering production and price risks?

The objective of this chapter is to determine and compare the relative economic profitability of the alternative crop rotation systems, considering production and price risks.

Specifically it must be determined, firstly, which crop rotation systems are the most profitable, secondly, which have the least risk and thirdly, which have the highest return on total capital investment?

4.2 LITERATURE STUDY

4.2.1 Review of literature

Wilson and Eidman (1981: 62) analysed and evaluated cash crops under centre pivot irrigation systems in Minnesota, USA. The profitability of the irrigation investment was analysed over a 15-year period using the internal rate of return method with an assumed 12 per cent interest rate. The irrigation system is used to irrigate a quarter section of fine textured soils. Water is pumped from wells and a crop rotation system of maize and soyabeans is used. Irrigation was found to be profitable only on the low water capacity soils.

Gill (1984: 87) analysed alternative irrigation investments in the St. Cloud-Becker area of central Minnesota. The most prevalent irrigation system used in the area, the centre pivot irrigation system, was analysed on three soil types, based on the water holding capacity and four well pumping capacities. Production and price risks were considered. The net present value method was used as the capital budgeting procedure. The results indicated that the irrigation system for 150 acres and a well capacity of 800 gpm were the most profitable.

Van der Walt (1988) researched the viability of existing mechanised irrigation systems for different crop rotation systems in the Orange Free State and Western Transvaal. The researcher considered the following variables: Four alternative crop rotation systems, static financial structure and variable discount rates. The net present value method is used. By using the results of the study the net present value of nineteen farmers could be improved.

Botes (1990) researched the effect of alternative irrigation scheduling methods and soil profile available water capacity on the economic profitability of wheat in the irrigation area of the P.K. le Roux Dam. The researcher considered the following variables: Three different soil profile available water capacities, four alternative irrigation scheduling methods. Production risk is also considered. A sensitivity analysis was done. The main result was that a procedure was developed for the economic evaluation of alternative irrigation scheduling strategies for wheat under centre pivot irrigation on soils with different profile available water capacities.

Meiring (1989) conducted an economic and financial analysis of typical centre pivot irrigation systems in the Vanderkloof State Water Scheme. Incorporating production and price risks the systems were evaluated for one typical crop rotation system. Two different soil types and two different pumping heights were considered. The net present value method was used to evaluate the investments on an equal basis. The researcher used the net benefit/investment criterion for the ranking of the investments. It was found that economically profitable systems are not necessarily also financially feasible.

4.2.2 Implications for this research

The research by Gill (1984), Meiring (1989) and Botes (1990) indicates that an economic profitability analysis cannot be conducted exhaustively without taking price and production risk into consideration. From the mentioned research it can be concluded that all researchers except Wilson and Eidman (1981) used the net present value method to calculate and evaluate the alternative irrigation systems or strategies. Meiring (1989) evaluated only one crop rotation system under irrigation.

Van der Walt (1988) evaluated alternative crop rotation systems under dryland conditions but did not consider production and price risks. On the basis of the mentioned research, it was concluded that this research can complement the literature by evaluating alternative crop rotation systems under centre pivot irrigation, by using the net present value method while price and production risk must be considered.

Meiring (1989) used a net present value method whereby the initial capital investment costs of the irrigation systems are determined independently and separately from the net margins of the crops. The net margins exclude the fixed irrigation system costs per crop. In this research a net present value method is used whereby this distinction is not made and a net margin is calculated including the fixed cost of the irrigation systems. The motivation for using this method is the emphasis on the determination of the profitability of the crop rotation systems and not of the irrigation system investment.

4.3 NET PRESENT VALUE CALCULATION PROCEDURE

The steps in the calculation of the net present value of the crop rotation systems are as follows:

(a) Choose an appropriate discount rate to reflect the time value of money;

(b) Calculate the annual net margin for each crop for each year and repeat this process twenty times;

(c) Calculate the summation total of the annual net margins of crops prevailing within a year period for each crop rotation system;

(d) Calculate the present value of the total annual crop net margins over the ten year period for each crop rotation system; and

(e) Compare the net present values and determine the ranking of the alternative crop rotation systems.

4.3.1 Step A

Choose an appropriate discount rate to reflect the time value of money. The discount rate reflects the weighted average cost of using own and debt capital and is used to readjust annual gross margins to their present value. Meiring (1989) used a real after-tax discount rate of 5 per cent. For this research the same rate is used.

4.3.2 Step B

The annual net margins for each crop and for each year are calculated on the basis of the developed crop budgets. The net margins are calculated by including both the fixed costs of the irrigation system and of the mechanisation system. The fixed costs of the irrigation system comprises the insurance, electricity, interest and depreciation. Due to the differences in land utilisation by the crop rotation systems, these fixed costs are calculated on the basis of the land utilisation percentage. The annual fixed costs of the mechanisation system are based on the per hour cost. The machinery per hour cost is calculated by dividing the total fixed cost over its lifespan by its assumed lifespan.

In the calculation of the annual net margins (net returns above costs shown) for each crop in each crop rotation system the following operational steps must be taken:

4.3.2.1 Step B.1

For the consideration of production and price risks the net margins of the crops must be calculated for alternative prices and yields. The alternative prices and yields are used in the developed crop budgets so that the net margins can be calculated.

The following process is used to select the prices and yields. For each year of the ten-year period, for which the crop rotation systems are analysed, the prices and yields are selected at random from the determined respective price and yield distributions. For maize and wheat the eleven simulated yields (Table 2.6) are coupled to the obtained 34 prices (Tables 3.7 and 3.8) so that 374 price-yield combinations are obtained. For lucerne hay the eleven simulated yields (Table 2.9) are coupled to 32 obtained prices (Table 3.9) so that 352 price-yield combinations are obtained. For dry beans the eleven simulated yields (Table 2.8) are coupled to 32 prices (Table 3.10) so that 352 price-yield combinations are obtained. For the crops cotton, peanuts and soyabeans only one price is given and these prices are coupled to the respective crop yields (Tables 2.7 and 2.8) so that for each crop eleven price-yield combinations are obtained. Crop transport, harvest costs and irrigation costs are dependent on yields and are calculated according to the selected crop yields.

4.3.2.2 Step B.2

For each crop in the crop rotation systems, it is determined in which year(s) over the ten-year period revenue is obtained. By using this method for each crop and for each year that revenue is obtained in each crop rotation system, a net margin is calculated. The following examples illustrate this method:

In crop rotation system 60W60S, revenue is obtained from wheat and soyabeans in each year. In crop rotation system 30W30S30C30L, revenue from wheat and soyabeans is obtained in the first, third, fifth, seventh and ninth year. Revenue from lucerne is obtained for each year, and revenue is obtained from cotton in the second, fourth, sixth, eight and tenth year.

4.3.2.3 Step B.3

The process of calculating a net margin for each crop and for each year that revenue is obtained in each crop rotation system, is extended by repeating these calculations twenty times. The object is to obtain twenty net margins for each crop. The twenty net margins are determined on a basis of randomly selected prices and yields from the respective price and yield distributions. Basically the net margins of each crop can be set out in a matrix consisting of a column for each year that revenue is obtained with each column consisting of twenty replications. In the annexure in Tables 4.5 to 4.17 the crop net margins are given.

4.3.3 Step C

Successively the following calculation must be done for each crop rotation system by multiplying the obtained twenty net margins for each crop and for each year with the size of the land planted to the respective crops. After these calculations, the total annual net margin of crops must be determined by the summation of these values (net margin x land size) of those crops, from which revenue is obtained in the same year. This total annual net margin is multiplied with 1 minus the marginal tax rate of 20 % (Meiring and Oosthuizen, 1989) to obtain the annual total after-tax net margins of crops for each year of the crop rotation system. The following equation (4.1) gives the annual total after-tax net margin of crops ($AXNM_t$):

$$AXNM_t = \{\Sigma(ANM_{at} \times LS_a)\}(1-mtr) \qquad (4.1)$$

where:

$AXNM_t$ = annual total after-tax net margin of crops
ANM_{at} = annual before-tax net margin from crop a in year t
LSa = size of land section for crop a
mtr = marginal tax rate (%)
t = year 1 to 10
a = crop 1 to 4.

4.3.4 Step D

Calculate the net present value of the total annual after-tax net margins of crops over the ten-year period. Summation of these discounted total annual after-tax net margins of crops into a single figure represents the net present value of the stream of the total annual after-tax net margins of crops for each crop rotation system.

The following net present value equation (4.2) is used to calculate the net present values of the total annual after-tax net margins of the crops.

$$NPV = \sum_{t=1}^{N} \frac{\Sigma \, AXNM_t}{(1+d)^{10-t}} \qquad (4.2)$$

where: NPV = net present values of the alternative crop rotation systems

$AXNM_t$ = total annual after-tax net margin of crops for year t for each crop rotation system

d = weighted average cost of capital.

A computer program, developed by Meiring (1989) to calculate the net present values of the irrigation systems, has been adapted to calculate the net present values for each crop rotation system.

4.3.5 Step E

Compare and rank the crop rotation systems.

4.4 RESULTS AND DISCUSSION OF RESULTS

For the crop rotation systems the net present values of the average, minimum, maximum, coefficient of variance, per year, per hectare and annually per hectare are given in the Tables 4.1 and 4.3. The crop rotation systems are ranked on the basis of the ratio of the average net present value to the mechanisation system investment and the ratio of the annual average net present value to the total investment. These ratios are given in Tables 4.2 and 4.4.

All the crop rotation systems are profitable, but a large variation can be distinguished between the net present values. The absolute difference between the net present values of the alternative crop rotation systems varies between R116 063 and R486 774 and between R170 691 and R534 706 for 60W60LM and 30W30S30C30L with respectively +10 m (IS+10) and -15 m (IS-15) pumping heights.

When analysing the annual net present values per hectare for both pumping heights, the crop rotation system with the highest value 30W30S30C30L is 3,1 and 4,2 times more profitable for respectively the +10 m and -15 m pumping heights than the crop rotation system with the lowest value 60W60LM. This difference is also obtained when considering the coefficient of variance where 60W60S is respectively 4,2 and 5,5 times more risky than 30W30S30C30L.

Table 4.1 Net present values, expressed in minimum, maximum and average per ha, annually per ha and coefficient of variance of the crop rotation systems, irrigated by irrigation system with +10 m pumping height (IS+10) in the irrigation area below the P.K. le Roux Dam, 1991

No	Crop rotation systems	Minimum (R)	Maximum (R)	Average (R)	Per ha (R)	Annually/ha (R)	Coeff.of variance
14	30W30S30C30L	437673	529969	486774	8112,90	811,29	5,17
13	30W30LM30C30L	414988	523511	470296	7838,27	783,83	6,78
10	30W30S30L	401466	531502	440141	7335,68	733,57	6,59
12	30W30S30LM30L	377497	473341	417417	6956,95	695,70	6,71
11	30W30LM30L	359607	466459	404833	6747,21	674,72	7,32
7	60W60S60C	239747	318700	267859	4464,31	446,43	7,62
8	60W45LM15D60C	240009	340464	276101	4601,68	460,17	8,69
6	60W60LM60C	195624	305783	233611	3893,51	389,35	12,39
9	45W45LM15P60C	194574	301692	238976	3982,93	398,29	8,48
1	60W60S	148253	213586	176479	2941,31	294,13	9,49
4	60W45LM15D	142286	271924	195028	3250,47	325,05	14,16
5	45W45LM15P	123734	240844	178057	2967,62	296,76	15,21
3	60W60LM60S	101858	195815	140052	2334,25	233,42	17,00
2	60W60LM	48373	155478	116063	1934,38	193,44	28,30

Table 4.2 Ratios of the net present values to mechanisation system investment and total investment of the crop rotation systems, irrigated by irrigation system with +10 m pumping height (IS+10) in the irrigation area below the P.K. le Roux Dam, 1991

No	Crop rotation * systems	ANPV (R)	MSI (R)	ANPV/MSI (R)	Per year (R)	TI (R)	p.y./TI (R)
14	30W30S30C30L	486774	347850	1,400	46792	1006294	0,0465
13	30W30LM30C30L	470296	347850	1,352	47029	1028887	0,0457
10	30W30S30L	440141	341530	1,289	44014	1028887	0,0427
12	30W30S30LM30L	417417	341530	1,222	41741	1048971	0,0398
11	30W30LM30L	404833	341530	1,185	40483	1048738	0,0386
7	60W45LM15D60C	276101	361931	0,763	27610	1055291	0,0261
8	60W60S60C	267859	341847	0,784	26785	1032532	0,0259
6	45W45LM15P60C	238976	361698	0,661	23897	1035207	0,0230
9	60W60LM60C	233611	339172	0,689	23361	1055058	0,0221
1	60W45LM15D	195028	355611	0,548	19502	1034890	0,0188
4	45W45LM15P	178057	355378	0,501	17805	1034890	0,0172
5	60W60S	176479	312934	0,564	17647	1034890	0,0170
3	60W60LM60S	140052	335527	0,417	14005	1041210	0,0134
2	60W60LM	116063	335527	0,346	11606	1041210	0,0111

* Crop rotation systems:
- ANPV = average net present value
- MSI = mechanisation system investment
- per year (p.y.) = average net present value per year
- TI = total investment (land + irrigation system + mechanisation system)

Table 4.3 Net present values, expressed in minimum, maximum and average per ha, annually per ha and coefficient of variance of the crop rotation systems, irrigated by irrigation system with -15 m pumping height (IS+10) in the irrigation area below the P.K. le Roux Dam, 1991

No	Crop rotation systems	Minimum (R)	Maximum (R)	Average (R)	Per ha (R)	Annually/ha (R)	Coeff.of variance
14	30W30S30C30L	484464	576173	534706	8911,76	891,17	4,82
13	30W30LM30C30L	462531	574399	519697	8661,61	866,16	6,21
10	30W30S30L	451253	554243	490221	8170,35	817,03	4,96
12	30W30S30LM30L	428071	525576	470921	7848,68	784,87	5,84
11	30W30LM39L	410870	519624	457131	7618,85	761,88	6,18
7	60W60S60C	291868	354929	318649	5310,81	531,08	6,38
8	45W45LM15P60C	257392	411580	323720	5395,33	539,53	8,34
6	60W45LM15D60C	290283	398637	330390	5506,50	550,65	7,25
9	60W60LM60C	246644	366614	288631	4810,52	481,05	10,10
1	60W60S	202663	279900	233066	3884,43	388,44	8,22
4	60W45LM15D	196185	342939	257507	4291,78	429,18	11,88
5	45W45LM15P	176052	307330	238512	3975,25	397,52	12,18
3	60W60LM60S	167387	269723	201128	3352,13	335,21	11,52
2	60W60LM	103922	267278	170691	2844,85	284,48	20,36

Table 4.4 Ratios of the net present values to mechanisation system investment and total investment of the crop rotation systems, irrigated by irrigation system with -15 m pumping height (IS-15) for in irrigation area below the P.K. le Roux Dam, 1991

No	Crop rotation * systems	ANPV (R)	MSI (R)	ANPV/MSI (R)	per year (R)	TI (R)	p.y./TI (R)
14	30W30S30C30L	534706	347850	1,537	53470	1006294	0,0531
13	30W30LM30C30L	519697	347850	1,494	51969	1028887	0,0505
10	30W30S30L	490221	341530	1,435	49022	1028887	0,0476
12	30W30S30LM30L	470921	341530	1,379	47092	1048971	0,0449
11	30W30LM30L	457131	341530	1,338	45713	1048738	0,0435
7	60W45LM15D60C	330390	361931	0,913	33039	1055291	0,0313
8	45W45LM15P60C	323720	361698	0,895	37372	1035207	0,0312
6	60W60S60C	318649	341847	0,932	31864	1032532	0,0308
9	60W60LM60C	288631	339172	0,850	28863	1055058	0,0273
1	60W45LM15D	257507	355611	0,723	25750	1034890	0,0248
4	45W45LM15P	238512	355378	0,671	23851	1034890	0,0230
5	60W60S	233066	312934	0,744	23306	1034890	0,0225
3	60W60LM60S	201128	335527	0,600	20112	1041210	0,0193
2	60W60LM	170691	335527	0,508	17069	1041210	0,0163

* Crop rotion systems:
- ANPV = average net present value
- MSI = mechanisation system investment
- per year (p.y.) = average net present value per year
- TI = total investment (land + irrigation system + mechanisation system)

The difference in the net present values between the two pumping heights on average is R90,47 per hectare per year.

Crop rotation system 60W60LM has the lowest net present values, and crop rotation system 60W60S has the next lowest net present values. These values indicate that a crop rotation system which includes late maize or soyabeans as the only summer crops are comparatively less profitable than the other summer crops. Crop rotation system 30W30S30C30L has the highest net present values, and crop rotation system 30W30LM30C30L the next highest net present values, which reflect the relatively high net margins of lucerne and cotton. The low net margins of late maize and soyabeans can be compensated for by the relatively higher net margins of lucerne and cotton. The low net margins of soyabeans and late maize are only partly compensated for by the relatively high net margins of dry beans and peanuts in crop rotation systems 45W45LM15P60C, 60W45LM15D60C, 60W45LM15D and 45W45LM15P. If, due to climatic conditions, cotton cannot be planted successfully, this crop should be substituted if possible by peanuts or lucerne.

The relatively high possible land utilisation percentages of crop rotation systems, including late maize and soyabeans, cannot compensate for the relatively low net margins of these crops.

When comparing the ratios of the average net present values per year to the total investments, it is significant to note that the ranking order of these ratios is similar to the ranking order of the average present values. The obtained values differ between 4,65 and 1,11 per cent for the +10 m pumping height and respectively 5,31 and 1,63 per cent for the -15 m pumping height. The obtained values are given in real terms.

When comparing the ratios of the average net present values to the mechanisation system investments it is significant to note that the ranking order of these ratios is similar to the ranking order of the average present values. Two exceptions are found:

Firstly, crop rotation system 60W60S has a relatively low average present value but still a relatively high ratio, due to the relatively lower investment costs. Secondly, although crop rotation system 60W60S60C has a lower average present value than the comparable values of crop rotation systems 45W45LM15960C and 60W45LM15D60C, the relatively high investment costs of the latter crop rotation systems reduces these ratios to a lower value than obtained for the former crop rotation system.

4.5 CONCLUSIONS

The most profitable crop rotation system is on average 3,65 times more profitable than the least profitable crop rotation system, which indicates the large variance in the relative economic profitability of the alternative crop rotation systems.

The most profitable are not on average the crops with the relatively lowest operating costs (soyabeans and late maize) but those with the relatively highest net receipts (dry beans, peanuts, cotton and lucerne).

Real returns on investments of an average 4,98 and 1,37 for respectively the most and least relative profitable crop rotation systems compare poorly with the credit interest rates.

The relatively low economic profitability of some crop rotation systems is reflected by the relatively high risk associated with these crop rotation systems.

The selection of the appropriate crops for inclusion in the crop rotation systems is essential for long-term profitability.

4.6 RECOMMENDATIONS

Due to the assumptions made, the analysis of the relative economic profitability of the alternative crop rotation systems is restricted by the selection of the available crops and the composition of crops in the alternative crop rotation systems. When a shift in the importance of crops such as potatoes, sweet maize and citrus occurs, the net present value method can be used to determine the effect of these crops in crop rotation systems on economic profitability.

The object of the composition of the different crops in the crop rotation system is to determine the effect of these crops in the crop rotation systems. In future studies other objectives can be pursued in the composition of the crop rotation systems so that the effect thereof on economic profitability can be analysed.

ANNEXURE

In the following tables, Tables 4.5 to 4.17 are the net margins of the different crops calculated for ten years from 1978/79 to 1987/88 and twenty replications within each year. The crops are irrigated by irrigation systems with two different pumping heights, respectively +10 m (IS+10) and -15 m (IS-15) for the irrigation area below the P.K. le Roux Dam.

Table 4.5 Net margins for late maize for ten years and twenty replications for the irrigation system with +10 m pumping height (IS+10) in the irrigation area below the P.K. le Roux Dam, 1991

Replica-tions	Year 1 (R)	2 (R)	3 (R)	4 (R)	5 (R)	6 (R)	7 (R)	8 (R)	9 (R)	10 (R)
1	-205	-395	-109	-110	-286	- 81	232	-99	441	-436
2	46	152	-344	-282	-413	-107	52	282	-376	253
3	-110	-94	-81	-344	-413	-344	-51	277	-273	-114
4	-291	-205	232	-177	-413	-51	-210	-395	-210	-352
5	-352	235	-177	44	-441	46	-188	-423	342	-274
6	5	-102	-282	-444	-441	-513	-202	-317	-107	-222
7	240	282	-102	240	-108	-413	-188	-436	240	340
8	-210	5	-413	-513	-205	-77	-419	-381	-285	3
9	-393	-204	-188	-256	-367	-188	-94	-273	-205	277
10	-454	-188	257	-77	-359	51	-299	-423	-344	-282
11	342	-378	-162	342	-363	-213	-213	346	-51	-162
12	-455	-376	-283	-413	-367	-222	5	-340	-285	-162
13	232	235	65	-344	257	-192	440	-376	-192	-317
14	-283	-108	-344	-175	-198	94	-352	-282	-110	-210
15	-381	-340	-175	-204	-198	235	-162	-205	422	3
16	-340	-317	155	-102	257	-436	-419	-413	-177	-460
17	-363	342	-192	-226	-285	-108	-282	-162	-436	-162
18	-513	5	-110	-304	-285	232	69	-64	257	-413
19	-384	-286	-423	- 99	-77	155	-204	-64	-423	-441
20	-109	65	-210	- 31	-393	-108	153	-307	-299	-107

Table 4.6 Net margins for late maize for ten years and twenty replications for the irrigation system with -15 m pumping height (IS-15) in the irrigation area below the P.K. le Roux Dam, 1991

Replica-tions	Year 1 (R)	2 (R)	3 (R)	4 (R)	5 (R)	6 (R)	7 (R)	8 (R)	9 (R)	10 (R)
1	-128	-313	-45	-28	-196	-6	310	-21	-363	-359
2	124	216	-278	-208	-211	-43	310	353	-299	328
3	-28	-17	-6	-278	-336	-278	128	354	-196	-32
4	-217	-128	310	-100	-128	19	19	-313	-132	-275
5	-275	312	-100	122	-336	124	-114	-348	406	496
6	69	-24	-218	-366	-363	-426	-138	-236	-43	-141
7	317	353	-24	317	-42	-366	-114	-359	317	404
8	-132	69	-336	-426	-128	-2	-344	-303	-198	68
9	-323	-138	-114	-186	-21	-114	-17	-196	-128	354
10	-367	-114	331	-2	-285	19	-17	-348	-278	-208
11	406	-291	-92	406	-100	-135	-135	412	19	-92
12	-374	-299	-217	-138	-288	-141	69	-276	-198	-92
13	310	312	139	-278	331	-117	-363	-299	-117	-236
14	-217	-42	-278	-88	242	165	-275	-208	-28	-132
15	-303	-276	-88	-140	-124	313	-92	-128	-348	68
16	-276	-236	242	-24	331	-359	-344	-336	-100	378
17	-288	406	-117	-141	-117	-42	-208	-92	-359	-92
18	-426	69	-28	-226	-124	-310	142	13	331	-366
19	-306	-211	-348	-21	-2	242	-138	13	-348	-363
20	-45	139	-132	56	-323	-42	220	-229	-222	-43

Table 4.7 Net margins for dry beans for ten years and twenty replications for the irrigation system with +10 m pumping height (IS+10) in the irrigation area below the P.K. le Roux Dam, 1991

Replica-tions	Year 1 (R)	2 (R)	3 (R)	4 (R)	5 (R)	6 (R)	7 (R)	8 (R)	9 (R)	10 (R)
1	1275	1245	917	1236	823	290	434	603	499	565
2	864	721	658	288	691	507	1062	496	977	689
3	1030	696	447	1419	665	1247	1062	687	360	426
4	462	1297	520	1015	713	735	743	543	425	526
5	534	291	434	414	450	458	346	1323	785	423
6	368	932	1473	578	826	1202	939	358	438	1275
7	703	786	1169	516	591	729	1007	374	981	840
8	875	839	546	319	482	1086	665	310	1026	1147
9	917	1007	528	735	785	550	729	390	428	254
10	385	949	372	704	1158	1211	1269	1086	426	212
11	674	560	620	835	658	588	1013	951	797	735
12	1037	1085	210	1062	456	435	516	480	1388	1405
13	1015	664	899	588	678	426	528	550	528	1009
14	614	903	1388	416	689	460	951	1223	658	473
15	458	864	554	1236	312	1310	768	342	424	364
16	710	435	978	516	1026	243	1060	503	1003	742
17	508	490	883	1133	462	743	288	723	1325	289
18	637	284	450	1005	392	410	1026	544	356	809
19	616	1060	480	588	955	1511	424	490	384	775
20	878	961	463	1228	497	703	743	276	482	696

Table 4.8 Net margins for dry beans for ten years and twenty replications for the irrigation system with -15 m pumping height (IS-15) in the irrigation area below the P.K. le Roux Dam, 1991

Replica-tions	Year 1 (R)	2 (R)	3 (R)	4 (R)	5 (R)	6 (R)	7 (R)	8 (R)	9 (R)	10 (R)
1	1337	1301	969	1299	885	349	493	665	550	616
2	922	779	722	347	751	569	1124	548	1032	740
3	1092	761	507	1481	727	1306	1124	742	424	484
4	524	1358	584	1074	780	793	798	603	489	587
5	596	358	493	465	506	517	404	1385	845	483
6	427	999	1525	639	892	1263	991	422	501	1337
7	761	844	1221	575	653	787	1068	436	1039	902
8	927	901	611	381	546	1148	727	366	1088	1199
9	969	1068	580	793	845	606	787	446	486	313
10	447	1011	434	766	1225	1272	1325	1138	484	279
11	726	622	687	894	722	655	1072	1016	886	793
12	1090	1143	277	1124	512	502	575	536	1446	1457
13	1074	728	960	655	740	484	580	606	587	1068
14	667	961	1446	467	740	512	1016	1287	722	540
15	517	916	613	1299	368	1374	826	406	485	429
16	772	502	1032	575	1088	307	1122	554	1064	804
17	567	552	945	1195	524	804	347	783	1383	356
18	704	346	506	1067	448	468	1088	606	417	860
19	674	1122	531	655	1017	1573	485	549	446	837
20	940	1016	525	1280	557	761	798	337	546	761

Table 4.9 Net margins for peanuts for ten years and twenty replications for the irrigation system with +10 m pumping height (IS+10) in the irrigation area below the P.K. le Roux Dam, 1991

Replica-					Year					
tions	1 (R)	2 (R)	3 (R)	4 (R)	5 (R)	6 (R)	7 (R)	8 (R)	9 (R)	10 (R)
1	1368	1421	1421	1230	1287	688	863	1064	1064	945
2	688	688	1287	945	1273	1368	945	1023	1368	1230
3	945	688	1064	688	1176	1287	1230	1176	1064	1421
4	1287	945	1368	1230	1023	863	1176	1064	1064	1023
5	688	1287	1064	1421	1023	1368	945	1287	1230	863
6	1023	1421	688	863	1273	1176	1368	1176	1176	1023
7	688	945	1064	1421	1176	1287	945	1064	1064	1421
8	688	1176	1287	1368	1421	1023	1023	1368	1368	1368
9	1064	688	1421	1230	1023	1230	1023	1421	1273	1421
10	1023	1421	1064	1023	1176	1023	1368	1176	688	1176
11	1368	1287	1064	1023	1023	1287	863	1176	863	1421
12	945	1368	1368	1421	1287	1176	688	1064	688	1176
13	1273	1368	1287	1368	1287	1064	1023	945	1176	945
14	1287	1287	1287	1287	1230	1230	1287	863	945	1287
15	945	1368	1176	945	1230	1023	688	688	1421	688
16	1230	1287	1023	1230	1230	945	1064	688	1023	863
17	1230	688	1230	1421	1368	1287	945	1273	1368	945
18	1176	1064	1287	688	1368	1421	1023	1230	1176	1287
19	1368	1230	1023	863	1421	1421	1176	1230	863	863
20	1421	1023	1064	1421	1368	1421	1421	945	945	1368

Table 4.10 Net margins for peanuts for ten years and twenty replications for the irrigation system with -15 m pumping height (IS-15) in the irrigation area below the P.K. le Roux Dam, 1991

Replica-tions	Year 1 (R)	2 (R)	3 (R)	4 (R)	5 (R)	6 (R)	7 (R)	8 (R)	9 (R)	10 (R)
1	1456	1513	1513	1334	1387	798	964	1164	1164	1045
2	798	798	1387	1045	1358	1456	1045	1123	1456	1334
3	1045	798	1164	798	1281	1387	1334	1281	1164	1513
4	1387	1045	1456	1334	1123	964	1281	1164	1164	1123
5	798	1387	1164	1513	1123	1456	1045	1387	1334	964
6	1123	1513	798	964	1358	1281	1456	1281	1281	1123
7	798	1045	1164	1513	1281	1387	1045	1164	1164	1513
8	798	1281	1387	1456	1513	1123	1123	1456	1456	1456
9	1164	798	1513	1334	1123	1334	1123	1513	1358	1513
10	1123	1513	1164	1123	1281	1123	1456	1281	798	1281
11	1456	1387	1164	1123	1123	1387	964	1281	964	1513
12	1045	1456	1456	1513	1387	1281	798	1164	798	1281
13	1358	1456	1387	1456	1387	1164	1123	1045	1281	1045
14	1387	1387	1387	1388	1334	1334	1387	964	1045	1387
15	1045	1456	1281	1045	1334	1123	798	798	1513	798
16	1334	1387	1123	1334	1334	1045	1164	798	1123	964
17	1334	798	1334	1513	1456	1387	1045	1358	1456	1045
18	1281	1164	1387	798	1456	1513	1123	1334	1281	1387
19	1456	1334	1123	964	1513	1513	1281	1334	964	964
20	1513	1123	1164	1513	1456	1513	1513	1045	1045	1456

Table 4.11 Net margins for soyabeans for ten years and twenty replications for the irrigation system with +10 m pumping height (IS+10) in the irrigation area below the P.K. le Roux Dam, 1991

Replica-tions	Year 1 (R)	2 (R)	3 (R)	4 (R)	5 (R)	6 (R)	7 (R)	8 (R)	9 (R)	10 (R)
1	79	-39	49	-8	121	-8	121	79	-19	-27
2	-8	-19	-19	-5	50	50	-10	-8	-5	79
3	50	79	-27	-5	-10	50	-10	-105	-8	121
4	79	79	-8	-105	-19	-5	-27	-8	-5	50
5	-8	-39	-8	-8	-19	-39	121	50	-10	-27
6	-19	-10	-8	-19	79	-5	-8	-5	-8	-8
7	79	-105	50	79	-8	-105	50	-27	-5	-39
8	-8	-8	50	-10	79	-105	-8	121	-10	-8
9	79	50	-10	-27	-8	50	-105	-5	-8	-8
10	-105	-5	-19	-8	-5	-8	121	-10	-105	-8
11	121	-19	-10	-10	-5	-39	-8	121	-8	-105
12	-10	-27	-105	121	-19	-105	50	-27	-27	-5
13	79	-27	79	-8	-39	-105	-19	-8	50	-105
14	-8	-8	50	-10	-10	-8	121	-10	-19	-8
15	-19	-8	-8	79	-10	121	-39	-105	79	-8
16	-5	121	-10	-19	121	-8	79	79	-39	-19
17	79	-19	-39	-105	-39	79	-10	79	-10	-39
18	-105	-39	79	-5	-39	79	-5	-8	-10	-8
19	-19	-27	-39	-10	-5	-39	-19	-5	79	50
20	-8	-8	79	-5	-8	-5	-10	-10	-8	79

Table 4.12 Net margins for soyabeans for ten years and twenty replications for the irrigation system with -15 m pumping height (IS-15) in the irrigation area below the P.K. le Roux Dam, 1991

Replica-tions	Year 1 (R)	2 (R)	3 (R)	4 (R)	5 (R)	6 (R)	7 (R)	8 (R)	9 (R)	10 (R)
1	138	29	121	59	181	59	181	138	55	42
2	61	55	55	62	121	121	60	61	62	138
3	121	138	42	62	60	121	60	-26	61	181
4	138	138	61	-26	55	62	42	59	62	121
5	61	29	61	61	55	29	181	121	60	42
6	55	60	61	55	138	62	59	62	61	59
7	138	-26	121	138	61	-26	121	42	62	29
8	59	61	121	60	138	-26	59	181	60	61
9	138	121	60	42	61	121	-26	62	61	61
10	-26	62	55	61	62	61	181	60	-26	59
11	181	55	60	60	62	29	59	181	61	-26
12	60	42	-26	181	55	-26	121	42	42	62
13	138	42	138	61	29	-26	55	61	121	-26
14	61	59	121	60	60	59	181	60	55	61
15	55	59	61	138	60	181	29	-26	138	61
16	62	181	60	55	181	59	138	138	29	55
17	138	55	29	-26	29	138	60	138	60	29
18	-26	29	138	62	29	138	62	59	60	59
19	55	42	29	60	62	29	55	62	138	121
20	61	61	138	62	59	62	60	60	59	138

Table 4.13 Net margins for lucerne under establishment (year 1 and 5) and under full production for ten years and twenty replications irrigated by irrigation system with +10 m pumping height (IS+10) in the irrigation area below the P.K. le Roux Dam, 1991

Replica-	Year									
tions	1 (R)	2 (R)	3 (R)	4 (R)	5 (R)	6 (R)	7 (R)	8 (R)	9 (R)	10 (R)
1	953	1897	1486	1462	1320	765	1746	1352	1699	1620
2	1151	2239	1583	1933	1715	721	2041	1721	1058	1479
3	1017	1411	2178	892	1508	1231	1392	1234	1539	1653
4	824	1729	932	2325	1715	952	2152	2041	2068	1290
5	1179	1646	1818	953	1851	1781	1143	1628	1371	1691
6	1563	1691	1814	2349	1420	1456	1855	1435	1289	1185
7	1736	1583	2506	1245	2017	1103	2152	2375	1133	2239
8	1158	1234	1779	2148	2025	1675	1111	1495	1350	1952
9	992	1785	1844	1322	2325	1242	1457	1498	960	1606
10	1412	1585	1479	1713	1692	1174	2065	1476	1759	1952
11	931	2152	1911	1857	1894	1621	1700	1851	1350	1813
12	972	1542	1435	1695	1152	1307	1331	2239	1499	2196
13	1744	1329	1433	1311	1897	1357	1331	2156	1897	1879
14	598	1462	1978	1930	1753	1125	2406	2274	1739	1290
15	1326	1587	1541	1952	1840	1477	1610	1855	1827	1700
16	1598	1582	1851	1892	1693	1373	1987	1853	1757	2174
17	844	1827	1651	2156	2069	1412	1892	1717	2155	1881
18	1744	1966	1911	1498	2087	984	1468	1896	1610	1582
19	972	1191	1977	1795	1731	1016	1183	2458	1779	1126
20	972	1853	1322	1844	1806	1270	1881	1185	1808	1454

Table 4.14 Net margins for lucerne under establishment (year 1 and 5) and under full production for ten years and twenty replications irrigated by irrigation system with -15 m pumping height (IS-15) in the irrigation area below the P.K. le Roux Dam, 1991

Replications	Year 1 (R)	2 (R)	3 (R)	4 (R)	5 (R)	6 (R)	7 (R)	8 (R)	9 (R)	10 (R)
1	1083	1905	1621	1585	895	1444	1879	1479	1822	1743
2	1247	2342	1711	2066	847	2479	2163	1844	1181	1612
3	1137	1542	2307	1020	1361	1643	1514	1274	1660	1780
4	949	1857	1053	2453	1082	1819	2256	2165	2087	1418
5	1307	1773	1953	1088	1900	1975	1271	1731	1493	1819
6	1675	1815	1943	2452	1585	1555	1983	1564	1424	1308
7	1848	1711	2514	1380	1222	2147	2256	2386	1266	2343
8	1286	1274	1913	2276	1776	2129	1236	1618	1472	2082
9	1110	1914	1968	1359	1370	2453	1591	1628	1082	1709
10	1543	1616	1608	1841	1286	1814	2168	1607	1886	2082
11	1061	2256	2045	1992	1748	2016	1823	1975	1353	1941
12	1100	1670	1564	1723	1438	1282	1458	2343	1627	2299
13	1864	1451	1563	1439	1484	2025	1458	2283	2020	2014
14	1726	1585	2100	2061	1307	1874	2536	2401	1862	1418
15	1437	1720	1573	2080	1606	1975	1739	1880	1957	1823
16	1726	1706	1975	2082	1501	1797	2114	1974	1888	2277
17	970	1957	1680	2283	1543	2198	2016	1850	2172	2008
18	1872	2101	2045	2294	1112	2190	1591	1919	1739	1706
19	1100	1294	2081	1628	1146	1853	1305	2562	1902	1261
20	970	1974	1359	1968	1400	1936	2008	1308	1941	1585

Table 4.15 Net margins for cotton for five years and twenty replications irrigated by irrigation system with +10 m pumping height (IS+10) (first five years) and with -15 m pumping height (IS-15) (second five years) in the irrigation area below the P.K. le Roux Dam, 1991

Replications	Year 1 (R)	2 (R)	3 (R)	4 (R)	5 (R)	1 (R)	2 (R)	3 (R)	4 (R)	5 (R)
1	934	1276	934	934	934	1211	1471	1283	866	1381
2	1093	1383	1169	755	1276	866	992	992	1471	803
3	755	886	886	1383	680	1471	1381	803	866	1376
4	1383	1276	680	755	1280	1283	803	866	1283	1376
5	1169	680	755	1169	1280	1211	1211	1211	992	1047
6	1093	1093	1093	886	934	1047	948	1381	1211	948
7	934	837	1276	1093	837	1283	1471	1211	1173	1381
8	1169	1383	1093	1057	1276	1471	948	1211	1173	992
9	1383	837	1093	1057	886	1381	1211	1211	1173	1173
10	1276	1093	1093	1057	1057	1283	866	1047	1283	1283
11	1169	755	934	1169	1169	1047	948	1047	1047	1283
12	934	837	934	934	1169	866	1381	1381	992	992
13	755	1276	1276	886	886	1173	1471	803	992	1211
14	1057	1383	680	886	1093	992	1471	866	1376	803
15	886	1383	755	1280	680	803	1381	1381	1381	866
16	680	1276	1276	1276	755	1471	803	866	1173	1381
17	1383	680	680	1057	1276	1381	1381	1471	1471	1173
18	1276	1276	1383	1383	1057	1047	803	1283	948	1173
19	934	680	1169	837	1057	803	1283	866	1047	1173
20	680	1169	755	934	1057	1047	1381	1381	1047	1047

Table 4.16 Net margins for wheat for ten years and twenty replications irrigated by irrigation system with +10 m pumping height (IS+10) in the irrigation area below the P.K. le Roux Dam, 1991

Replica-	Year									
tions	1 (R)	2 (R)	3 (R)	4 (R)	5 (R)	6 (R)	7 (R)	8 (R)	9 (R)	10 (R)
1	288	183	257	216	317	388	215	388	554	216
2	159	210	520	234	419	257	520	191	237	171
3	221	244	383	452	257	198	487	534	183	335
4	291	534	251	165	454	159	454	216	425	210
5	425	158	221	321	425	583	352	288	126	549
6	352	335	265	221	454	352	352	284	188	284
7	434	183	224	158	130	251	237	414	215	284
8	158	210	356	588	198	291	352	255	419	251
9	284	291	323	249	98	244	130	210	624	288
10	215	244	251	138	191	165	215	210	419	414
11	554	484	515	588	549	454	171	215	419	265
12	383	595	323	484	452	388	454	624	321	352
13	335	454	288	321	288	249	284	595	249	284
14	169	284	191	98	352	244	165	284	138	452
15	288	215	158	255	255	583	500	249	215	183
16	221	194	183	224	317	216	191	312	191	159
17	249	454	366	216	534	169	454	312	283	352
18	159	158	284	194	191	388	382	624	283	244
19	388	215	188	419	194	257	595	130	335	520
20	388	583	352	98	366	383	521	130	244	283

Table 4.17 Net margins for wheat for ten years and twenty replications irrigated by irrigation system with -15 m pumping height (IS-15) in the irrigation area below the P.K. le Roux Dam, 1991

Replica-tions	Year 1 (R)	2 (R)	3 (R)	4 (R)	5 (R)	6 (R)	7 (R)	8 (R)	9 (R)	10 (R)
1	366	262	336	295	398	466	296	466	632	295
2	239	292	602	317	500	336	599	270	319	253
3	300	326	462	533	336	284	566	620	262	418
4	372	620	327	250	530	239	530	295	505	292
5	505	237	300	402	505	666	428	366	206	628
6	428	418	351	300	530	428	428	361	266	360
7	516	262	304	237	211	327	319	496	296	360
8	237	292	435	669	284	372	428	336	500	327
9	360	372	404	330	119	326	211	326	700	366
10	296	326	326	220	270	250	296	292	500	496
11	632	565	598	670	628	530	253	553	499	351
12	462	675	404	565	533	466	530	296	402	428
13	418	505	366	402	366	330	360	675	330	360
14	251	360	270	179	428	326	250	360	220	533
15	366	296	237	336	336	666	582	496	296	262
16	300	275	262	304	398	295	270	330	270	239
17	330	534	452	295	620	251	530	394	362	428
18	239	237	360	275	270	466	466	700	362	326
19	466	296	266	500	275	336	675	700	418	599
20	466	666	428	179	452	462	599	211	326	362

CHAPTER 5

FINANCIAL FEASIBILITY ANALYSIS OF ALTERNATIVE CROP ROTATION SYSTEMS CONSIDERING PRICE, PRODUCTION AND FINANCIAL RISKS

5.1 INTRODUCTION

The capital investment in mechanisation and irrigation systems involves the commitment of large sums of money and, besides the profitability, also affects the liquidity and feasibility position of the farmer. The large capital cost of the systems usually cannot be contributed completely from the farmer's own resources and debt financing is required. The associated financing costs depend on the financing methods selected.

When the investment is financed by debt capital the investment is subject to financial risk. The financial risk plus the production and price risks are the total risks involved in the economic and financial analysis of crop rotation systems.

In the previous chapter the profitability of the crop rotation systems has been determined. The next step is to determine whether these crop rotation systems are also financially feasible. The purpose of financial feasibility is to determine whether or not the investments will generate sufficient cash income to meet the financial obligations. These obligations result from using debt capital acquired to finance the investment (Boehlje and Eidman, 1984: 332).

The problem is defined as: How does the financial feasibility of the alternative crop rotation systems differ, considering production, price and financial risks?

The objective for this chapter, which is also the main objective of the study, is the determination of the financial feasibility of the alternative crop rotation systems, considering production, price and financial risk.

5.2 LITERATURE STUDY

5.2.1 Review of literature

Wilson and Eidman (1981: 62) analysed and evaluated cash crops, irrigated by centre pivot irrigation systems in Minnesota, USA. Water was pumped from wells and a crop rotation system of maize and soyabeans was used. Irrigation was found to be profitable only on the low water capacity soils. Concerning financial feasibility the researchers found that under the given assumptions, negative cash flows were generated during the loan repayment period and cash deficits occurred.

In South Africa Niksch (1988) conducted analyses on the economic viability (profitability and feasibility) of irrigation in the Kroonstad district. For given assumptions a static analysis of the influence of total debt per hectare on the viability was conducted. The results indicate that in order to break even, increased irrigation system cost must be offset by decreased land and water right prices when financed by debt capital. An analysis was conducted for given assumptions on the effect of the extent of equity capital on the viability. The results indicated that in order to reduce the risk, to be profitable and to maintain feasibility the investment must be financed by a minimum of 30 % equity capital. At increasing credit rates this percentage must be increased to 50 %. Further an analysis was conducted in the determination of the effect of financing method, especially the length of the repayment term, on the viability. For given assumptions the results indicated that longer repayment terms positively influence feasibility and reduce financial risk. An analysis for the determination of the effect of different discount rates of capital on the viability was conducted. The results of this indicate that the higher discount rates must be offset by longer repayment terms to maintain viability.

Gill (1984) analysed both the economic profitability and financial feasibility of alternative irrigation systems investments in Minnesota. A given financing method of one fourth financed by debt capital and the rest by own capital and a given interest rate were used. The results indicated that the financial feasibility of crops on soils with low water holding capacity was on average more favourable than that of crops on soils with a high water holding capacity.

Besides the economic profitability analysis, Meiring (1989) also conducted a financial analysis of typical centre pivot irrigation systems for a given crop rotation system in the Vanderkloof irrigation area. Financial feasibility analyses were done for selected economic profitable centre pivot investments. The researcher made use of two different financing methods either by Land Bank or by agricultural cooperatives. On the basis of randomly selected prices and yields the effect of financial risk on financial feasibility could be evaluated. The following decision rule was used to determine when a range of cash flows from an investment was financially feasible:

(a) If for the twenty replications in a given year more than ten of them are negative then the year is considered to be a deficit year.

(b) If for the given ten-year period at least one year has a deficit then this period is considered to be a deficit period.

It was found that economically profitable systems were not necessarily also financially feasible. The financing method used largely causes differences in the feasibility of the investments.

5.2.2 Implications for this research

Considering the mentioned literature with regard to financial feasibility the following shortcomings are observed. In the research by Wilson and Eidman (1981), Gill (1984), Niksch (1988) and Meiring (1989) the financial feasibility studies were analysed on a farming enterprise level. The researchers considered only the effects of one irrigation system investment, without taking a complete farm situation into consideration. Meiring (1989) and Gill (1984) considered price and production risk, but Wilson and Eidman (1981) and Niksch (1988) omitted these. Financial risk was dealt with as it flowed from using different prices and yields, but none of the mentioned researchers analysed the effect of different debt to asset ratios. The methods used by the mentioned researchers on price and production risks are employed in this study. Considering the shortcomings in the mentioned research, a useful complementation can be made by this study, whereby alternative crop rotation systems are analysed for financial feasibility for a hypothetical farm situation, whereby financial risk flowing from using different prices and yields and from different farm debt to asset ratios is considered.

5.3 PROCEDURE

5.3.1 Capital structure and financing costs

Meiring and Oosthuizen (1989) identified three different debt to asset ratios for farmers in the research area, namely with equity proportions of respectively 30 per cent, 50 per cent and 80 per cent. The liability structure consisted of respectively 40 per cent current term, 25 per cent medium term and 35 per cent long term liabilities. In the analysis of the liability structure of these farmers, the results indicated that no relation between the equity proportion and this liability structure existed.

An analysis of the current term liabilities showed that 70 per cent are overdrafts, 20 per cent are production loans and 10 per cent are monthly accounts. Medium-term liabilities consisted mainly of hire purchases and long-term liabilities consisted of bond loans. For this research, these debt to asset ratios are analysed for financial feasibility. In Figure 5.1 the debt to asset ratio drawn up from the components is shown.

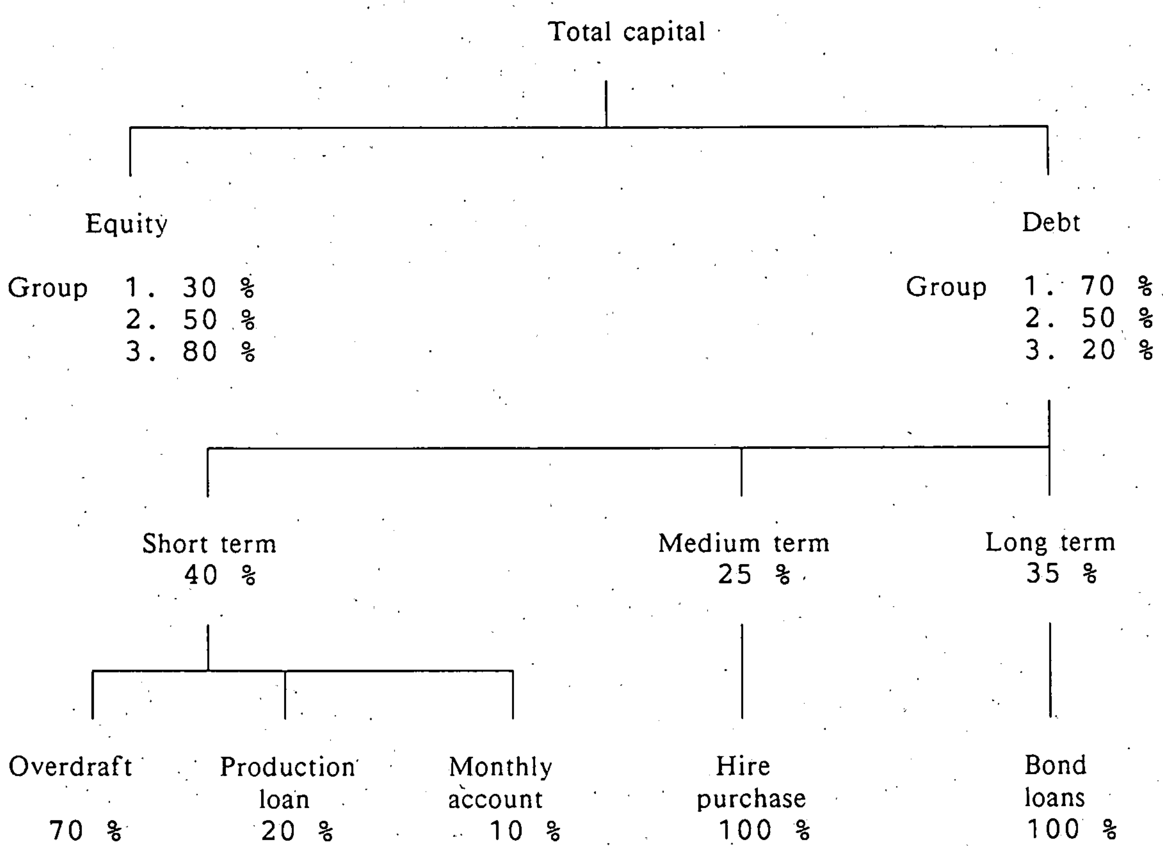

Figure 5.1 Typical capital structure of three groups of farms in the irrigation area below the P.K. le Roux Dam

The Land Bank provides long-term credit for a 20 year period for the purchase of land against an interest rate of 17 per cent. A compulsory annual insurance premium of a factor of 0,004062325 (Land Bank, March 1991) on the land price must be taken out by farmers. This factor is determined by the age of the farmer.

Research by Meiring and Oosthuizen (1989) in the research area indicated the farmer's average age can be determined at between 35 and 45 years.

Medium-term credit for a period of 4 years is available for the purchase of machinery in the mechanisation system at an interest rate of 19,5 per cent. Agricultural cooperatives provide short-term credit for financing agricultural production input factors in the form of a monthly account and a production loan, on which respectively 22 and 21 per cent must be paid. The monthly account is to be paid back monthly. Medium-term credit for a period of 4 years is available for the purchase of machinery and an interest rate of 19,75 per cent must be paid. Commercial banks provide predominantly short-term credit in the form of an overdraft facility and medium-term credit for hire purchases on which 24 per cent must be paid. Farmers negotiate with the bank for the repayment of the overdraft. Meiring (1989) determined that the overdraft balance is the average of a six month crop production period. Usually crop revenues are firstly used to repay the overdraft. The medium-term credit is available for a 4-year period. The commercial banks contribute 70 to 75 per cent of the financing for the medium-term investments.

5.3.2 Determination and valuation of the investments

For this study the hypothetical farm consists of two irrigated sixty hectare areas on which two similar crop rotation systems are used. To analyse the effect of the crop rotation systems the assumption is made to use the same crop rotation system and to plant the crops within the crop rotation system in the same year. Only the associated revenues and costs are analysed over the ten-year period and no provision is made in the analysis for domestic expenses. Research By Meiring and Oosthuizen (1989) into the capital structure of the farmers in the research area gave an indication of the prices for corresponding farms. The few farm transactions preceding that time indicated that completely developed irrigation farms sold for R5 778 per hectare. This figure includes the centre pivot systems and buildings. The cost of a developed farm unit with 120 hectares irrigated is R693 360.

The mechanisation system is not included in this price and the costs thereof for each crop rotation system must be determined separately. The assumption is made first that new implements are purchased, and secondly, that the individual implements are replaced continuously according to the length of their determined economic lifespan and are financed completely by the commercial banks. For each crop rotation system the total investment and the average capital investments of the mechanisation systems are calculated. The average capital investment is the average of the summation of the purchase price and the salvage value. The total capital investment is the summation of purchase price of the developed farm and the average capital investment of the mechanisation systems. In Table 5.1 these results are shown.

5.3.3 Financial feasibility calculation procedure

The following three steps, derived from Boehlje and Eidman (1984: 332), need to be taken for financial feasibility analysis of an investment:

(a) Calculate the total annual after-tax cash net income;

(b) Calculate the total annual after-tax cash costs; and

(c) Compare the annual after-tax cash net income to the annual after tax cash costs to determine the net cash flow.

The total annual after-tax cash net income can either be positive or negative. The decision rule used by Meiring (1989) is implemented to determine when a range of cash flow results over a number of years make the investment feasible or not feasible.

Table 5.1 Capital investment in mechanisation system, land, average mechanisation system and total average investments of the fourteen crop rotation systems in the irrigation area below the P.K. le Roux Dam

No	Crop rotation system	Mechanisation system investment (R)	Average mechanisation system investment (R)	Land investment (R)	Total average (R)
1	60W60S	312934	171818	693360	865178
2	60W60LM	335527	184243	693360	877603
3	60W60LM60S	335527	184243	693360	877603
4	60W45LM15D	355611	195290	693360	888650
5	45W45LM15P	355378	195161	693360	888650
6	60W60LM60C	339172	186248	693360	879608
7	60W60S60C	341847	187719	693360	881079
8	60W45LM15D60C	361931	198766	693360	892126
9	45W45LM15P60C	361698	198637	693360	891997
10	30W30S30L	341530	187545	693360	880905
11	30W30LM30L	341530	187545	693360	880905
12	30W30S30LM30L	341530	187545	693360	880905
13	30W30LM30C30L	347850	191021	693360	884381
14	30W30S30C30L	347850	191021	693360	884381

The following equation (5.1) is used to calculate the surplus or deficit (FF_t) of the after-tax cash flow.

$$FF_t = ATXCIF_t - ATXCCF_t \qquad (5.1)$$

where:
FF_t = annual after-tax cash flow in year t
$ATXCIF_t$ = annual total after-tax net cash incomes in year t
$ATXCCF_t$ = annual total after-tax cash costs in year t

5.3.4 Calculation of annual total after-tax cash income

In the calculation of the annual total after-tax cash flow for each crop rotation system the following operational steps must be taken:

5.3.4.1 Step A

Calculate the annual net cash income for each crop. This net cash income is based on the crop net margins. The annual net cash income is the net cash income in the actual year in which the income is received. In the previous chapter the crop net margins were calculated as the revenue minus the variable production cost and minus the fixed mechanisation and irrigation system costs. Some of these fixed costs are of non-cash nature (depreciation and capital recovery costs) and must not be taken into account in the crop cash flow. The cash fixed costs (electricity and insurance) for both the mechanisation system and the irrigation system are calculated on a hectare basis for different land utilisation percentages (degree of double cropping) and pumping heights. In Table 5.2 the cash fixed costs are shown. On basis of the results in Tables 3.10, 3.15 to 3.22 and 5.2 the non-cash fixed costs are determined by subtracting the cash fixed costs from the summation of the fixed mechanisation system and irrigation system costs. In Table 5.3 the non-cash fixed costs for the crops are given on the basis of land utilisation percentage and pumping height.

The following equation (5.2) is used to calculate the annual non-cash fixed costs ($NCFCMSIS_a$).

$$NCFCMSIS_a = TFCMSIS_a - CFCMSIS_a \qquad (5.2)$$

where: $NCFCMSIS_a$ = non-cash fixed costs of the mechanisation and irrigation systems for crop a

$TFCMSIS_a$ = total fixed costs of the mechanisation and irrigation systems for crop a

$CFCMSIS_a$ = cash fixed costs of the mechanisation and irrigation systems for crop a

The next step is to add to the crop net margins the non-cash fixed costs. The following equation (5.3) is used to calculate the annual cash net income (ACIFat).

$$ACIF_{at} = ANM_{at} + NCFCMSIS_a \quad (5.3)$$

where: $ACIF_{at}$ = annual before-tax net cash income from crop a in year t

ANM_{at} = annual before-tax net margin from crop a in year t

$NCFCMSIS_a$ = fixed costs of non-cash nature of the mechanisation and irrigation systems from crop a

Table 5.2 Cash fixed costs of the mechanisation systems and irrigation systems for the alternative crops, considering different land utilisation percentages (137,5; 150; 175 or 200) and different pumping heights (+10 m or -15 m)

	+10 m (IS+10)				-15 m (IS-15)			
Crops	137,5 % (R)	150 % (R)	175 % (R)	200 % (R)	137,5 % (R)	150 % (R)	175 % (R)	200 % (R)
Wheat	55,12	42,82	37,90	34,21	48,29	41,48	36,74	33,20
Peanuts	60,68	50,33	45,41	41,72	59,21	48,99	44,25	40,71
Late maize	40,43	36,41	31,49	27,80	38,96	35,07	30,37	26,79
Dry beans	51,21	43,82	38,90	35,21	49,74	42,48	37,74	34,20
Cotton	44,69	39,32	34,40	30,71	43,20	37,98	33,24	29,70
Soyabeans	41,31	41,14	36,22	32,53	45,24	39,80	35,06	31,52
Lucerne (E)	48,64	42,05	37,13	33,44	47,17	40,71	35,97	32,43
Lucerne (F)	52,26	44,54	39,62	35,93	50,79	43,20	38,46	34,92

5.3.4.2 Step B

Multiply the annual net cash income for each crop with the number of hectares planted to these respective crops for each crop rotation system. The result is that for each crop rotation system the annual total net cash incomes are determined.

5.3.4.3 Step C

The annual total net cash income is calculated initially on a before-tax basis. Income taxes are, however, relevant and these

Table 5.3 Non-cash fixed costs of the mechanisation systems and irrigation systems for the alternative crops, considering different land utilisation percentages (137,5; 150; 175 or 200) and different pumping heights (+10 m or -15 m)

Crops	+10 m (IS+10) 137,5 % (R)	150 % (R)	175 % (R)	200 % (R)	-15 m (IS-15) 137,5 % (R)	150 % (R)	175 % (R)	200 % (R)
Wheat	368,46	337,76	302,37	275,83	353,12	323,70	290,33	265,28
Peanuts	480,55	440,51	403,12	376,58	463,03	424,45	391,08	366,03
Late maize	297,25	272,48	237,09	210,55	281,91	258,42	225,05	200,00
Dry beans	374,95	343,71	308,32	281,78	359,61	329,65	296,28	272,23
Cotton	366,91	336,34	300,95	274,41	351,57	322,28	288,91	263,86
Soyabeans	373,70	342,56	307,17	280,63	350,36	328,50	295,13	270,08
Lucerne (E)	358,01	328,18	292,79	266,25	342,67	314,12	280,75	255,70
Lucerne (F)	674,30	563,16	527,77	501,23	599,01	549,10	515,73	490,68

cash incomes must be converted to an after-tax basis. The annual total net cash income is converted to after-tax basis by multiplying this income with one minus the marginal tax rate to obtain the annual total after-tax net cash income. The result is that for each crop rotation system the annual total after-tax net cash incomes are determined.

5.3.4.4 Step D

In the previous chapter the annual crop net margins were determined for each crop and for each year in the ten-year period. In order to incorporate production and price risk, the process was repeated twenty times. In this feasibility analysis the effect of production and price risk must also be incorporated by using similarly the distributions of crop net margins and repeating the procedure of the mentioned steps twenty times with the determined randomly selected yields and prices.

The equation of the annual total after-tax net cash income for a hypothetical farm ($ATXCIF_t$) is shown in (5.4).

$$ATXCIF_t = \Sigma(ACIF_{at} \times LS_a) \times 2 \times (1-mtr) \quad (5.4)$$

where: $ATXCIF_t$ = annual total after-tax net cash income in year $_t$

$ACIF_{at}$ = annual before-tax net cash income from crop $_a$ in year $_t$

LS_a = size of land section planted to crop a

mtr = marginal tax rate (%)

t = year 1 to 10

a = crop 1 to 4

5.3.5 Calculation of annual total after-tax cash costs

The total capital investment (Table 5.1) and the debt to asset ratio are the basis for the calculation of the obligatory annual payments on land and the mechanisation system. In the calculation of the annual capital and interest payments for each crop rotation system the following operational steps must be taken:

5.3.5.1 Step A

Divide the investment, which includes developed land plus mechanisation systems into a part of the investment that is financed by own capital and into a part that is financed by debt capital, according to the three groups of debt to asset ratios. Successively for each group the total capital that is loaned (debt capital) is divided into three terms, respectively 40 per cent short term, 25 per cent medium term and 35 per cent long term. The short-term capital is divided into 70 per cent overdraft, 20 per cent production loan and 10 per cent monthly account.

5.3.5.2 Step B

The purchase of the land is financed through the Land Bank on the long-term loan. The total long-term loan is repaid in the form of twenty annual instalments. The annual instalment consists of capital and interest parts. The distinction between the capital and the interest part is made for tax-saving purposes and will be dealt with in Step C. As the simulation research is over a period of ten years only the interest and capital parts for these years are taken into account. The following equation (5.5) is used to calculate the capital part ($CAPlt_t$) of the instalments.

$$CAPlt_t = INSTlt_t - INTlt_t \qquad (5.5)$$

where: $CAPlt_t$ = long-term capital in year t
$INSTlt_t$ = long-term instalment in year t
$INTlt_t$ = long-term interest in year t

The mechanisation systems are financed by medium-term loans from the Land Bank, commercial banks and cooperatives, with 70 to 75 per cent financed by the commercial banks (Volkskas Bank, 1991). The continuous replacement of implements of the mechanisation system is taken to be financed by these banks. The farmers repay these medium-term loans by means of annual instalments. The annual effective interest rate (i_a) paid on these loans is based on the monthly interest rate (i_m) and is calculated according to the following equation (5.6):

$$i_a = (1 + i_m/12)^{12} \qquad (5.6)$$

where: i_a = annual effective interest rate
i_m = monthly interest rate.

On the monthly interest rate of 2 per cent the annual effective interest rate is 26,84 per cent. The annual implement purchases are repaid by means of instalments. As the medium-term from the commercial banks is for four years, each annual purchase is divided into four annual instalments. The medium-term debt (MT) consists of the capital parts ($CAPmt_t$) of the instalments that remained to be paid. In any year the medium-term debt consists of four fourth-year, three third-year, two second-year and one first-year remaining capital parts to be paid. The following equations (5.7 to 5.17) are used firstly to calculate the total of capital parts that remain to be paid, and secondly to calculate the annual purchase of implements (MSAP) of the mechanisation systems:

$$MT_0 = CAPmt_1 + CAPmt_2 + CAPmt_3 + CAPmt_4 \quad (5.7)$$
$$MT_{-1} = CAPmt_2 + CAPmt_3 + CAPmt_4 \quad (5.8)$$
$$MT_{-2} = CAPmt_3 + CAPmt_4 \quad (5.9)$$
$$MT_{-3} = CAPmt_4 \quad (5.10)$$
$$MT = MT_0 + MT_{-1} + MT_{-2} + MT_{-3} \quad (5.11)$$
$$= (4 \times CAPmt_4) + (3 \times CAPmt_3) + (2 \times CAPmt_2) + (1 \times CAPmt_1) \quad (5.12)$$
$$CAPmt_t = INSTmt_t - INTmt_t \quad (5.13)$$
$$INTmt_1 = MSAP \times i_a \quad (5.14)$$
$$INTmt_2 = (MSAP - CAPmt_1) \times i_a \quad (5.15)$$
$$INTmt_3 = (MSAP - CAPmt_2 - CAPmt_1) \times i_a \quad (5.16)$$
$$INTmt_4 = (MSAP - CAPmt_3 - CAPmt_2 - CAPmt_1) \times i_a \quad (5.17)$$
$$MT = 1(INSTmt_t - INTmt_1) + 2(INSTmt_t - INTmt_2) + 3(INSTmt_t - INTmt_3) + 4(INSTmt_t - INTmt_4)$$
$$= 10INSTmt_t - 1INTmt_1 - 2INTmt_2 - 3INTmt_3 - 4INTmt_4$$
$$INTmt_2 = (MSAP - INSTmt_t + INTmt_1) \times i_a$$
$$= (INTmt1/ia - INSTmt_t + INTmt1) \times i_a$$
$$MSAP = f(CAPmt_1, CAPmt_2, CAPmt_3, CAPmt_4, INTmt_1, INTmt_2, INTmt_3, INTmt_4 \text{ and } MT). \quad (5.18)$$

The annual purchases are a function of the mentioned factors and can by means of the continued process of substitution be calculated:

where: MT_s = medium-term debt

MT_0 = Capital parts of instalments that remain to be paid the next four years with regard to purchases made this year ($_s$=0)

MT_{-1} = Capital parts of instalments that remain to be paid the next three years with regard to purchases made last year ($_s$=-1)

MT_{-2} = Capital parts of instalments that remain to be paid the next two years with regard to purchases made two years ago ($_s$=-2)

MT_{-3} = Capital part of instalments that remains to be paid this year with regard to purchases made three years ago ($_s$=-3)

$INSTmt_t$ = annual instalment in year t
$INTmt_t$ = annual interest redemption in year t
$CAPmt_t$ = annual capital redemption in year t
MSAP = annual purchases of implements

i_a = annual effective interest rate
t = year 1 to 4
s = year 0 to -3

During the crop growth process non-production costs, such as domestic expenses, are incurred and paid for with the overdraft account from the commercial banks (short-term credit). Interest on the amount is determined as the actual interest rate multiplied with the balance of the account. At the end of a production period the revenue obtained from the crop is used firstly to repay this account. The following equation (5.19) is used to calculate the overdraft interest rate (INTov):

$$INTov = (Bov \times i_m \times 6) \times 2 \quad (5.19)$$

where: INTov = interest on overdraft
Bov = overdraft balance
i_m = monthly interest rate.

The cooperatives provide short term credit in the form of a production loan and a monthly account. The production loan is used by the farmers to purchase production inputs. These inputs plus the interest are already included in the crop budgets and no additional provision has to be made for them. The monthly account is used for non-direct production costs, for example labour rations. This account is to be cleared monthly and the interest thereon must be accounted for. The interest is calculated as the average of 17/30 of the balance multiplied with the monthly interest rate for the 12 months. The 17/30 refers to the seventeenth day of the month. The following equation (5.20) is used to calculate the interest on the monthly account (INTma):

$$INTma = (17/30 \times Bma \times i_m) \times 12 \quad (5.20)$$

where: INTma = interest monthly account
Bma = Balance monthly account
i_m = monthly interest rate.

It is assumed that this account and the overdraft remain and increase constantly throughout the year.

5.3.5.3 Step C

The purpose of dividing the instalments into capital and interest parts is to determine the tax that can be saved on the interest, as interest is a tax deductible cost. The net interest to be paid is the interest before tax deductions multiplied with 1 minus the marginal tax rate. The interest before tax is the different interest parts from the long and medium instalments and short-term loans. The following equations (5.21 to 5.24) are used to calculate the net interest on the different accounts (NINT):

$$NINTlt_t = INTlt_t \times (1-mtr) \quad (5.21)$$
$$NINTmt_t = INTmt_t \times (1-mtr) \quad (5.22)$$
$$NINTov_t = INTov_t \times (1-mtr) \quad (5.23)$$
$$NINTma_t = INTma_t \times (1-mtr) \quad (5.24)$$

where: $NINTlt_t$ = net interest on long-term in year t
$NINTmt_t$ = net interest on medium-term in year t
$NINTov_t$ = net interest on overdraft in year t
$NINTma_t$ = net interest monthly account in year t
$INTlt_t$ = interest on long-term in year t
$INTmt_t$ = interest on medium-term in year t
$INTov_t$ = interest on overdraft term in year t
$INTma_t$ = interest on monthly account in year t
mtr = marginal tax rate.

5.3.5.4 Step D

The required annual premium on a life insurance policy linked to a long term loan from the Land Bank is calculated as the mentioned factor multiplied with the total developed land price. The equation of the annual premium (PREM) is given in (5.25):

$$PREM = LP \times pf \quad (5.25)$$

where: PREM = annual insurance premium on land
LP = purchase price of developed land
pf = premium factor (0.00406235)

5.3.5.5 Step E

Depreciation is not a cash cost item but generates tax savings. It is assumed that the farmer replaces the individual implements of the mechanisation system continuously after their economic life has expired. On the purchase of new implements the farmer is allowed to depreciate 50, 30 and 20 per cent annually in respectively the first, second and third year. The accumulated depreciation of the implements purchased over three years is multiplied with the marginal tax rate to determine the tax savings. The following equation (5.26) calculates the depreciation tax savings (DTSt):

$$DTS_t = \{(MSAP1x0,5) + (MSAP2x0,3) + (MSAP3x0,2)\} \times mtr \quad (5.26)$$

$$DTS_t = MSAP \times mtr \quad (5.27)$$

where:
- DTS_t = depreciation tax savings in year t
- $MSAP_1$ = annual purchases of implements in year t=1
- $MSAP_2$ = annual purchases of implements in year t=2
- $MSAP_3$ = annual purchases of implements in year t=3
- $MSAP_1 = MSAP_2 = MSAP_3$
- mtr = marginal tax rate

The following equation ($ATNCOF_t$) represents the annual payments on net interest, capital insurance minus depreciation tax savings, which is compiled from the equations (5.21), (5.5), (5.22), (5.13), (5.23), (5.24), (5.25) and (5.27).

$$ATXCCF_t = NINTlt_t + CAPlt_t + NINTmt_t + CAPmt_t + NINTov_t + NINTma_t + PREM - DTS_t \quad (5.28)$$

where:
- $ATXCCF_t$ = annual total after-tax cash costs in year t
- $NINTlt_t$ = net interest on long-term in year t
- $NINTmt_t$ = net interest on medium-term in year t
- $NINTov_t$ = net interest on overdraft in year t
- $NINTma_t$ = net interest on monthly account in year t
- PREM = annual insurance premium on land
- DTS_t = depreciation tax savings in year t
- $CAPmt_t$ = capital on medium-term in year t
- $CAPlt_t$ = capital on long-term in year t

5.3.6 Financial feasibility calculation

The equations (5.4), (5.28) and (5.1) are used to calculate the financial feasibility for each crop rotation system for both irrigation systems and for each debt to asset ratio:

$$FF_t = ATXCIF_t - ATXCCF_t \quad (5.1)$$

$$ATXCCF_t = NINTlt_t + CAPlt_t + NINTmt_t + CAPmt_t + NINTov_t + NINTma_t + PREM - DTS_t \quad (5.28)$$

$$ATXCIF_t = \Sigma(ACIF_{at} \times LS_a) \times 2 \times (1-mtr) \quad (5.4)$$

where: FF_t = annual after-tax cash flow in year t

$ATXCIF_t$ = annual total after-tax net cash incomes in year t

$ATXCCF_t$ = annual total after-tax cash costs in year t

The other terms are defined as above.

The analysis is done over the period of ten years and repeated twenty times for each year. The LOTUS program is used in the compilation of the files and calculations of financial feasibility. The values obtained represent the annual real net cash flow. A positive cash flow indicates that the cash inflow exceeds cash payments and a negative cash flow indicates that the cash payments exceed the cash inflow. The previously mentioned decision rule is used to determine when a given year is feasible and secondly to determine whether a given ten-year period is feasible.

5.4 RESULTS AND DISCUSSION OF RESULTS

In Table 5.4 an example is given of the annual net surplus or deficit for the crop rotation systems 30W30S30C30L for a +10 m pumping height and a 70/30 debt to asset ratio. This crop rotation system does have respectively 3,1,1,2,3,2,0,4,2 and 3 cash deficits out of a possible of 20 replications for 10 years and therefore it is not financially feasible according to the decision rule.

Table 5.4 Annual net cash surplus or deficit for crop rotation system 30W30S30C30L for a pumping height of +10 m (IS+10) and a 70/30 debt to asset ratio for twenty replications over a period of ten years

Replica-tions	Year 1 (R)	2 (R)	3 (R)	4 (R)	5 (R)	6 (R)	7 (R)	8 (R)	9 (R)	10 (R)
1	9701	12866	8048	6122	-10407	-1687	4583	6415	15086	2710
2	21303	24617	25393	28488	8352	16401	16739	-5693	5265	12652
3	-7034	14757	5914	-12805	5280	2937	9785	13046	1354	-3221
4	13423	9239	26744	43378	-4083	3962	22994	22891	24250	3272
5	15931	23731	-11091	-9609	20189	3089	4915	9973	16474	18648
6	22419	21875	37176	27695	11216	21280	7902	-3471	-2899	7851
7	24463	31738	15222	7117	21828	25677	43404	16716	6473	29558
8	-856	7285	35526	42735	34548	11074	4627	12357	19048	18857
9	18622	31606	7479	17522	29150	7793	4450	-7180	-12508	-3132
10	15264	12491	11797	16507	10364	19465	16302	8879	21405	17205
11	28312	41721	22946	22684	28713	23944	30020	21586	19548	19018
12	1788	5698	12046	3301	-3554	6059	25448	25990	29642	23737
13	10094	-6706	9950	23559	27300	11520	15286	27976	20359	26056
14	12725	15071	36854	32756	2233	16379	38501	22341	9658	12839
15	7687	6342	25218	32333	11106	7551	24730	27664	9369	3634
16	7891	10225	31259	24256	18157	24870	30513	28212	25472	25144
17	15246	24377	21357	30821	19277	13346	17487	25246	41893	19786
18	31031	29858	18538	25498	25389	8422	21315	23751	8141	16300
19	-6755	10395	14576	8303	7348	-5205	20117	34379	2152	-11018
20	3293	4913	21085	34724	12067	11729	1045	-927	14783	1248

The summary of the financial feasibility results for all crop rotation systems according to the decision rule is given in Tables 5.5, 5.6, 5.7, 5.8, 5.9 and 5.10. The tables reflect the influence of the two irrigation areas and the influence of the three alternative debt to asset ratios for all typical crop rotation systems on financial feasibility.

The results indicate that the debt to asset ratio of the farmer is the main factor influencing financial feasibility.

For farmers with a 70/30 debt to asset ratio all crop rotations systems are unfeasible for the +10 m (IS+10) pumping height.

Table 5.5 Number of replications out of 20 per year with annual cash flow deficits over a 10-year period for a 70/30 debt to asset ratio and a pumping height of +10 m (IS+10) for the crop rotation systems

Crop rotation system	Year 1	2	3	4	5	6	7	8	9	10	Total
1 60W60S	20	20	20	20	20	20	20	20	20	20	200
2 60W60LM	20	20	20	20	20	20	20	20	20	20	200
3 60W60LM60S	20	20	20	20	20	20	20	20	20	20	200
4 60W45LM15D	20	20	20	20	20	20	20	20	20	20	200
5 45W45LM15P	20	20	20	20	20	20	20	20	20	20	200
6 60W60LM60C	20	20	20	20	20	20	20	20	20	20	200
7 60W60S60C	20	20	20	20	20	20	20	20	20	20	200
8 60W45LM15D60C	20	20	20	20	20	20	20	20	20	20	200
9 45W45LM15P60C	20	20	20	20	20	20	20	20	20	20	200
10 30W30S30L	11	8	7	7	3	11	5	6	9	8	85
11 30W30LM30L	13	12	12	11	14	15	10	10	16	13	126
12 30W30S30LM30L	11	12	7	11	3	15	5	10	8	13	95
13 30W30LM30C30L	6	4	3	4	5	7	5	7	5	7	52
14 30W30S30C30L	3	1	1	2	3	2	0	4	2	3	21

Table 5.6 Number of replications out of 20 per year with annual cash flow deficits over a 10-year period for a 70/30 debt to asset ratio and a pumping height of -15 m (IS-15) for the crop rotation systems

Crop rotation system	Year 1	2	3	4	5	6	7	8	9	10	Total
1 60W60S	20	20	20	20	20	20	20	20	20	20	200
2 60W60LM	20	20	20	20	20	20	20	20	20	20	200
3 60W60LM60S	20	20	20	20	20	20	20	20	20	20	200
4 60W45LM15D	20	20	20	20	20	20	20	20	20	20	200
5 45W45LM15P	20	20	20	20	20	20	20	20	20	20	200
6 60W60LM60C	20	20	20	20	20	20	20	20	20	20	200
7 60W60S60C	20	20	20	20	20	20	20	20	20	20	200
8 60W45LM15D60C	20	20	20	20	20	20	20	20	20	20	200
9 45W45LM15P60C	19	19	19	19	20	20	19	20	20	19	194
10 30W30S30L	0	0	1	1	0	1	0	0	2	0	5
11 30W30LM30L	9	9	6	5	5	9	7	8	7	8	73
12 30W30S30LM30L	5	9	2	5	1	9	3	8	5	8	55
13 30W30LM30C30L	2	0	0	2	1	0	0	4	2	3	14
14 30W30S30C30L	0	0	0	0	0	0	0	0	0	0	0

Table 5.7 Number of replications out of 20 per year with annual cash flow deficits over a 10-year period for a 50/50 debt to asset ratio and a pumping height of +10 m (IS+10) for the crop rotation systems

Crop rotation system	Year 1	2	3	4	5	6	7	8	9	10	Total
1 60W60S	15	17	17	17	16	16	16	17	18	16	165
2 60W60LM	17	19	19	19	20	17	17	19	18	18	185
3 60W60LM60S	17	18	19	19	20	18	18	18	19	18	183
4 60W45LM15D	16	16	20	17	18	11	11	16	15	15	158
5 45W45LM15P	16	15	17	17	18	20	20	16	16	17	166
6 60W60LM60C	13	8	10	11	13	14	14	13	15	12	124
7 60W60S60C	5	6	5	6	7	9	9	7	7	7	66
8 60W45LM15D60C	9	4	5	8	8	5	5	10	9	7	73
9 45W45LM15P60C	10	7	6	8	8	9	8	10	8	8	82
10 30W30S30L	0	0	0	0	0	0	0	0	0	0	0
11 30W30LM30L	0	0	0	0	0	0	0	0	0	0	0
12 30W30S30LM30L	0	0	0	0	0	0	0	0	0	0	0
13 30W30LM30C30L	0	0	0	0	0	0	0	0	0	0	0
14 30W30S30C30L	0	0	0	0	0	0	0	0	0	0	0

Table 5.8 Number of replications out of 20 per year with annual cash flow deficits over a 10-year period for a 50/50 debt to asset ratio and a pumping height of -15 m (IS-15) for the crop rotation systems

Crop rotation system	Year 1	2	3	4	5	6	7	8	9	10	Total
1 60W60S	9	9	13	7	7	7	3	8	7	7	77
2 60W60LM	16	16	19	19	18	13	14	17	17	17	166
3 60W60LM60S	16	14	15	17	16	12	12	16	16	16	150
4 60W45LM15D	12	7	9	11	11	10	9	11	11	7	98
5 45W45LM15P	13	7	9	13	11	12	10	12	12	10	109
6 60W60LM60C	10	6	4	6	8	9	8	6	9	19	75
7 60W60S60C	1	0	3	2	3	4	3	2	4	2	24
8 60W45LM15D60C	2	1	1	2	3	3	4	3	3	4	26
9 45W45LM15P60C	4	2	2	2	4	4	3	4	4	6	35
10 30W30S30L	0	0	0	0	0	0	0	0	0	0	0
11 30W30LM30L	0	0	0	0	0	0	0	0	0	0	0
12 30W30S30LM30L	0	0	0	0	0	0	0	0	0	0	0
13 30W30LM30C30L	0	0	0	0	0	0	0	0	0	0	0
14 30W30S30C30L	0	0	0	0	0	0	0	0	0	0	0

Table 5.9 Number of replications out of 20 per year with annual cash flow deficits over a 10-year period for a 20/80 debt to asset ratio and a pumping height of +10 m (IS+10) for the crop rotation systems

Crop rotation system	Year 1	2	3	4	5	6	7	8	9	10	Total
1 60W60S	0	0	0	0	0	0	0	0	0	0	0
2 60W60LM	2	0	0	1	1	1	1	0	1	2	9
3 60W60LM60S	0	0	0	0	0	0	0	0	0	0	0
4 60W45LM15D	0	0	0	0	0	0	0	0	0	0	0
5 45W45LM15P	0	0	0	0	0	0	0	0	0	0	0
6 60W60LM60C	0	0	0	0	0	0	0	0	0	0	0
7 60W60S60C	0	0	0	0	0	0	0	0	0	0	0
8 60W45LM15D60C	0	0	0	0	0	0	0	0	0	0	0
9 45W45LM15P60C	0	0	0	0	0	0	0	0	0	0	0
10 30W30S30L	0	0	0	0	0	0	0	0	0	0	0
11 30W30LM30L	0	0	0	0	0	0	0	0	0	0	0
12 30W30S30LM30L	0	0	0	0	0	0	0	0	0	0	0
13 30W30LM30C30L	0	0	0	0	0	0	0	0	0	0	0
14 30W30S30C30L	0	0	0	0	0	0	0	0	0	0	0

Table 5.10 Number of replications out of 20 per year with annual cash flow deficits over a 10-year period for a 20/80 debt to asset ratio and a pumping height of -15 m (IS-15) for the crop rotation systems

Crop rotation system	Year 1	2	3	4	5	6	7	8	9	10	Total
1 60W60S	0	0	0	0	0	0	0	0	0	0	0
2 60W60LM	1	0	0	0	0	0	0	0	0	0	1
3 60W60LM60S	0	0	0	0	0	0	0	0	0	0	0
4 60W45LM15D	0	0	0	0	0	0	0	0	0	0	0
5 45W45LM15P	0	0	0	0	0	0	0	0	0	0	0
6 60W60LM60C	0	0	0	0	0	0	0	0	0	0	0
7 60W60S60C	0	0	0	0	0	0	0	0	0	0	0
8 60W45LM15D60C	0	0	0	0	0	0	0	0	0	0	0
9 45W45LM15P60C	0	0	0	0	0	0	0	0	0	0	0
10 30W30S30L	0	0	0	0	0	0	0	0	0	0	0
11 30W30LM30L	0	0	0	0	0	0	0	0	0	0	0
12 30W30S30LM30L	0	0	0	0	0	0	0	0	0	0	0
13 30W30LM30C30L	0	0	0	0	0	0	0	0	0	0	0
14 30W30S30C30L	0	0	0	0	0	0	0	0	0	0	0

For farmers with a 70/30 debt to asset ratio all crop rotations systems except 30W30S30C30L are unfeasible for the -15 m (IS-15) pumping height.

For farmers with a 50/50 debt to asset ratio the crop rotation systems 60W60S to 45W45LM15P60C are not feasible while the crop rotation systems 30W30S30L to 30W30S30C30L are feasible. The order of feasibility of the crop rotation systems reflects the same order as obtained in the present values. The number of cash flow deficits out of a possible of 200 (20 replications * 10 years) for each crop rotation system indicate the comparative degree of infeasibility of these crop rotation systems. Crop rotation systems 60W60LM and 60W60LM60S are the most unfeasible, while crop rotation systems 60W60S60C and 60W45LM15D60C are the least unfeasible.

For farmers with a 20/80 debt to asset ratio all crop rotations systems except 60W60LM are feasible for the +10 m (IS+10) pumping height.

For farmers with a 20/80 debt to asset ratio all crop rotations systems except 60W60LM are feasible for the -15 m (IS-15) pumping height.

The difference in the pumping height does not much influence the above-mentioned results. Only the relatively most profitable crop rotation system 30W30S30C30L with a pumping height of -15 m (IS-15) is financially feasible for a 70/30 debt to asset ratio. Only the relatively least profitable crop rotation system 60W60LM with pumping heights of both + 10 m (IS+10) and -15 m (IS-15) is financially unfeasible for a 20/80 debt to asset ratio.

For a 50/50 debt to asset ratio the crop rotation systems which are unfeasible with a pumping height of -15 m remains unfeasible but have correspondingly less cash flow deficit years.

In the annexure in Tables 5.11 to 5.27 seventeen financial feasibility results are given for crop rotation systems

30W30S30C30L, 30W30S30L and 45W45LM15P60C for respectively all three debt to asset ratios and both pumping heights. These specific crop rotation systems are shown as 30W30S30C30L as the relatively most profitable and feasible crop rotation system, 30W30S30L as the relatively most profitable crop rotation system, which excludes cotton and 45W45LM15P60C as the relatively most profitable crop rotation system which excludes lucerne.

5.5 CONCLUSIONS

For the given crop rotation systems the ranking order of financial feasibility conforms not completely with the ranking order of economic profitability. The most financially feasible crop rotation system is also the relatively most economic profitable system. On basis of the least deficit years the most financially feasible crop rotation system which excludes lucerne is 60W60S60C, while the relatively most economic profitable crop rotation system is 45W45LM15P60C.

For the given crop rotation systems the debt to asset ratio is more important than the crop rotation system when maintaining financial feasibility on farm level.

The difference in the pumping height does not considerably influence the results on financial feasibility.

5.6 RECOMMENDATIONS

Apart from the analysis of the crop rotation systems for three different debt to asset ratios the break-even debt to asset ratio for each crop rotation system can be determined.

A sensitivity analysis can be performed on determining the effect of different interest rates on the financial feasibility of the crop rotation systems.

ANNEXURE

The following tables, Tables 5.11 to 5.27, show the annual net cash surplus or deficit for three selected crop rotation systems with two pumping heights and three debt to asset ratios.

Table 5.11 Annual net cash surplus or deficit for crop rotation system 30W30S30C30L for a pumping height of +10 m (IS+10) and a 50/50 debt to asset ratio for twenty replications over a period of ten years

Replica-					Year					
tions	1	2	3	4	5	6	7	8	9	10
	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)
1	51374	54554	49757	47853	31349	40099	46404	48279	56998	44679
2	62976	66306	67101	70219	50108	58188	58560	36171	47177	54622
3	34640	56446	47622	28926	47036	44723	51606	54910	43267	38748
4	55096	50927	68452	85109	37673	45749	64816	64755	66162	45242
5	57604	65420	30617	32122	61945	44875	46736	51837	58386	60617
6	64093	63563	78885	69426	52973	63067	49724	38392	39014	49821
7	66136	73426	56931	48848	63584	67463	85226	58580	48386	71527
8	40817	48974	77234	84466	76304	52860	46449	54221	60961	60826
9	60295	73294	49187	59253	70906	49580	46272	43683	29404	38837
10	56937	54179	53505	58238	52120	61252	58124	50743	63317	59174
11	69985	83410	64654	64415	70469	65730	71842	63449	61460	60988
12	43461	47386	53755	45032	38202	47845	67270	67854	71554	65707
13	51767	34983	51658	65290	69056	53306	57108	69840	62272	68025
14	54398	56759	78562	74487	43989	58165	80323	64205	51570	54808
15	49360	48031	66976	74064	52862	49337	66552	69528	51281	45604
16	49564	51913	72968	65987	59913	66656	72335	70076	67384	67114
17	56919	67166	63065	72552	61033	55132	59309	67110	83806	61755
18	72704	71547	60246	67229	67145	50208	63137	65615	50053	58270
19	34918	52083	56284	50034	49105	36581	61938	76243	44065	30951
20	44966	46602	62794	76455	53823	53515	42866	40937	56695	43218

Table 5.12 Annual net cash surplus or deficit for crop rotation system 30W30S30C30L for a pumping height of +10 m (IS+10) and a 20/80 debt to asset ratio for twenty replications over a period of ten years

Replica-tions	Year 1 (R)	2 (R)	3 (R)	4 (R)	5 (R)	6 (R)	7 (R)	8 (R)	9 (R)	10 (R)
1	113884	117089	112319	110449	93984	102779	109138	111075	119867	107633
2	125486	128840	129664	132815	112743	120868	121294	98967	110046	117575
3	97149	118980	110185	91522	109671	107404	114340	117705	106135	101702
4	117606	113462	131015	147705	100308	108429	127649	127550	129031	108195
5	120114	127954	93180	94718	124580	107556	109470	114633	121254	123571
6	126603	126098	141447	132022	115607	125747	112457	101188	101882	112774
7	128646	135961	119493	111444	126219	130143	147959	121375	111254	134481
8	103327	111508	139797	147062	138939	115540	109182	117017	123829	123780
9	122805	135828	111750	121848	133541	112260	109005	97479	92273	101791
10	119447	116713	116068	120834	114755	123932	120857	113538	126186	122128
11	132495	145944	127217	127010	133103	128411	134575	126245	124329	123941
12	105971	109920	116317	107628	100837	110526	130003	130649	134422	128660
13	114277	97517	114221	127886	131691	115987	119841	132635	125140	130979
14	116908	119294	141125	137082	106624	120846	143056	127001	114439	117762
15	111870	110565	129489	136660	115497	112018	129285	132323	114149	108557
16	112074	114448	135530	128583	122548	129336	135068	132872	130253	130067
17	119429	129700	125628	135148	123668	117812	122043	129906	146674	124709
18	135214	134081	122809	129825	129780	112888	125871	128411	112922	121224
19	97428	114618	118847	112630	111739	99262	124672	139038	106933	93905
20	107476	109136	1235356	139051	116458	116195	105600	103733	119564	106171

Table 5.13 Annual net cash surplus or deficit for crop rotation system 30W30S30C30L for a pumping height of -15 m (IS-15) and a 70/30 debt to asset ratio for twenty replications over a period of ten years

Replica-	Year									
tions	1	2	3	4	5	6	7	8	9	10
	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)
1	17307	20404	18151	16444	293	9164	15375	16782	25404	13154
2	31439	34989	35805	54168	34433	26903	27168	4890	15752	23065
3	3534	25261	16316	-2005	16069	13334	17609	20943	12166	7577
4	23265	18993	36984	53437	6276	14552	33372	31114	31977	13196
5	26678	34632	24170	11400	30527	13524	15077	20096	26775	28992
6	32784	32568	47535	38183	22407	32400	18565	7009	7542	18091
7	34607	39882	23412	18051	32267	35177	50593	24874	16730	39044
8	7700	16037	45859	52372	44183	21204	15305	22684	29359	29527
9	28217	41619	15958	26059	40001	18784	15484	3595	-2618	6402
10	23785	20690	22663	27358	20682	29243	26635	19722	32126	28295
11	38269	52066	34063	33429	39323	34579	40577	29187	27188	29576
12	12493	16447	20395	11896	7549	16642	35381	36253	39924	33922
13	22051	5768	19845	33128	37515	21983	25846	38412	30923	36306
14	23473	25635	46765	42745	13076	27397	49161	32825	20295	23584
15	18058	14657	33055	42674	21995	18061	32372	35591	20300	14214
16	18657	20739	42983	35722	28082	35467	40992	38439	35464	35229
17	25158	33439	30038	41787	30194	24373	28525	33471	50113	30375
18	41964	40673	45199	51211	34591	18281	28779	31417	18844	27213
19	3454	19928	17941	12080	17925	5396	30109	44347	12971	12365
20	10950	13527	29604	45200	22521	22325	11616	9811	25868	9114

Table 5.14 Annual net cash surplus or deficit for crop rotation system 30W30S30C30L for a pumping height of -15 m (IS-15) and a 50/50 debt to asset ratio for twenty replications over a period of ten years

Replica-					Year					
tions	1	2	3	4	5	6	7	8	9	10
	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)
1	58981	62093	59860	58174	42050	50951	57198	58646	67317	55124
2	73113	76678	77514	95898	76190	68690	68991	46754	57665	65035
3	45208	66950	58025	39725	57826	55121	59432	62807	54079	49547
4	64939	60682	78693	95167	48033	56339	75195	72978	73890	55166
5	68352	76321	41879	43130	72284	55311	56900	61960	68688	70962
6	74458	74257	89244	79913	64164	74187	60388	48873	49455	60061
7	76281	81571	65121	59781	74024	76964	92416	66738	58643	81014
8	49374	57726	87568	94102	85940	62991	57128	64548	71272	71497
9	69891	83308	57667	67789	81758	69571	57307	45459	39295	48372
10	65459	62379	64372	69088	62439	71030	68458	61586	74039	70265
11	79943	93755	75772	75159	81080	76366	82400	71051	69101	71546
12	54167	58136	62104	53626	49306	58429	77204	78117	81837	75892
13	63725	47457	61554	74858	79272	63770	67669	80276	72836	78276
14	65147	67324	88474	84475	54833	69184	90984	74689	62208	65554
15	59732	56346	74764	84404	63752	59848	74195	77455	62213	56184
16	60331	62428	84692	77452	69839	77254	82815	80303	77377	77199
17	66832	75128	71747	83517	71951	66160	70348	75335	92026	72345
18	83638	82362	86908	92941	76348	60068	70602	73281	60757	69183
19	45128	61617	59650	53810	59682	47183	71932	86211	54884	42035
20	52624	55216	71313	86930	64278	64112	53439	51675	67781	51084

Table 5.15 Annual net cash surplus or deficit for crop rotation system 30W30S30C30L for a pumping height of -15 m (IS-15) and a 20/80 debt to asset ratio for twenty replications over a period of ten years

Replica-					Year					
otions	1	2	3	4	5	6	7	8	9	10
	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)
1	121491	124627	122422	120770	104684	113631	119932	121442	130185	118078
2	135623	139212	140076	158494	138824	131370	131725	109550	120533	127989
3	107718	129484	120587	102321	120460	117801	122166	125603	116947	112501
4	127449	123216	141255	157763	110667	119019	137929	135774	136758	118120
5	130862	138855	104441	105726	134918	117991	119634	124756	131556	133916
6	136968	136791	151806	142509	126798	136867	123122	111669	112323	123015
7	138791	144105	127683	122377	136658	139644	155150	129534	121511	143968
8	111884	120260	150130	156698	148574	125671	119862	127344	134140	134451
9	132401	145842	120229	130385	144392	123251	120041	108255	102163	111326
10	127969	124913	126934	131684	125073	133710	131192	124382	136907	133219
11	142453	156289	138334	137755	143714	139046	145134	133847	131969	134500
12	116677	120670	124666	116222	111940	121109	139938	140913	144705	138846
13	126235	109991	124116	137454	141906	126450	130403	143072	135704	141230
14	127657	129858	151036	147071	117467	131864	153718	137485	125076	128508
15	122242	118880	137326	147000	126386	122528	136929	140251	125081	119138
16	122841	124962	147254	140048	132473	139934	145549	143099	140245	140153
17	129342	137662	134309	146113	134585	128840	133082	138131	154894	135299
18	146148	144896	149470	155537	138982	122748	133336	136077	123625	132137
19	107638	124151	122212	116406	122316	109863	134666	149007	117752	104989
20	115134	117750	133875	149526	126912	126792	116173	114471	130649	114038

Table 5.16 Annual net cash surplus or deficit for crop rotation system 30W30S30L for a pumping height of +10 m (IS+10) and a 70/30 debt to asset ratio for twenty replications over a period of ten years

Replica-	Year									
tions	1	2	3	4	5	6	7	8	9	10
	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)
1	-10327	10735	-1254	-7225	-3105	-19200	12218	-534	19229	-1384
2	-11234	29434	12760	16428	17350	-24775	34786	3588	-26128	-5213
3	-11897	-3983	34304	-23099	-3222	-3149	2072	-8000	5736	13009
4	-16433	24746	-30927	27095	15756	-21081	36103	20116	31390	-13825
5	2880	-2515	10204	-26560	20892	37481	-10100	6506	-16599	18029
6	17314	9583	12124	35091	6307	12413	17860	-5545	-17473	-18083
7	34241	-7510	46126	-16197	15193	-14235	29353	44689	-23535	31070
8	-10945	-18289	17570	43516	23061	255176	-17857	1949	-3554	17128
9	-8685	14783	16273	-13277	28461	-422	-16550	-6109	-12373	2321
10	-683	320	-5202	1092	2695	-10241	27531	-7366	11453	24936
11	3332	38396	28740	29557	29581	23613	1714	17149	-3461	6517
12	-9163	14039	7962	23008	-11392	2190	377	28670	-1933	33866
13	29880	-2924	-893	-9411	15533	-2112	-11070	43815	17379	10592
14	10911	-3816	19227	9505	13116	-6234	41490	34488	1152	-4980
15	2809	1123	-6095	22359	12651	30546	11689	8126	13799	1820
16	13348	3826	9906	13273	14820	1754	20647	19853	3642	22846
17	-17463	21361	7653	21453	35602	7656	24469	13339	28568	17117
18	12548	12882	21911	-6395	19994	-4500	862	32735	2384	-962
19	-9369	-21064	14777	18415	4711	-14896	-3280	36140	17284	-6773
20	-8839	29320	-3130	5597	16429	4938	27137	-25197	10091	-100

Table 5.17 Annual net cash surplus or deficit for crop rotation system 30W30S30L for a pumping height of +10 m (IS+10) and a 50/50 debt to asset ratio for twenty replications over a period of ten years

Replica-	Year									
tions	1	2	3	4	5	6	7	8	9	10
	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)
1	31181	52260	40291	34341	38487	22422	53876	41165	60976	40420
2	30275	70959	54304	57994	58941	16846	76444	45288	15619	36591
3	29612	35743	75848	18467	38369	38473	43730	33699	36012	54812
4	25076	66271	10617	68661	57348	20541	77761	61815	73137	27979
5	44389	39011	51748	15006	62484	79102	31558	48206	25148	59832
6	58822	51108	53669	76657	47899	54035	59517	36154	24274	23720
7	75750	34015	87670	25369	56784	27387	71010	86388	18212	72873
8	30564	23236	59114	85082	64653	296798	23801	43648	38193	58932
9	32824	56309	57817	28289	70053	41200	25108	35590	29375	44125
10	40825	41845	36342	42658	44286	31381	69189	34334	53200	66739
11	44841	79922	70284	71123	71172	65235	43372	58848	38286	48320
12	32345	55565	33583	64574	30200	43812	42035	70370	39815	75670
13	71388	38602	40651	32155	57124	39510	30588	85514	59127	52395
14	52420	37709	60772	51071	54707	35388	83148	76188	42899	36824
15	44317	40402	35449	63925	54242	72168	53346	49826	55547	43624
16	54856	45352	51450	54839	56412	43376	62305	61552	45389	64650
17	24046	62887	49197	63019	77193	49278	66127	55038	70315	58921
18	54057	54407	63455	35171	61585	37122	42519	74434	44131	40842
19	32140	20461	56322	59981	46302	26726	38377	77839	59031	35031
20	32670	70846	38415	47163	58020	46560	68794	16503	51839	40796

Table 5.18 Annual net cash surplus or deficit for crop rotation system 30W30S30L for a pumping height of +10 m (IS+10) and a 20/80 debt to asset ratio for twenty replications over a period of ten years

Replica-	Year									
tions	1	2	3	4	5	6	7	8	9	10
	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)
1	93446	114549	102607	96691	100875	84856	116363	103715	123598	103127
2	92539	133248	116621	120344	121330	79281	138931	107837	78241	99298
3	91876	99831	138165	80817	100758	100907	106217	96249	98633	117520
4	87340	128560	72934	131011	119736	82975	140248	124365	135759	90686
5	106653	101299	114065	77356	124872	141537	94045	110755	87770	122540
6	121087	113397	115985	139007	110287	116469	122005	98704	86896	86428
7	138014	96304	149987	87719	119173	89821	133498	148938	80834	135581
8	92828	85525	121431	147432	127041	359232	86288	106198	100815	121639
9	95088	118597	120134	90639	132441	103634	87595	98140	91996	106832
10	103090	104134	98659	105008	106675	93815	131676	96883	115822	129447
11	107105	142210	132601	133473	133561	127669	105859	121398	100908	111028
12	94610	117853	95899	126924	92588	106246	104522	132919	102436	138377
13	133653	100890	102968	94505	119513	101944	93075	148064	121748	115103
14	114684	9998	123088	113421	117096	97822	145635	138737	105521	99531
15	106582	102691	97766	126275	116631	134602	115834	112375	118168	106331
16	117121	107640	113767	117189	118800	105810	124792	124102	108011	127357
17	86310	125175	111514	125369	139582	111712	128614	117588	132937	121628
18	116321	116696	125772	97521	123974	99556	105007	136984	106753	103549
19	94404	82750	118638	122331	108691	89160	100865	140389	121653	97738
20	94934	133134	100731	109513	120409	108994	131282	79052	114460	103504

Table 5.19 Annual net cash surplus or deficit for crop rotation system 30W30S30L for a pumping height of -15 m (IS-15) and a 70/30 debt to asset ratio for twenty replications over a period of ten years

Replica-tions	Year 1 (R)	2 (R)	3 (R)	4 (R)	5 (R)	6 (R)	7 (R)	8 (R)	9 (R)	10 (R)
1	12797	28442	23176	16100	19552	4382	35059	23057	42659	22732
2	21714	52115	36568	39813	71157	-240	61033	28687	-3030	17965
3	12524	19417	58714	226	21555	22268	26883	13398	20134	35813
4	25899	48652	-5521	51590	38142	4015	59124	43471	51530	9485
5	46128	21814	34965	-1730	44462	65185	12492	28465	8307	42356
6	25519	32962	36965	57584	29629	35559	41267	17615	7287	5097
7	24912	16167	65905	8142	39871	18075	51418	65808	-207	58555
8	27717	3724	42014	67117	45324	14014	5443	25755	21386	41560
9	13161	38126	40847	8519	53522	41591	7220	19021	11693	25570
10	5894	20869	18428	25610	28309	22903	49218	16416	35755	48766
11	66752	60996	52385	53525	54412	23374	25096	52100	14777	30502
12	46643	38947	17078	42914	12531	32517	23902	51950	22465	55781
13	32062	22571	22316	15107	38954	17283	12989	70037	40427	34469
14	37565	19364	44928	33238	38009	31821	64661	57848	24688	19571
15	3815	22533	16430	45578	37767	47444	35297	35985	37160	26030
16	10410	26476	30336	39934	36507	29239	45164	41657	28115	45446
17	15815	46205	28549	32267	59449	7262	47635	36599	48860	40940
18	1071	37560	44874	49035	43177	20202	24109	53106	25969	22548
19	37072	2216	37032	27904	29559	23622	21716	81771	40254	17755
20	52088	55507	28597	28729	40370	37202	52172	9565	33784	22238

Table 5.20 Annual net cash surplus or deficit for crop rotation system 30W30S30L for a pumping height of -15 m (IS-15) and a 50/50 debt to asset ratio for twenty replications over a period of ten years

Replica-tions	Year 1 (R)	2 (R)	3 (R)	4 (R)	5 (R)	6 (R)	7 (R)	8 (R)	9 (R)	10 (R)
1	54306	69968	74721	57666	61144	46004	76717	64757	84407	64536
2	63223	93641	78113	81379	112749	41382	102691	70387	38718	59769
3	54033	60943	100259	41792	63147	63890	68541	55098	61882	77617
4	67408	90178	36024	93156	79734	45637	100782	85171	93278	51289
5	87637	63340	76510	39836	86054	106807	54150	70165	50055	84160
6	67028	74488	78510	99150	71221	77181	82925	59315	49035	46901
7	66421	57693	107450	49708	81463	59697	93076	107508	41541	100359
8	69226	45250	83559	108683	86916	55636	47101	67455	63134	83364
9	54670	79652	82392	50085	95114	83213	48878	60721	53441	67374
10	47403	62395	59973	67176	69901	64525	90876	58116	77503	90570
11	108261	102522	93930	95091	96004	64996	66754	93800	56525	72306
12	88152	80473	58623	84480	54123	74139	65560	93650	64213	97585
13	73571	64097	63861	56673	80546	58905	54647	111737	82175	76273
14	79074	60890	86473	74804	79601	73443	106319	99548	66436	61375
15	45324	64059	57975	87144	79359	89066	76955	77685	78908	67834
16	51919	68002	71881	81500	78099	70861	86822	83357	69863	87250
17	57324	87731	70094	73833	101041	48884	89293	78299	90608	82744
18	42580	79086	86419	90601	84769	61824	65767	94806	67717	64352
19	78581	43742	78577	69470	71151	65244	63374	123471	82002	59559
20	93597	97033	70142	70295	81962	78824	93830	51265	75532	64042

Table 5.21 Annual net cash surplus or deficit for crop rotation system 30W30S30L for a pumping height of -15 m (IS-15) and a 20/80 debt to asset ratio for twenty replications over a period of ten years

Replica-	Year									
tions	1	2	3	4	5	6	7	8	9	10
	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)
1	16570	132256	127037	120016	123532	108438	139204	127306	147028	127243
2	125487	155929	140429	143729	175137	103816	165178	132936	101339	122476
3	116297	123231	162575	104142	125535	126324	131028	117647	124503	140324
4	129672	152466	98340	155506	142122	108071	163269	147720	155899	113996
5	149901	125628	138826	102186	148442	169241	116637	132714	112676	146867
6	129292	136776	140826	161500	133609	139615	145412	121864	111656	109608
7	128685	119981	169766	112058	143851	122131	155563	170057	104162	163066
8	131490	107538	145875	171033	149304	118070	109588	130004	125755	146071
9	116934	141940	144708	112435	157502	145647	111365	123270	116062	130081
10	109667	124683	122289	129526	132289	126959	153363	120665	140124	153277
11	170525	164810	156246	157441	158392	127430	129241	156349	119146	135013
12	150416	142761	120939	146830	116511	136573	128047	156199	126834	160292
13	135835	126385	126177	119023	142934	121339	117134	174286	144796	138980
14	141338	123178	148789	137154	141989	135877	168806	162097	129057	124082
15	107588	126347	120291	149494	141747	151500	139442	140234	141529	130541
16	114183	130290	134197	143850	140487	133295	149309	145906	132484	149957
17	119588	150019	132410	136183	163429	111318	151780	140848	153229	145451
18	104844	141374	148735	152951	147157	124258	128254	157355	130338	127059
19	140845	106030	140893	131820	133539	127678	125861	186020	144623	122266
20	155861	159321	132458	132645	144350	141258	156317	113814	138153	126749

Table 5.22 Annual net cash surplus or deficit for crop rotation system 45W45LM15P60C for a pumping height of +10 m (IS+10) and a 70/30 debt to asset ratio for twenty replications over a period of ten years

Replica-tions	Year 1 (R)	2 (R)	3 (R)	4 (R)	5 (R)	6 (R)	7 (R)	8 (R)	9 (R)	10 (R)
1	-42290	-48548	-35969	-25763	-39616	-42031	-43617	-49429	-45986	-42297
2	-38414	-34666	-18959	-29723	-28909	-30880	-61209	-62130	-30629	-21313
3	-54953	-57512	-50483	-45582	-40676	-54775	-28519	-25292	-66249	-58309
4	-24693	-25755	-22202	-1484	-40418	-56898	-56524	-67647	-32187	-24830
5	-39519	-11282	-44438	-62013	-56240	-44114	-20743	-43111	-34248	-35258
6	-28904	-28036	-28720	-44085	-46687	-50517	-62192	-57309	-46775	-33921
7	-29181	-24617	-38371	-50849	-28406	-11943	-23201	38822	-52314	-45831
8	-44011	-30466	-18398	-32199	-40966	-43712	-37183	-25592	-29304	-38481
9	-31265	-29048	-55104	-45791	-32428	-37282	-41799	-48432	-62291	-62924
10	-41603	-27301	-35109	-23464	-23315	-35924	-41830	-50299	-48549	-54010
11	-1730	-28682	-51171	-46153	-36494	-18942	-5155	-30690	-32284	-2957
12	-52974	45095	-42189	-38922	-44133	-48278	-26187	-26295	-32760	-40243
13	-34618	-33442	-4187	-11359	-17614	-31462	-48956	-28442	-29812	-31073
14	-44456	-38227	-18475	-27039	-64257	-58269	-51881	-53537	-34574	-37161
15	-56031	-49547	-28352	-24778	-57090	-61035	-32466	-28951	-57920	-68138
16	-63412	-61961	-34381	-20623	-21113	-27975	-26644	-13886	-35741	-57436
17	-29471	-10645	-37085	-49890	-49564	-48615	-39602	-42499	-20722	-25386
18	-43933	-26661	-26736	-28289	-18695	-32978	-36350	-27650	-43581	-54307
19	-45139	-43323	-61817	-69311	-46872	-37238	-45009	-37658	-35337	-47235
20	-46824	-45402	-14934	-24399	-52709	-42090	-42765	-56581	-41169	-30520

Table 5.23 Annual net cash surplus or deficit for crop rotation system 45W45LM15P60C for a pumping height of +10 m (IS+10) and a 50/50 debt to asset ratio for twenty replications over a period of ten years

Replica-	Year									
tions	1	2	3	4	5	6	7	8	9	10
	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)
1	-258	-6500	6099	16326	2499	116	-1435	-7205	-3713	34
2	3618	7382	23108	12367	13206	11267	-19027	-19906	11644	21018
3	-12921	-15464	-8415	-3493	1439	-12628	13664	16931	-23976	-15978
4	17339	16293	19865	40605	1697	-14751	-14342	-25423	10086	17501
5	2513	30766	-2371	-19923	-14125	-1967	21439	-888	8025	7072
6	13128	14012	13348	-1995	-4572	-8370	-20009	-15085	-4502	8410
7	12851	17431	3696	-8760	13709	30204	18981	3401	-10041	-3501
8	-1979	11582	23670	9890	1149	-1566	4999	16631	12969	3849
9	10767	13000	-13037	-3701	9687	4865	384	-6208	-20018	-20594
10	429	14747	6958	18626	18800	6222	352	-8075	-6276	-11679
11	40302	13366	-9103	-4063	5622	23205	37027	11534	9989	39374
12	-10942	-3047	-121	3168	-2018	-6131	15995	15929	9513	2088
13	7414	8606	37880	30731	24502	10684	-6774	13782	12461	11257
14	-2424	3821	23592	15051	-22142	-16122	-9699	-11313	7699	5170
15	-13999	-7499	13715	17312	-14975	-18889	9716	13273	-15647	-25808
16	-21380	-19913	7687	21467	21002	14171	15538	28337	6532	-15105
17	12561	31403	4983	-7800	-7449	-6469	2580	-275	21551	16945
18	-1901	15387	15331	13801	23420	9169	5832	14573	-1308	-11976
19	-3107	-1275	-19749	-27221	-4757	4909	-2827	4565	6936	-4904
20	-4792	-3354	27133	17691	-10594	57	-583	-14358	1104	11811

Table 5.24 Annual net cash surplus or deficit for crop rotation system 45W45LM15P60C for a pumping height of +10 m (IS+10) and a 20/80 debt to asset ratio for twenty replications over a period of ten years

Replica-	Year									
tions	1	2	3	4	5	6	7	8	9	10
	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)
1	62791	56573	69200	79462	65674	63336	61839	56131	59697	63530
2	66667	70455	86210	75502	76381	74487	44247	43430	75054	84514
3	50128	47609	54686	59643	64614	50592	76937	80268	39434	47518
4	80388	79366	82967	103741	64872	48469	48932	37913	73496	80997
5	65562	93839	60731	43212	49050	61253	84713	62449	71435	70569
6	76177	77085	76449	61140	58603	54850	43264	48251	58908	71906
7	75900	80504	66798	54376	76884	93424	82255	66738	53369	59996
8	61070	74655	86771	73026	64324	61655	68273	79968	76379	67346
9	73816	76073	50065	59434	72862	68085	63657	57128	43392	42903
10	63478	77820	70060	81761	81975	69443	63626	55261	57134	51817
11	103351	76439	53998	59072	68796	86425	100301	74870	73399	102870
12	52107	60026	62980	66303	61157	57089	79269	79265	72923	65584
13	70463	71679	100982	93866	87676	73905	56500	77118	75871	74754
14	60625	66894	86694	78186	41033	47098	53575	52023	71109	68666
15	49050	55574	76817	80447	48200	44332	72990	76609	47763	37689
16	41669	43160	70788	84602	84177	77392	78812	91674	69942	48391
17	75610	94476	68084	55335	55726	56752	65854	63061	84961	80441
18	61148	78460	78433	76936	86595	72389	69106	77910	62102	51520
19	59942	61798	43352	35914	58418	68129	60447	67902	70346	58592
20	58257	59719	90235	80826	52581	63277	62691	48979	64514	75307

Table 5.25 Annual net cash surplus or deficit for crop rotation system 45W45LM15P60C for a pumping height of -15 m (IS-15) and a 70/30 debt to asset ratio for twenty replications over a period of ten years

Replica-tions	Year 1 (R)	2 (R)	3 (R)	4 (R)	5 (R)	6 (R)	7 (R)	8 (R)	9 (R)	10 (R)
1	-32087	-38132	-25955	-16367	-29784	-31444	-33036	-38591	-35062	-31980
2	-27628	-24367	-10025	-20824	-18822	-20508	-50868	-47377	-16282	-11138
3	-44506	-47117	-40212	-35508	-30718	-44996	-19538	-15984	-55326	-47283
4	-15562	-16515	-12028	8591	-29775	-46118	-45949	-49626	-15236	-15473
5	-28970	-818	-33550	-51166	-45971	-33893	-10368	-31677	-23619	-25515
6	-18886	-17610	-18068	-33708	-36197	-39645	-52130	-47451	-36664	-24120
7	-18577	-14363	-28336	-40544	-18375	-2047	-12706	-28536	-42275	-35369
8	-33481	-20473	-9513	-22917	-30366	-32899	-26384	-15111	-19229	-28162
9	-22453	-20252	-45016	-35637	-21980	-26838	-31403	-28156	-42494	-53052
10	-31216	-17464	-24600	-12863	-12936	-25540	-31302	-39700	-38062	-43139
11	8021	-17964	-40447	-36038	-26250	-8918	4848	-13540	-15221	6820
12	-42431	-34864	-32008	-29117	-34225	-30823	-25152	-32205	-22219	-29617
13	-24333	-23134	4638	-2484	-7583	-21885	-39384	-18439	-19890	-21200
14	-34191	-27962	-9791	-18355	-53772	-47047	-41400	-30313	-10983	-27051
15	-45993	-40138	-19705	-15100	-46350	-51168	-23283	-19401	47094	-57208
16	-53011	-50963	-24185	-10244	-10812	-17951	-16567	-3946	-25405	-47465
17	-20254	-1738	-26571	-39067	-39061	-37865	-28881	-28863	-7420	-15244
18	-33508	-17133	-17255	-18164	-9465	-23778	-26965	-18189	-32847	-43366
19	-34893	-33010	-50913	-58448	-36594	-26850	-34617	-27495	-24946	-36750
20	-48009	-34653	-4515	-13887	-42493	-31632	-32054	-46508	-30807	-31789

Table 5.26 Annual net cash surplus or deficit for crop rotation system 45W45LM15P60C for a pumping height of -15 m (IS-15) and a 50/50 debt to asset ratio for twenty replications over a period of ten years

Replica-tions	Year 1 (R)	2 (R)	3 (R)	4 (R)	5 (R)	6 (R)	7 (R)	8 (R)	9 (R)	10 (R)
1	9945	3916	16112	25723	12331	10702	9146	3633	7211	10351
2	14404	17681	32042	21266	23294	21639	-8686	-5154	25991	31192
3	-2474	-5069	1856	6582	11397	-2849	22645	26239	-13053	-4953
4	26470	25533	30040	50680	12340	-3971	-3767	-7402	27037	26857
5	13062	41230	8517	-9076	-3855	8254	31814	10546	18654	16816
6	23146	24438	24000	8382	5919	2501	-9947	-5227	5609	18211
7	23455	27685	13732	1545	23740	40100	29476	13688	-2	6962
8	8551	21575	32555	19172	11749	9248	15798	27112	23044	14169
9	19579	21796	-2949	6452	20136	15308	10779	14067	-221	-10722
10	10816	24584	17468	29226	29179	16607	10880	2524	4211	-809
11	50053	24084	1620	6052	15865	33229	47030	28683	27052	49151
12	-399	7184	10059	12972	7890	11324	17031	10018	20054	12714
13	17699	18915	46705	39605	43532	20262	2798	23784	22383	21131
14	7841	14086	32276	23735	-11657	-4901	782	11911	31290	15280
15	-3961	1910	22363	26990	-4235	-9021	18899	22823	-4821	-14878
16	-10979	-8915	17882	31845	31303	24196	25615	38278	16868	-5135
17	21778	40310	15496	3023	3055	4282	13301	13360	34853	27086
18	8524	24915	24812	23925	32650	18368	15217	24034	9426	-1035
19	7139	9038	-8846	-16359	5521	15297	7565	14728	17327	5581
20	-5977	7395	37552	28202	-378	10515	10128	-4284	11466	10541

Table 5.27 Annual net cash surplus or deficit for crop rotation system 45W45LM15P60C for a pumping height of -15 m (IS-15) and a 20/80 debt to asset ratio for twenty replications over a period of ten years

Replica-	Year									
tions	1	2	3	4	5	6	7	8	9	10
	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)	(R)
1	72994	66989	79214	88858	75506	73923	72420	66969	70621	73847
2	77453	80754	95144	84401	86468	84859	54588	58183	89401	94688
3	60575	58004	64957	69717	74572	60371	85918	89576	50357	58543
4	89519	88606	93141	113816	75515	59249	59507	55934	90447	90353
5	76111	104303	71619	54059	59319	71474	95088	73883	82064	80312
6	86195	87511	87101	71517	69093	65722	53326	58109	69019	81707
7	86504	90758	76833	64681	86915	103320	92750	77024	63408	70458
8	71600	84648	95656	82308	74924	72468	79072	90449	86454	77665
9	82628	84869	60153	69588	83310	78529	74053	77404	63189	52774
10	73865	87657	80569	92362	92354	79827	74154	65860	67621	62687
11	113102	87157	64722	69187	79040	96449	110304	92020	90462	112647
12	62650	70257	73161	76108	71065	74544	80304	73355	83464	76210
13	80748	81987	109807	102741	97707	83482	66072	87121	85793	84627
14	704890	77159	95378	86870	51518	58320	64056	75247	94700	78775
15	59088	64983	85464	90125	58940	54199	82173	86159	58589	48618
16	52070	54158	80984	94981	-94478	87416	8889	101614	80278	58361
17	84827	103383	78598	66158	66229	67502	76575	76697	98263	90582
18	71573	87988	87914	87061	95825	81589	78491	87371	72836	62461
19	70188	72111	54256	46777	68696	78517	70839	78065	80737	69077
20	57072	70468	100654	91338	62797	73735	73402	59052	74876	74037

CHAPTER 6

SUMMARY

6.1 INTRODUCTION

The study entails the analysis and determination of the economic profitability and financial feasibility of alternative crop rotation systems under centre pivot irrigation in the Southern Free State sub-area, specifically the irrigation areas below the P.K. le Roux Dam. The area is selected on the basis of its importance as irrigation area and availability of data. The same method and procedures in this study can also be applied in other irrigation areas to estimate economic profitability and financial feasibility of crop rotation systems.

A study of the relevant literature on the economics and feasibility of irrigated crop rotation systems has indicated that there is a need to consider price, production and financial risks explicitly in the analyses. The research done on the subject has indicated that price, production and financial risk must be considered. Equally, the lack of established crop rotation systems has shown that more research on these systems has to be done. Neither of the researchers also has approached crop rotation systems on a farm-level point of view. Considering the shortcomings and the lack of a complete study on irrigated crop rotation systems with considering production, price and financial risks it was felt that the time and costs involved in this study are justified. Still no intention is made to consider the study complete and expanding in this study field horizontally and vertically is required in future studies.

The major objective of the study was to determine the economic profitability and financial feasibility for alternative irrigated crop rotation systems, considering price, production and financial risks.

To obtain this objective the following sub-objectives were pursued:

(1) Determine the yields and gross water requirements of wheat, late maize, cotton, peanuts, soyabeans, dry beans and lucerne under uncertain climatic circumstances and determine to what extent the gross water requirements of the alternative crop rotation systems can be satisfied from the available annual water quotas.

(2) Determine how the relative economic profitability of the different crops in the crop rotation systems differs.

(3) Determine how the economic profitability of the alternative crop rotation systems differs, considering price and production risks.

(4) Determine how the financial feasibility of the alternative crop rotation systems differs, considering price, production and financial risks.

6.2 ANALYSIS OF THE YIELDS AND GROSS WATER REQUIREMENTS OF ALTERNATIVE CROP ROTATION SYSTEMS, SUBJECT TO SPECIFIED WATER QUOTAS

In order to consider the effect of production risk on crop yields and crop gross water requirements accurate and comparable, data concerning the research area over a period of time are required. The lack of this type of data necessitated the use of simulation models to generate the yields and gross water requirements for the required crops.

A previously used and tested computer model is updated and adapted to meet the output requirements. The PUTU P9MZAB3 model is calibrated and evaluated by the researcher for the crops on basis of available crop, soil and weather data for the research area. The calibrated model could after this calibration process be used with confidence to generate the required yields and gross water requirements of the crops. Subsequently the calibrated model is used in combination with predetermined BEWAB crop irrigation schedules to generate a distribution of yields and gross water requirements for the following crops over a period of eleven consecutive years: wheat, late maize, cotton, peanuts, soyabeans, dry beans and lucerne.

Previous research has indicated that the crop rotation systems practised, largely influence the viability of irrigation farming. The lack of adequate information on crop rotation systems, which are used in practice, necessitated the development of these systems. On the basis of economical, practical and agronomical factors, fourteen typical crop rotation systems are developed that run over a period of ten years. The systems are developed for 60 hectares under irrigation by centre pivots on predominantly sandy soils in the research area. Equally, the crop rotation systems are developed in order to determine the economic and feasibility effect of alternative crops within the crop rotation systems. As the crop rotation systems utilise the land available differently the different land utilisation percentages must be taken into consideration. Each crop rotation system requires a specific set of implements to have the succession of cultivation activities for the different crops done and a mechanisation system which comprises all these implements is developed for each crop rotation system.

For the alternative crop rotation systems the corresponding gross water requirements are estimated on the basis of the simulated crop gross water requirements and the size of the area planted to these crops over the period of eleven consecutive years. Farmers in the research area are entitled to an annual predetermined water quota of 660 000 m^3 and can purchase another 240 000 m^3 for the same water unit costs if surplus water is available. In a final analysis the simulated gross water requirements for each crop rotation system for the eleven years are compared to the annual maximum available water quota, to determine whether enough water is available for each crop rotation system.

In the summary the following average yields and gross water requirements are generated by the PUTU model over the eleven years:

Wheat	6 679 kg/ha,	760 mm/ha.
Late maize	8 588 kg/ha,	698 mm/ha.
Peanuts	3 230 kg/ha,	971 mm/ha.
Cotton	3 661 kg/ha,	1 102 mm/ha.
Dry beans	2 040 kg/ha,	515 mm/ha.
Soyabeans	2 715 kg/ha,	628 mm/ha.
Lucerne (full production)	21 350 kg/ha,	1 285 mm/ha.
Lucerne (establishment)	20 805 kg/ha,	1 239 mm/ha.

The following order of crops indicates the ranking order of gross water requirements from highest to lowest: Lucerne, cotton, peanuts, wheat, late maize, soyabeans and dry beans.

On the basis of these gross water requirements of the crops, the total gross water requirements of the crop rotation systems are calculated and subtracted from the maximum available water quota of 900 000 m^3. Only crop rotations systems 45W45LM15P, 30W30S30L, 30W30LM30L, 30W30S30LM30L, 30W30S30C30L and 30W30LM30C30L can be satisfied in the total gross water requirements for all the years from the maximum quota. For no crop rotation system the standard water quota of 660 000 m^3 was found to be sufficient.

The number of hectares planted, the gross water requirements and the relative distribution of water during the growth season are the main factors which determine whether the total gross water requirements of the crop rotation systems can be met. The land utilisation percentage of the crop rotation systems as such was found not to be a dominant indication of whether the total gross water requirements could be met.

6.3 ESTIMATION OF CROP PRICES AND COSTS ASSOCIATED WITH IRRIGATED CROPS IN THE IRRIGATION AREA BELOW THE P.K. LE ROUX DAM

Price risk is the result of continuous changing crop prices over time. For late maize and wheat the respective boards have determined price scenarios which are based on national production levels for these crops. On the basis of historical national production levels for these crops, the adjusted 1990 national production levels could be calculated by using linear regression analysis. Based on these adjusted 1990 national production levels and the price scenarios, a distribution of prices for 1990 could be estimated. The prices for dry beans and lucerne are determined largely by supply and demand and a procedure was followed to provide for the significant price variability. The procedure firstly calculated the 1990 adjusted prices, on the basis of indices of intermediate agricultural goods, after which the variability in these obtained prices is reduced in order to obtain a distribution of prices with reduced deviations and with a determined average price. For soyabeans, cotton and peanuts no quantifiable price risk exists and the production thereof could within limits be sold for a single predetermined fixed price per grade.

The following weighted average prices are used:

Lucerne hay R200,00; peanuts R1 357,72; peanut hay R125,00; soyabeans R625,00; dry beans R1 346,00; late maize R210,00; wheat R414,14 and cotton R1 200,00.

By using an existing irrigation system cost calculation method the fixed, variable and marginal costs are calculated for two centre pivot irrigation systems with two different pumping heights +10 m (Sarel Hayward canal) and -15 m (Ramah area). The fixed costs are calculated on a hectare basis and the marginal costs are calculated to determine the total unit water cost and application costs. The calculation of the marginal cost is based on the weighted average cost with regard to different electricity tariffs. The distinction had to be made to provide for the quantity of water that is pumped with the high electricity tariff and the quantity that is pumped with the low tariff. The variable irrigation costs are successively calculated for the eleven consecutive years by multiplication of the gross water requirements of the crops with the weighted average marginal cost.

Based on the simulated production data on crops, the crop prices, the crop yields, the calculated variable irrigation costs and mechanisation costs, consecutive budgets could be developed separately for each crop. The APLAND budget generator is used to generate these budgets. The mechanisation costs include the fixed costs of the irrigation system and the total costs of the mechanisation system. Based on the determined simulated yields, gross water requirements and price distributions of the crops, the average of these values is calculated. These average values are subsequently incorporated in the corresponding crop budgets to determine a single crop net margin for each crop. On basis of the net margins and the ratio of net margins to operating costs a relative measure of economic profitability could be determined for each crop.

Soyabeans and late maize have relatively low gross receipts and low ratios which in turn have largely contributed to negative net margins. Cotton has the highest net margin due to the high gross receipts, which more than compensates for the relatively high total operating costs. Peanuts and lucerne (F) have relatively high net margins due to the relatively highest gross receipts and ratios. Wheat has a relatively low net margin due to relatively high total operating costs and low gross receipts.

6.4 ECONOMIC PROFITABILITY ANALYSIS OF THE CROP ROTATION SYSTEMS, SUBJECT TO PRICE AND PRODUCTION RISKS

After having developed the crop budgets, the next step is to evaluate and compare the alternative crop rotation systems on economic profitability. By using the net present value method it is possible to compare the crop rotation systems on an equal basis as the total associated revenue and costs are discounted to a present value. On the basis of randomly selected prices and yields from the respective determined price and yield distributions, a distribution of the net margins could be calculated for each year of the ten-year period for each of the crops. This process was repeated twenty times within each year for the ten-year period to provide for the production risk. The result was that for each crop a matrix of net margins consisting of a number of columns equal to the number of times that the crop is planted in the ten-year period with each column consisting of 20 replications. On the basis of the determined net margins of the prevailing crops and the sections of the land planted to these crops, the net present values of the alternative crop rotation systems could be calculated by using a computer program. Successively the crop rotation systems were compared on the basis of the minimum, maximum and average net present values and the ratios of the average net present values to total investments. A coefficient of variance was also calculated to obtain an indication of a measure of the risk associated with the average net present results obtained.

All the crop rotation systems were found to be profitable, but a large variation between the crop rotation systems with respectively the lowest and highest average net present values was obtained. The following results indicate this absolute difference: R116 063 and R486 774 for respectively crop rotation system 60W60LM and 30W30S30C30L for the +10 m pumping height (IS+10) and R170 691 and R534 706 for the crop rotation systems for the -15 m (IS-15) pumping heights. Crop rotation system 30W30S30C30L is relatively 3,65 and 4,85 times more profitable than crop rotation system 60W60LM for respectively both pumping heights. The return on investments varies for these crop rotation systems between 4,65 and 1,11 for the +10 m pumping height and between 5,31 and 1,63 for the -15 m pumping height. The coefficient of variation reflects the same pattern with the least and most profitable crop rotations having a relative risk value of respectively 28,3 and 5,17 for the +10 m pumping height. For the -15 m pumping heights the values are respectively 20,36 and 4,82.

Crop rotation systems including late maize and soyabeans, which have relatively low net margins, are comparatively not profitable. Crop rotation systems including lucerne and cotton, which have relatively high net margins, have the highest present values. The low net margins of late maize and soyabeans can be compensated for largely by the relatively higher net margins of lucerne and cotton. The low net margins of soyabeans and late maize can only partly be compensated for by the relatively high net margins of dry beans and peanuts. This effect is due to the small sections planted of these two crops. If, due to climatic conditions, cotton cannot successfully be planted, this crop should be substituted if possible by lucerne or peanuts.

The relatively high possible land utilisation percentages of crop rotation systems, including late maize and soyabeans, can not compensate for the relatively low net margins of these crops.

6.5 FINANCIAL FEASIBILITY ANALYSIS OF THE ALTERNATIVE CROP ROTATION SYSTEMS CONSIDERING PRICE, PRODUCTION AND FINANCIAL RISKS

The crop rotation systems are analysed for financial feasibility for a hypothetical farm in the research area with the hypothetical farm defined as the irrigation of two sixty hectare areas. In the feasibility analysis only the revenues and the costs associated with the crop rotation systems are considered. The domestic expenses are, therefore, considered to be excluded. The purpose of a feasibility analysis is to determine whether the annual after-tax cash costs can be met from the after-tax cash income. In the study the feasibility analysis was done for all the crop rotation systems in order to determine the effect of the different crop rotation systems on the annual cash flow. The annual after-tax cash income was calculated on the basis of the determined net margins minus the fixed non-cash costs of the prevailing crops and the sections of the land planted to these crops. The same crop net margins as used for the calculation of the profitability were used again. A feasibility analysis comprises only the real cash effects and therefore the fixed non-cash cost must be excluded from the net margins calculation procedure. The annual after-tax cash cost was calculated for the crop rotation systems for each year of the ten-year period for both pumping heights and for the three different debt to asset ratios. By having incorporated in the analysis the distribution of the crop net margins, obtained from the randomly selected prices and yields, the price and production risks are considered to be included. The different debt to asset ratios and the variation in the net margins per crop represent the financial risks. According to each of the three debt to asset ratios the total annual after-tax interest and capital redemption on instalments on medium- and long-term liabilities and the after-tax interest on short term credit could be determined. The effect of tax savings from depreciation of the annual purchase of implements for the mechanisation system was also considered. In a final calculation for each crop rotation system the total annual after-tax costs were subtracted from the total annual after-tax income. On the basis of a decision rule it was then determined whether a crop rotation systems was feasible or not feasible.

The results indicate that the debt to asset ratio is the main factor influencing financial feasibility. For the 70/30 debt to asset ratio all crop rotations systems are unfeasible for the irrigation system with +10 m pumping height and unfeasible, except one, (30W30S30C30L) for the irrigation system with the -15 m pumping height. For the 50/50 debt to asset ratio only five crop rotation systems, (30W30S30L, 30W30S30LM30L, 30W30LM30L, 30W30LM30C30L and 30W30S30C30L) are feasible for both pumping heights. For the 20/80 debt to asset ratio all crop rotations systems except one (60W60LM) are feasible for both pumping heights.

6.6 CONCLUSIONS

Using the maximum water quota the total gross water requirements of only the following crop rotation systems 45W45LM15P, 30W30S30L, 30W30LM30L, 30W30S30LM30L, 30W30S30C30L and 30W30LM30C30L can be satisfied for all years. For no crop rotation systems the standard water quota was found to be sufficient.

The net margins of the crops indicate a wide distribution from negative net margins for late maize of -R210,27 to a relatively high net margin of R2424,67 for cotton.

The net benefit investment ratios of the crop rotation systems which are used to rank the crop rotation systems in order of relative profitability, vary between 4,84 and 1,11 per cent. The most profitable crop rotation system is 30W30S30C30L. The net present value of this crop rotation system varies

R437 674 to R529 970. Each of the five most profitable crop rotation systems include lucerne. The least profitable crop rotation system is 60W60LM.

The debt to asset ratios of the farmers determine to a large extent the financial feasibility of the crop rotation systems. Production, price and financial risks are responsible for cash flow deficits. Only the crop rotation system 30W30S30C30L is still financially feasible for a 70/30 debt to asset ratio and with the positive pumping height. With the negative pumping height the crop rotation systems 30W30S30L, 30W30LM30L and 30W30S30LM30L also become feasible for the 70/30 debt to asset ratio. Four additional crop rotation systems become feasible when the debt to asset ratio improves to 50 per cent with the positive pumping height and crop rotation systems 60W45L15P60C and 45W45LM15P60C also become feasible with the negative pumping height. When the debt to asset ratio improves to 20 per cent all crop rotation systems are feasible.

6.7 IMPLICATIONS FOR FUTURE RESEARCH

The economic and financial results are directly influenced by the simulated relative yields and water requirements. The development of better crop growth simulation models, with refined results, improves the accuracy of the analyses.

The proposed crop rotation systems need to be evaluated in practice over time in respect of management requirements and practical feasibility.

The economic and financial analyses of the crop rotation systems need to be extended to other major irrigation areas.

Crop rotation systems must be developed for a larger range of crops and must include more crops.

Financial, production and price risk must be considered in economic and financial analyses.

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