

**MARKET RISK, WATER MANAGEMENT AND THE
MULTIPLIER EFFECTS OF IRRIGATION AGRICULTURE
WITH REFERENCE TO THE NORTHERN CAPE**

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NORTHERN CAPE**

Volume 1: Micro and regional models report
Volume 2: Macro modelling report
Volume 1 of 2

Report to the
Water Research Commission

by

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EXECUTIVE SUMMARY

The overall project is divided into two volumes: Volume 1 reports on the micro and regional models and Volume 2 on the macro-economic modelling part. For the sake of completeness, this executive summary covers the entire project, i.e. volumes 1 and 2, and is therefore duplicated in both volumes.

NEED FOR THE RESEARCH:

Background and problem statement

Despite the fact that the Northern Cape is the largest province in terms of land area in South Africa, covering almost 30% (361 830 km²) of the total area (1 219 090 km²) of the Republic of South Africa, the Northern Cape's economy is considered the smallest amongst all the provinces. This economy rests basically on three pillars, namely agriculture, mining, and community service.

Water shortages are a looming threat for agricultural as well as urban users in South Africa. Irrigated areas account for about 30 percent of agricultural production in South Africa, so growth in irrigated output per unit of land and water is essential. Improved efficiency in agricultural water use is required both to maintain productivity growth and to allow reallocation of water from agriculture to urban and industry use.

Maximum productive efficiency can be said to exist when the factors of production are used in optimal proportions with optimal technology and are applied to those uses where total value product is maximised. The economic welfare of the owners of the factors of production is a function of the productive efficiency of the factors, and, in turn, the economic welfare of the community is a function of the welfare of the factor owners.

Theoretically, provided that there are no externalities, each factor will be optimally allocated (used) when the values of marginal product of that factor in various uses and among competing users are equal. One of the conditions for perfect competition is that factors are free to seek employment where they can bring maximum returns to their owners. If factors are immobile because of transfer restrictions, the values of marginal

products will probably be below optimum levels in current uses and the observed market prices will probably reflect the lower productivity.

However, farmers are not direct users of water. The utility of irrigation water is indirect, as an input to production of other goods demanded by consumers. Willingness to pay for water would, therefore, depend upon the increased value of the output over and above the cost of producing that extra output. This concept is referred to as producer surplus. As product prices decrease, the derived demand for water tends to become more elastic. The long-run value of water is estimated as the residual after returns to long-run production factors are subtracted from the short-run value estimates. Kulshreshta and Tewari found that only under high-price scenarios for products is there a long-run return to water, i.e. greater than zero. For low-price scenarios they found a negative return to water, indicating that the costs of fixed factors of production were not fully recovered.

The Water Research Commission (WRC) recognised the need for research to determine the effect of market risk on the efficient allocation of water and the multiplier effects of irrigation agriculture. They also recognised the need to develop a policy framework for irrigation agriculture that would reduce risks and improve the financial viability of the individual farmers and of irrigation schemes. The Northern Cape was identified as an appropriate case study area since irrigation agriculture makes a substantial contribution to the provincial economy and since it is fairly easy to isolate irrigation agriculture from the total agricultural output of the province. The Department of Agricultural at the University of the Free State submitted a project proposal to the WRC to address this research need during 2000, and the project commenced in May 2001.

Aims and objectives of the research

The primary objective of this project was to quantify the impact of market risk on the efficient use of irrigation water and to determine the multiplier effects of irrigation accompanied by a shift in production patterns, with reference to the middle and lower Orange River, on the total economy of the Northern Cape. The sub-objectives of the project included:

1. Identifying and quantifying risk factors in irrigation agriculture;
2. Developing a decision-making framework that farmers can use to reduce their risk;
3. Comparing present water-use practices with optimal risk-reducing practices and finding reasons for deviations from the optimal; and
4. Developing a policy framework for irrigation agriculture that would reduce risk and improve the financial viability of the individual farmers and of irrigation schemes.

The emphasis of the second part of the study falls on the quantification of changes in market risk factors affecting irrigation agriculture on the wide economy of the NCP. Volume 1 of the report addresses only sub-objectives 1-4, whereas Volume 2 covers the remaining sub-objectives (5-8), including:

5. Identifying and quantifying the relevant products and economic sectors in the Northern Cape economy;
6. Distinguishing between the irrigation and non-irrigation agricultural sectors;
7. Deriving the relevant coefficients for the Northern Cape from the national input-output model by using the product balance approach; and
8. Developing a policy framework on effective water management for regions where irrigation agriculture makes a major contribution to the economy.

As a result of the integrated nature of the policy frameworks proposed, i.e. sub-objectives 4 and 8, a combined policy framework covering risk and improved viability, as well as effective water management, is provided in Chapter 7, Volume 2.

METHODS

Micro and regional economic modelling framework (Volume 1)

The literature review revealed that during recent years, the marketing environment has become more risky and more volatile, in terms of both operational and strategic risk. The literature review highlighted the importance of external help / tools that producers and other decision-makers should use in developing risk management strategies. It is therefore important to know what tools are available, the advantages and disadvantages of each tool, and how they can be used individually or together to manage risk. This will help producers

to become more effective managers and allow them to continue to be competitive in the global marketplace.

The principal purpose of risk-return analysis lies in ranking alternative farm plans on the basis of risk and examining trade-offs between risk and mean income. However, analysing trade-offs between risks (defined as deviations from mean income) and mean income is subject to question, since risk is not expressed in a pure sense, i.e. such a risk expression is not independent of, but rather dependent on, mean income. Grove (2005) points out that special additions to the methodology are necessary when using the Motad methodology in multi-period models. These additions are discussed in section 2.5.

The literature abounds with models for analysing alternative water allocation mechanisms and for analysing risk. The dynamic linear programming (DLP) technique used in this study has been extensively used in other countries, especially the USA and Europe, and in SA. Any attempt to simulate the farm system should at least include the objectives of the farm unit, the resources available to achieve these objectives, and the alternative means of achieving them. It is an extremely useful tool to analyse "what if" questions.

Within regional spatial modelling, the use of DLP has been limited by computer capacity. It is only during recent years that it has become both possible and practical to embed several DLP whole-farm models in a spatial framework and to solve these models in a reasonable time. The modelling framework that was developed in this study is probably the most comprehensive and largest of its kind ever attempted with the use of DLP in a spatial context in South Africa.

Risk management in agriculture has become an important part of the management function for primary producers, industry bodies and government alike. Analytical tools used as part of a framework to aid decision-makers in formulating risk-management strategies can be extremely useful. However, decision-makers will only use these analytical tools if their value can be proven in terms of making better decisions. Water allocation and water-use efficiency is an important component of the New Water Act (1998). It is therefore of paramount importance to consider the impact of market risk on efficient water allocation and water-use efficiency. The first step in the development of a decision-making

framework is to describe the system. In this study, the system is irrigation agriculture in the Northern Cape (approximately 143 000 ha). The second step is to develop a modelling framework to enable decision-makers to get a better understanding of how the system reacts to impulses (negative or positive) from the outside (the environment). In this study, the impulses are those with a direct or indirect link to the market risks discussed.

The description of the irrigation regions of the Northern Cape enabled the researchers to demarcate the total irrigation into 7 modelling regions. A farm survey of the regions revealed major differences in farm structure and economies of scale for the northeast, middle and western parts of the Vaal, Riet and Orange Rivers. From the farm survey data, 22 typical farms were developed to be included in the decision-making framework. There is a large variance between typical farms and regions in terms of farm structure, labour use per hectare, and the ratio between canal abstraction and abstraction directly from the river. This is important in understanding the results of the models, since it will determine the reaction of each typical farm to changes in parameters when scenarios are analysed. Different typical farms will react differently when the same parameters are changed due to economies of scale, farm structure, water usage, etc.

The intention of Volume 1, Chapter 5, is to give the reader some kind of background to the marketing environment for selected crops grown in the Northern Cape. The project team realised that the information was already outdated at the time of writing, since the entire modelling exercise was based on 2000-2002 prices. However, a decision was made to update the information to 2006 values, and the results of this effort can be found in Appendix A of Volume 1.

The development of any modelling structure is a dynamic process. There is always scope for improvement as the computational capacity of computers increases and new information and techniques become available. However, the models that were developed in this project will add tremendous value when it comes to improving decision-making at both policy level and farm level. The models have been tested (with the consent of the WRC) on at least four case-study farms (three in terms of the affordability of irrigation water and one in terms of the impact of minimum wages and land tax on farm profitability) in the region and have proven to be extremely valuable (Louw, 2001a; Louw, 2001b; Louw, 2002;

Louw, 2003). Several tests were executed to test the models for validity, including a simple spreadsheet formulation calculated manually to replicate the model results. The authors are therefore convinced that the models are both mathematically correct and that they produce valid results.

The models were developed in GAMS and solved with the CPLEX solver. The model outputs for different scenarios are transformed from a "text" format into an Excel spreadsheet for additional calculations to present results in a user-friendly format. The model structure is efficient, since all the data files are linked to a single worksheet that is compatible with GAMS. The data to run the models can therefore easily be updated. A defensible theoretical structure was developed to examine data intuitively and to permit comprehensive evaluation. These theoretically structured models were then used to illustrate the capacity of the models to analyse the impact of market risk on the efficient use of water and to show the link between the regional model and the CGE model (Volume 2).

It was also pointed out that the development of both the typical farm models and the regional models provides the analytical framework to analyse alternative risk-reducing strategies (sub-objective 2). The table-grape scenario is an extremely useful case study, since it contains all the elements to illustrate how a lack of marketing information can lead to non-optimal resource allocation and to suggest risk-reducing practices whereby the situation could have been managed in a more effective way.

Macro-economic modelling framework (Volume 2)

In order to achieve the objectives covering the macro-economic part of the study, the project team originally proposed the use of an input-output (I/O) model by means of the product balance approach. The literature on macro-economic modelling shows that it is a very wide and well-researched field; however, new methodological frameworks are currently in the process of being developed internationally (as is surely the case with most other modelling fields). Following the intensive literature survey on macro-economic methodologies, the project team recognised the advantages of using a Social Accounting Matrix (SAM) – Computable General Equilibrium (CGE) modelling framework instead. Among the most important advantages are the full circular flow and the inclusion of

transactions between institutions, which provides significantly more detailed information for policy analysis purposes. This implies that a much more detailed analysis and therefore more valuable information will be generated by the proposed CGE framework, largely associated with the availability of social information in the economy.

The CGE model used for macro-economic analysis purposes is mainly based on the standard static International Food Policy Research Institute (IFPRI) CGE model. The CGE model was calibrated to a National Social Accounting Matrix (SAM) for South Africa by the Provincial Decision-Making Enabling (PROVIDE) project. The calibration of the CGE model to the SAM implies that the base solution of the CGE model literally duplicates the original database or SAM, after which shocks or simulations can be applied with the model. The IFPRI model is written to follow the disaggregating of activities, commodities, factors and institutions distinguished in the SAM. Unlike other mathematical programming models, a CGE model has no objective function but utilises the equations specified to define the behaviour of the different actors in the economy (Lofgren et al., 2002). The basic characteristics of the CGE model can be grouped into four segments (as explained in Chapter 2 of Volume 2) including: 1) activities, production and factor markets, 2) institutions, 3) commodity markets and 4) macro balances or closure rules.

In addition to the CGE model, economic multipliers that typically measure the nature and extent of the impact or effect of an autonomous change/shock in a specific economic (i.e. export) quantity on other economic quantities (i.e. employment of production) were also calculated from the same SAM described above. Pyatt (1988) explains, however, that multipliers show how an economy operates given a certain set of assumptions, which should therefore be interpreted within the appropriate context.

Two key assumptions made by typical SAM-Leontief multiplier models are, firstly, that fixed relative prices exist and, secondly, that perfect elastic supply conditions, i.e. excess production capacity in all sectors, exist. Sadoulet and De Janvry (1995) explain that these assumptions lead to the central assumption in this type of analysis that sectoral production is completely demand driven and that the underlying production function assumes constant returns to scale and no substitution among the different inputs.

Despite these shortcomings, in order to estimate the macro-economic impact of simulated changes at farm (micro-economic) level, three sets of economic multipliers (i.e. labour, production, and value added) are calculated from an aggregated version of the NCP SAM. For purposes of calculating the multipliers, various accounts in the original version of the SAM described above were aggregated. In terms of commodity accounts, all non-agricultural commodities were aggregated, whereas all activities except for the agricultural activities in the NCP were aggregated. The same was done in terms of production factor accounts and households, where all accounts except the NCP labour factors and NC households were aggregated. This aggregated SAM version used to calculate the economic multipliers consists in total of 35 accounts (i.e. 7 commodities, 9 production activities, 8 factors of production, 6 household groups, a margin account, a government account, a capital account, and a rest-of-the-world account).

MAIN RESULTS

Results at micro-economic and regional-economic level (Volume 1)

The following conclusions can be drawn from the typical farm model results:

- The result of the CGE model corresponds with the observed reduction in table-grape prices in the Orange River region. The CGE model calculated that the local farm-level price (delivered in port) will decrease by 22% if the international price of fruit is reduced by 20%. This result is important to illustrate the link between the CGE (macro-economic) and micro-economic models.
- The typical farm-model scenarios showed that a decrease of 20% in the price of table grapes reduced the return on capital investment from 37.4% in the base to around 18.5% (reduction of more than 50% in net farm income). This represents a huge decrease in profitability. It is also important to note that a 20% reduction in the price of table grapes is an average in reduction. There is substantial variation between the price that farmers actually receive, since it will depend on the markets where the farmers sell their fruit and on the cost structure of the exporter. In this regard, farmers can reduce their risk. For example, it was pointed out that a reduction of around 40% is unfeasible (farmers go bankrupt), but on the other hand there will also be farmers

with a reduction of less than 20%, since they are actively involved in the marketing of their product. From a risk management point of view, it is therefore important for farmers to get involved in the marketing side of the supply chain. This is not only true for table-grape farmers but for the farmers of all crops, as a powerful tool to manage marketing risks.

- It was also pointed out that marketing information is the key to managing marketing risks. In this regard, industry organisations such as the Deciduous Fruit Producers' Trust and the so-called Joint Marketing Forums (JMFs) should play an important role. Within the JMFs, producers and exporters collaborate to share supply information (crop estimates, fruit intake, and shipments) and demand information (southern hemisphere shipments and price information for alternative markets).
- Timely and accurate fruit intake and shipment information and the availability of accurate market compliance and price information are obviously keys to efficient marketing decisions. In this regard, government can play an extremely important role in partnerships with industry organisations to develop information systems to improve the accuracy and timeliness of information and thereby create an environment where the private sector can take advantage of marketing opportunities and reduce marketing risk.
- The results also clearly indicated that a more diverse farming structure is a key strategy when it comes to reducing marketing risks. The results indicated that the optimum farm structure after a reduction in the price of table grapes is different to the observed farm structure. If farmers had better marketing information and the skills to interpret this information, they would have made different production decisions. The results clearly show that the farm structure would have been more diversified. A more diversified farm structure enables farmers to absorb market failures more efficiently than with a specialised farm structure.
- A huge increase in the price of raisins does not necessarily combat the reduction in table grapes. Since sultana grapes are more flexible than other table grapes, the results indicate that farmers do alternate between grapes for export and grapes for raisins when the price of table grapes is reduced. It is, of course, not an optimum market risk-reduction strategy, since farmers need to produce what the market wants. What the market wants changes over time, and it will therefore not be feasible to produce sultanas only. However, since sultana production represents approximately

45% of the total table-grape crop mix, it is to some extent part of the risk-reduction strategy. This result also corresponds with the observed reaction of table-grape farmers in the Orange River area. It is not uncommon to hear industry leaders and exporters talk about the "sultana factor" creating enormous challenges for crop estimates, since it is unknown before the season how many farmers will convert from grapes for export to grapes for raisins.

- An extremely difficult result of marketing to manage risk is its impact on land value. Since 2002, the observed market value of land has been reduced by more than 50%. Farms purchased in excess of R150 000 per ha have been auctioned off for less than R70 000 per ha. The impact on financing should be obvious, since financiers react to the observed value of land when their security is reduced. Farms that were solvent became insolvent over a short period simply because of a revaluation of the property. The analysis shows that the model results are consistent with what has been observed. The average capitalised marginal land value decreased from R204 000 per ha (base) to R107 000 per ha with a 20% reduction in the price of table grapes. One way of managing this risk is to ensure that financing decisions are highly conservative and that there is greater emphasis on the ability to pay than on property value. A proper price and yield sensitivity analysis should accompany any application for production loans. In the opinion of the authors, banks have also been guilty in this regard. They should play an important role in reducing marketing risks by being more conservative and insisting on a proper sensitivity analysis.
- Capitalised marginal water value decreases with a reduction in the price of table grapes. These results are consistent with the micro-economic theory that the demand for irrigation water is derived from the demand for irrigation crops. From a policy point of view, this result is important. The spirit of the New Water Act lies in the use of water at its highest value. The indirect effect of an inability to manage market risks is that it creates potential for inefficient water use. It was pointed out that it is extremely difficult to change the farm structure on a farm designed to produce table grapes. However, if the farms were designed to be more flexible to cope with marketing risks, the farms would have a greater ability to absorb marketing risks.
- It was also pointed out that a reduction in the cost structure of farms should be part of marketing risk management. On the one hand, farmers and marketers should continuously strive towards a reduction in production and supply-chain costs, while

on the other hand, government should also play an important role in reducing the cost of doing business. For example, agricultural labour, land and water policies should consider the risks involved in agriculture (variation in crop yield and price, as well as natural disasters).

- The importance of training farmers in market analysis and market intelligence was pointed out. A casual observation in the region is that there are still many farmers without adequate training to cope with the new marketing environment after deregulation. It is especially the new emerging farmers and older farmers who fall into this category. The Department of Agriculture in partnership with industry bodies can play an extremely useful role in educating these farmers to cope with marketing risks.
- Finally, it was pointed out that although only one market-risk scenario was illustrated, the typical farm models can be extremely useful in testing risk-aversion strategies for specific typical farms with different farm structures. Although it is possible to suggest general risk-aversion strategies, it will be necessary to develop very specific strategies for different regions, farm structures and farm sizes.

The results of the regional model drew more or less the same conclusions as with the table-grape scenario with the following additional conclusions:

- The overall conclusion regarding the regional model is that the model is extremely useful in indicating the direction in which water will trade in order to remove inefficiencies from overall water allocations.
- By analysing scenarios with and without water trade, it is possible to theoretically identify regions with surplus water and inefficiencies in water allocations on the one hand, and on the other hand to identify the regions with water shortages.
- The analysis shows that approximately 10% of the total allocation of water-use rights in the Northern Cape went unused during 2002. Most of the unused water was in the western regions below Boegoeberg. On the other hand, the analysis showed that there was a shortage of approximately 8 600 ha (77 million m³) in the Vaalharts region. It can therefore be concluded that farmers either extract more water than their allocation or they do not irrigate optimally (sub-optimal irrigation). The authors are of the

opinion that the latter is most likely the case, since the DWAF uses aerial photographs to identify these farmers and the penalty for over-abstraction is severe.

- When the price of table grapes is reduced by 20% and it is not possible to make structural changes, the total net output of the Northern Cape is reduced by R6.33 billion over 20 years or R316.5 million per annum (this is the cumulative effect of a reduction of 20% in the price of table grapes over 20 years). This figure gives an indication of the cost of "not knowing".
- The analysis also indicates that if farmers can make structural adjustments, they will change their farm structure to adjust to the reduction in the price of table grapes.
- When water trade is possible, it can contribute to reducing the impact slightly. However, the results indicate that there is no significant difference between the scenarios where structural change is possible and the same scenarios but with water trade. This means that inefficiencies will be removed from the system through a combination of structural changes and the reallocation of water.
- When water trade is activated in the model, most of the trade is towards Vaalharts. This result can be explained by the calculations that were made to determine where water shortages exist. In general, water flows from regions with unused water to those with a shortage.
- It was also pointed out that the wheat/maize double-cropping system requires between 9 150 and 15 000 m³ depending on cultivar (early/late). It is therefore obvious that in a region where the average water-use allocation is 9 000 m³, double-cropping is impossible unless crops are irrigated sub-optimally.
- The reduction in the net farm income per region is almost identical to that of the typical farm model for Augrabies/Blouputs. This is to be expected, since the same data is used in each of the models.
- Significant structural changes are induced by a reduction in the price of table grapes. Although this is not shown in the results, most of the changes in long-term crops are towards olives, pecan nuts, citrus, and lucerne. This result is important, because similarly to the typical farm model, the importance of a diverse farming structure when it comes to coping with market risks is emphasised.
- It was also pointed out that the impacts of a long-term market trend (such as the reduction in the price of table grapes) pose serious long-term financial problems for farmers. Even if they wish to make structural changes, their financial situation and

the reduction in the value of their properties prevents them for securing finance to make these changes.

- The analysis also shows that there is a substantial increase in land and water use in the Vaalharts region when trade is possible. Land use increases from 119% to 138% when the calibration restrictions are released and water trade is possible. Overall water-use efficiency increases, since water can relocate from water-surplus regions to water-shortage regions.
- The crop water usage per hectare is also an indication of water-use efficiency. Although water markets induce an increase in total water usage, the water requirement per hectare decreases when water trade is activated.
- The results also show that crop water usage per hectare increases when the price of table grapes is reduced. This result indicates that the structural changes induced by the reduction in the price of table grapes will not necessarily be more water-use efficient.
- An analysis of capitalised marginal water value reveals important information. The analysis clearly shows that in general, water trade is towards the regions with the highest marginal value for water, from the western regions to the north-eastern regions.
- Although relatively large volumes of water trade over the 20-year planning horizon, less than 1% of the total annual water allocation is traded.
- Water tariffs are a major issue for irrigation farmers and for government. To get some insight into the impact of water tariffs, several scenarios with trade, without trade, and with a reduction in crop prices were analysed. These scenarios fall into the category of the impact of input-cost increases on farm profitability and also on the ability to absorb market risks. The following can be concluded from the analysis:
 - Water tariff increases in the order of 100-200% have not been uncommon in the Northern Cape since 2002, with a significant increase being observed in especially the tariff for direct abstraction from the river.
 - Water costs as a percentage of total production cost vary between less than 1% for most long-term crops and between 5-12% for short-term crops. It is therefore obvious that increased production costs will impact more negatively on farm profitability in the regions where the majority of crops are short term.

- This result indicates that without water trade, the impact of a 150% increase in water tariffs is a reduction in the total value (objective function value) of irrigation farming by about 3.4%. This amounts to a cumulative effect of R290 million in present-value terms over the 20-year planning horizon.
- The analysis also indicates that water trade reduces the impact of an increased water tariff to some extent, since water is allocated more efficiently.
- When the price of table grapes is reduced by 20% and grain by 10%, the result is significant since it is a fairly realistic scenario that has unfolded over the past few years. The results indicate that grain farmers can now not absorb more than a 110% increase in water tariffs. However, at the same time, it is also pointed out that not all farms are in the same position. The impact on the regions where long-term crops are produced is insignificant.
- The total net farm income is reduced by 9.9% when crop prices are reduced and water tariffs are increased by 110%.
- The results also indicate that structural changes are insignificant at the base analysis crop prices when water tariffs are increased. However, when crop prices are reduced, significant structural changes take place, but they are induced not by higher water tariffs but by the reduction in crop prices.
- At a water tariff increase of 250%, total water usage only declines by approximately 6.8%. This result is consistent with the results from other studies indicating a highly inelastic water demand function for agriculture and specifically for long-term crops.
- Also, this result indicates that when crop prices are reduced and water tariffs are increased, the net result will not necessarily be a reduction in total water usage, since farmers will make structural changes and the new structure may use more water.
- The results reported in the two bullets directly above are important from a water demand management point of view, indicating that water tariffs in agriculture are not necessarily an efficient tool to induce more efficient water use. There are other market-related factors that carry more weight when farmers make crop-production decisions.
- In general, capitalised marginal water value increases in all regions as water tariffs are increased. This result is even clearer when water trade is activated. Table 7.51 shows huge increases in the marginal value of water, especially when water tariffs are

increased by more than 150%. The explanation for this result is that increased water tariffs increase the scarcity value of water.

- The water trade results are similar to the table-grape scenarios in that water flows mainly to the Vaalharts region. The result also indicates that more water will trade at higher water tariffs. Also, the results indicate that when crop prices are reduced, there will be a reduction in water trade compared to a scenario with the same water tariff but with base crop prices.
- The results also indicate that when crop prices are reduced and water tariffs are increased, trade increases substantially from about 6.8 million m³ to approximately 22 million m³. This result is important, since it shows that a reduction in crop prices increases the sensitivity of farms to increased water tariffs. The result of these scenarios also shows that the water market becomes more active. Although the total volume of trade towards Vaalharts increases (139 million m³ compared to 104.9 million m³ in Base C), the relative contribution to total trade decreases. The reason for this (although it is not shown in the analysis) is a significant increase in crops such as citrus, pecan nuts, and olives.

Results at the macro-economic modelling level (Volume 2)

The results for the two different macro-economic methodological approaches, i.e. the CGE model and the economic multiplies, are presented. In the case of the CGE model a 20% decrease in the world fruit price was simulated (abbreviated as PWEDECR). This shock was simulated to quantify its impact with specific reference to irrigation agriculture within the NCP. In addition, two alternative employment specifications were investigated, i.e. one a full employment and the other where unemployment of the unskilled labour categories was allowed. A critical and central assumption made at macro-economic level is that all arable crops grown in the NCP are irrigated. In other words, due to the relatively low rainfall, rain-fed arable crop production is virtually impossible and therefore negligibly small in the NCP. It is, however, important to remember that the SAM used in this analysis is a national SAM for South Africa, with disaggregated detail for agricultural activities, specifically within the NCP. Having said that, cognisance should be taken that if a tariff or price (exogenous world price) of a commodity is "shocked", it reflects a national change, i.e. the tariff or price of the commodity is changed nationwide. In order to quantify the

impact of the shocks on the economy of the NCP, selected NCP variables were then analysed. This was then treated as a top-down linkage approach to the micro-economic (farm and regional) models.

For this purpose a commodity subset was created for arable crop commodities (labeled CIARG in the GAMS model code), which included the following 7 agricultural commodity groups: summer cereals (C1a), winter cereals (C1b), other field crops (C1c_e), potatoes and vegetables (C1f), wine grapes (C1g), fruit (C1ijk), and other horticulture crops (C1k). Therefore it is assumed that if a shock is applied to arable agricultural production, the effect thereof can be directly linked to irrigation agriculture in the NCP. It is, however, important to note that this only applies to the NCP, given that the simulations are national, as the rain-fed component of irrigation agriculture in the remaining parts of South Africa is quite significant on a macro level. Some of the main results from the 20% decrease in the world price of fruits include:

- The national GDP is reduced by 0.027%.
- The effect of NC1 and NC8 on regional GDP is found to be in contrast with the simulated effects on the other six regions. Being the largest fruit-producing region in the NCP, it therefore seems logical that the PWEDECR simulation will most affect NC1 (Gordonia, Namakwaland and Kenhardt) with a decline in regional GDP of 15.7%, followed by Kimberley (NC8) with a negative impact of 0.7%. The impact on the remaining six regions is positive throughout, with an average increase of 7.7%.
- This high level of concentration of fruit production in one region (NC1) of the NCP, as well as relative dominance of fruit in terms of the total agricultural output within NC1, can be seen as the reason for the relatively large simulated impact. NC8 (Kimberly), which has the second highest share of fruit output, experiences a 0.7% and 2.2% decrease in fruit output respectively for the full-employment and unemployment scenarios as a result of the change in the world fruit price simulation. The fruit output of the remaining six regions, all with a regional fruit output share of less than 4%, are expected to increase their fruit outputs, ranging between 6.6% and 8.6%. In contrast to NC7, which produces 3.5% of the total fruit within the NCP, the simulated changes to all other NC regions can be disregarded, as the changes are from such a small/insignificant base.

- The intermediate input prices for the majority of the activities accounted for in the model experience a decline ranging between 0.27% and 0.03%. Certain NCP agricultural activities, namely NC1, NC4, NC6, NC7 and NC8, all experience a decline in their respective output prices, ranging from a low of 0.1% for both NC6 and NC7 to a maximum decline of 1.5% for NC1. From the reported declines in the NCP activities, the positive correlation between the producer price decline and the share of fruit production within each region is clear. For example, the largest decline in activity producer prices (1.5%) for NC1 corresponds to the fact that fruit is the most dominant commodity (64% of the total output quantity) produced within NC1. Similar NC8, which has the second highest fruit output share (13.6%), recorded the second highest decline in activity producer prices with the NCP. In terms of the other provinces, the Western Cape (WC), Eastern Cape (EC), Limpopo (LP) as well as Mpumalanga (MP) also show a decrease of 0.7%, 7.3%, 10.5% and 12.6% respectively in their activity output levels. Again, it should be kept in mind when interpreting these changes that the relative importance of fruit as a commodity within each production activity (i.e. region) plays a pivotal role in the magnitude of the simulated change.
- The largest negative impact felt among the eight NCP activities are in NC1 with an estimated R199 million decline in total value added, followed by NC8 with nearly R2 million. The value added in other provinces like WC, EC, LP and MP also decreases by between R67 million for WC and R488 million for MP. The relatively significant change in total value added experienced by NC1, LP and MP all result from the relatively large share (>10%) in the quantity of fruit produced within the specific activity.
- The domestic supply prices (of commodities produced and sold domestically) of potatoes and vegetables (3%), other field crops (0.94%), summer cereals (0.29%) and other horticulture (0.15%) increase for both employment scenarios, while the corresponding prices of fruit (8.3%) and winter cereals (1.9%) are negatively affected as a result of the decrease in the world fruit price.
- The quantity of fruit exports decreases by 37% on average for both employment scenarios. In addition to fruit exports, the export quantity of all other arable crops (with the exception of winter cereals, which increases by nearly 5%) decreases by between approximately 1% for summer cereals and 11% for potatoes and vegetables.

- On the import side, the simulation shows a 15% decrease in the quantity of fruit imports, again with an insignificant difference between the two employment scenarios. The decrease in fruit imports is probably substituted for by locally produced fruit no longer exported as a result of the lower world fruit price. The imports of summer cereals (0.2%), other field crops (0.6%) and potatoes and vegetables (5.5%) increase as a result of the simulation under investigation, whereas winter cereals and other horticultural imports also decline similar to the fruit imports.
- With regard to the semiskilled and unskilled labour categories employed in the NCP, African labour increases by 0.4%, whereas Coloured and White labour decrease by 1.1% and 2.2% respectively. Overall for all provinces, the largest decline experienced is in semiskilled and unskilled White labour residing in the NCP, i.e. -2.2%. On average the simulated employment levels of all semiskilled and unskilled labour categories are down by 0.4%.
- The rate of return to land as primary production factor increases marginally by 0.2% on average for the country as a whole following the 20% decrease in the world price of fruit. More specifically, the return to land in the NCP increases on average by 2.7%. However, underlying this positive impact is the fact that the major fruit-producing regions in the NCP (NC1 and NC8) are affected negatively.
- Resulting from the world fruit price shock, 18% (7 out of 39) of the national household (HH) categories increase their consumption expenditure by 0.18% on average for both the full-employment and the unemployment labour scenarios. The average decrease in HH consumption expenditure for the remaining 32 HH categories is 0.3% for the full-employment and 0.42% for the unemployment labour scenario.
- With regard to the equivalent variation (EV), a welfare measure indicating whether, in terms of the money equivalent, the HH is better or worse off as a result of the shock/simulation, the HH residing in the NCP are R31 million worse off as a result of the fruit price shock, which is the net result of a R3.6 million increase in the total welfare of NC African HHs and the R34.6 million decline in the welfare of the NC Coloured and White HHs.
- In the case of the full-employment scenario (PWDECR), the larger national government deficit or (dis-) saving comes as a result of the larger decrease in government income (-0.13%) compared to the decrease in government expenditure (-0.08%).

- In the case of the unemployment scenario (PWEDECUE), government income nationally decreases even further to (-0.2%), and with government expenditure being equal for both employment scenarios (-0.08%) the government deficit increases by 1.12% compared to the base (initial equilibrium).

The economic multipliers calculated use the same SAM as the macro-economic database in the CGE case described above, but a slightly more aggregated version. Three sets, i.e. labour, production, and value-added multipliers, were calculated for all activities in the economy as a group in the SAM. The direct, indirect and induced multipliers, which sum to total multipliers, are reported for all activities in Chapter 6 of Volume 2. These multipliers were then used in the form of a bottom-up approach to simulate/quantify the macro-economic impacts of the micro-level (farm and regional) simulations. Four micro-economic scenarios were selected, all characterised by a 20% reduction in the price (producer or farm-gate price) of table grapes, whereas they differ in terms of the variation allowed in area produced, as well as water trade. Scenario 2 is the same as the base with a 20% deviation allowed in long-term crop area, whereas scenario 5 represents a 60% permitted deviation in the long-term crop area. Scenarios 9 and 12 are respectively the same as scenarios 2 and 5 above, but with water trade allowed. The annual and long-term (20-year) objective function value of the regional level (micro-economic) model was used as proxy to illustrate the macro-economic impacts. Some of the main multiplier results include:

Labour impacts:

- According to the annual R1 264 million output from irrigation agriculture in the NCP (from the micro-economic model), 17 828 full-time jobs (direct) are created within irrigation agriculture within the NCP, which leads to an additional 3 580 full-time job opportunities in the industries supplying production inputs to irrigation (i.e. indirect effect). In terms of the induced effects, a further 12 547 full-time jobs are created as a result of the demand for consumables created from the wages and salaries paid out in the direct and indirect sectors. The total employment effect therefore amounts to 33 955 full-time jobs created from the R1 264 million worth of output in irrigated agriculture in the NCP.

- Scenario 2 (see Volume 1) results in a 33% or R316 million decrease in the objective value or output from regional irrigation agriculture, which in turn results in a total lost of 8 505 full-time jobs, consisting of 4 465 farm-level (direct) jobs, 897 input-supplying industry-level (indirect) jobs, and 3 143 induced job opportunities.

Production impacts:

- The R1 264 million output from irrigation agriculture in the NCP results in additional indirect production to the value of R778 million and an induced production demand of R1 827 million, aggregating to a total production (output) of R3 869 million.
- In the case of scenario 2, total production decreases by R969 million as a result of the 20% decrease in the farm-gate price of table grapes.
- When water trade is allowed the impact is less severe, with an observed decline in total economic output of R793 in the case of scenario 9. An increase in total production (R147 million) can be expected when structural adjustments are allowed in long-term irrigated agricultural crops in the case of scenario 5, whereas the same scenario – together with the possibility of water trade – results in a R321 million increase in total economic output.

Value-added impacts:

- The R1 264 million increase in irrigated agricultural output results in R796 million worth of direct value added, R298 million worth of indirect value added, and R786 million worth of induced value added, indicating that each R1 worth of production leads to an additional R1.88 worth of value added.
- The ability of farmers to trade irrigation water results in a nearly R100 million improvement in agricultural and related value added. However, when the model allows structural adjustments in terms of crop areas, the impact is significantly greater with an improvement of over R540 million in total value added in both cases.

RECOMMENDATIONS

Micro-economic and regional-economic level (Volume 1)

- The scenario results illustrate the extremely useful role that models can play in farm planning and the formulation of agricultural policies. An attempt is also made to point out the interaction between the CGE model, the farm models, and the regional model. Although an analysis of several more scenarios could have added value, the authors believe that these should be dealt with in a technology transfer project where specific scenarios can be analysed in detail in collaboration with the various stakeholders, with the results transferred to all relevant stakeholders.
- Chapter 8 (Volume 1) of this report focuses on the development of a policy framework to manage agricultural risks and specifically direct and indirect marketing risks. It is pointed out that there is a clear role in managing market risks for the individual farm, industry organisations and organised agriculture, provincial government and national government. There should also be opportunities for public-private partnerships to address and reduce many of the marketing risks. In this regard, the authors propose that marketing risk forums should be established. These forums should be on different levels, starting at the provincial level where local farmers and service providers should identify and attempt to quantify potential risk factors. If they cannot manage the risk factors within the local industry, the matter should be referred to a higher level that can deal with the issue. In this regard, industry-specific forums, provincial forums and national forums could be extremely useful in creating awareness of marketing risks and developing strategies and responsibilities for coping with these risks.

The following recommendations are a logical outflow from the findings and conclusions:

- The first overall recommendation is that a technology transfer project (TTP) should be formulated and funded by the Water Research Commission. The authors believe that the efforts to develop the analytical tools used in this study would all have been in vain if there is no effort to implement them in the Northern Cape. It is impossible within the scope of this report to conduct analyses and make recommendations

regarding all the potential risks for irrigation farmers. A TTP can address several more scenarios and can be used to refine existing scenarios.

- Flowing from this, it is proposed that a Northern Cape Agricultural Risk Management Policy Framework (ARMPF) should be developed and that Marketing Risk Management Forums (MRMFs) be established on different levels to discuss marketing risks and to develop strategies to manage them. The analytical framework developed in this study can play an extremely useful role in analysing these risks. It is also proposed that innovative ways be found during the proposed TTP to fund these forums. There are several possibilities; they could, for example, be funded through statutory funds such as the WRC levy or through a partnership between government agencies such as the National Agricultural Marketing Council (NAMC), industry organisations such as the DFPT and Grain SA, and the financial institutions.
- The MRMFs should be constituted in such a way that knowledgeable industry representatives, financiers, marketing experts and other experts in the supply chain are represented in order to really make a difference.
- It is also pointed out that marketing information is the key to managing marketing risks. In this regard, industry organisations such as the DFPT and the so-called Joint Marketing Forums (JMFs) should play an important role. Within the JMFs, producers and exporters collaborate to share information on supply (crop estimates, fruit intake and shipments) and demand (southern hemisphere shipments and price information for alternative markets). The grain industry and other commodities do have industry organisations that provide marketing information. However, it is proposed that there should be more emphasis on market risk management.
- Timely and accurate crop estimate, crop intake, and shipment information, the availability of accurate market compliance information and price information are obviously the keys to the efficiency of marketing decisions. In this regard, government can play an important role in partnership with industry organisations to develop information systems to improve the accuracy and timeliness of information, thereby creating an environment where the private sector can take advantage of marketing opportunities and reduce marketing risks. In this regard, the proposed MRMFs could be important communication vehicles whereby market data and information are collated, interpreted, and transformed into messages to be communicated to irrigation farmers.

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- The results also clearly indicate that a more diverse farming structure is a key strategy to reduce marketing risks. In this regard, there should be a continuous research effort to find alternative crops for the irrigation regions of the NCP.
 - One way of managing this risk is to ensure that financing decisions are highly conservative and that more emphasis is placed on ability to pay than on property value. A proper price and yield sensitivity analysis should accompany any application for production loans. In the opinion of the authors, the major financial institutions have also been guilty in this regard. They should play an important role in reducing marketing risks by being more conservative and insisting on proper sensitivity analysis. They should also be actively involved in the proposed MRMFs.
 - The spirit of the New Water Act (1998) is to use water at its highest value. The indirect effect of the inability to manage market risk is that it creates a potential for inefficient water use. Since efficient water allocation and water use is a national issue, there is a good argument for government to support innovative ways of reducing market risks.
 - It is also pointed out that a reduction in the cost structure of farms should be part of market-risk management. On the one hand, farmers and marketers should continuously strive towards a reduction in production and supply chain costs. On the other hand, government should also play an important role in reducing the cost of doing business. For example, agricultural labour, land and water policies should consider the risks involved in agriculture (variation in crop yield and price, as well as natural disasters). The proposed MRMFs can potentially also make a important input in the formulation of agricultural policies, even if it is just to make policymakers aware of the importance of a low-cost supply chain as a strategy to cope with market risk.
 - The importance of training farmers in market analysis and market intelligence is pointed out. A casual observation in the region is that there are still many farmers that do not have adequate training to cope with the new marketing environment after deregulation. It is especially the new and emerging and older farmers that fall into this category. The Department of Agriculture, in partnership with industry bodies, can play an extremely useful role in educating these farmers to cope with marketing risks. There is also a need to train farmers in whole-farm planning and in

methodologies to analyse alternative crops and introduce them into an existing farm structure.

- By keeping transaction costs low, an active water market can be encouraged. When water trade is possible, it can contribute to reducing the impact of market risks in the long run, since it will encourage the relocation of water. However, the results indicate that there is no significant difference between the scenarios where structural change is possible and the same scenarios but with water trade. Therefore, inefficiencies will be removed from the system through a combination of structural changes (induced by better market information) and the reallocation of water.
- The results indicate that high water tariffs in agriculture are not necessarily an efficient tool to induce more efficient water use. There are other, market-related factors that carry more weight when farmers make crop-production decisions. Therefore, the conclusion is that an effort to provide farmers with better market information will be more efficient when it comes to improving the efficiency of water allocation and water use.

Macro-economic modelling level (Volume 2)

Compared to international standards and examples, the current South African water law is a very well-written and thought-out part of the South African legislation. The major current challenges with such relatively "new legislation" rest with the implementation and in some cases the interpretation of these regulations. Some specific policy frameworks or institutional responses suggested to improve the effectiveness of water management include the following:

- • Due to the highly political nature of a strategic natural resource like water, it is recommended that the DWAF, together with the implementation bodies created, should strive to engage in managing water distant from political pressures to ensure effective management and utilisation. This implies that the DWAF should become more independent from government while still reporting to government.
- It is estimated, for example, that four out of the ten water management areas currently in deficit would change to a surplus with a 10% saving in current water-use requirements (DWAF, 2002). Water-demand management (as a reconciliation intervention) in South Africa is relatively underdeveloped compared to supply-side

management, despite numerous existing world-class examples of improved water-use efficiency in some industrial and agricultural areas that assist with the setting of benchmarks and standards. Combined innovative technological development that will only be possible via cutting-edge research in this field will ultimately advance effective water use.

- The inability to properly measure water flow may lead to the over-use (and hence the likely inefficient use) of water. Further improvements in the enforceability of volumetric allocation are likely to improve the effectiveness of water use in all sectors, especially in irrigation agriculture, where water supply is constantly under pressure. Stricter enforcement and incentives for "water savers" should therefore be implemented.
- In terms of equity, the reallocation of water amongst user sectors is suggested as an obvious and powerful option, with compulsory licensing supported by water-demand management and the trading of water-use authorisations as a main enabling mechanism (DWAF, 2002). This challenge calls for thorough and in-depth multidisciplinary research in this field to generate innovative mechanisms that will assist with the licensing procedure. It is particularly in this field that the macro-economic modelling framework developed in this part of the study can assist to a great extent with "what if" policy or implementation strategies.
- Water (re-)allocation through pricing and markets is proposed, but only under certain conditions, for example preventing subsistence farmers from selling water rights for short-term gain and rather promoting the leasing of water rights that may enable these farmers to raise cash for development. Provided that such a leasing arrangement is done correctly in partnership (or in the form of a mentorship programme/agreement) with commercial farmers already established in existing agricultural value chains, it may help to facilitate the process of installing these subsistence farmers into mainstream agriculture. In this way, PPPs should be nurtured, encouraged and facilitated by the institutions involved in order to ensure and improve the current effectiveness of irrigation water use.
- Research in this field of virtual water can provide valuable information to irrigators in terms of new developments or the re-establishment of current crops or cultivars. Creating common public awareness among consumers of their individual water footprint can therefore stimulate a more careful use of water. The reduction of virtual

water in consumers' diets may contribute significantly to water savings and therefore the effective use of scarce irrigation water. Government can therefore support research on this issue of VW and also run public awareness campaigns on water footprints in order to promote the effective use of this resource. According to the World Water Council (2004) the effects of changing diets on water resources have to be addressed through education. In this regard trading and manufacturing companies could help to enhance awareness by publicising the VW content and food miles, for example, of their products together with nutritional information.

- The development of a code of conduct for irrigators, in close collaboration with all role players involved, including the irrigation farmers, will assist in ensuring the effective use of this resource. Such a code of conduct for irrigators can also be used to outline the mandate of the DWAF and thereby distance itself from highly political pressures. The role of the public sector therefore reduces to that of a watchdog, ensuring that improved efficiency in water use and service delivery is not to the detriment of equity and social balance.
- An integrated approach to irrigation-water management, with the advantages of such an inclusive (i.e. bottom-up) management approach being in the very consultative nature of this process, will allow farmers to ensure that their needs and therefore inputs have beneficial outcomes.
- Water charges should ultimately be on a full-cost-recovery basis for all water users. However, the public nature of irrigation-water infrastructure (dams, channels, etc.) often complicates such charges, which are often high and therefore subsidised. The DWAF can also introduce incentives in terms of charges for irrigators to switch to more effective irrigation technologies or higher-value (i.e. virtual water content) crops.
- The macro-economic impacts and multiplier effects reaffirm that agriculture is one of the main pillars of the economy in the NCP.
- From the simulated macro-economic results it is clear that any shock affecting irrigation agriculture to some extent has tremendous repercussions on employment, HH and government income, consumption expenditure and therefore the welfare of HHs, especially in a province like the NC. It is therefore the responsibility of the national and provincial government to ensure that the necessary support systems in terms of efficient extension, operating capital as well as technical and marketing

expertise are available to the recipients or beneficiaries of these equity schemes. This will require the full spread of services, since the support required by individual farmers varies significantly. It is only when such proper support systems are in place and functioning well that sustainable, efficient and effective water use can be expected from these newcomers.

- In order to be successful in all this, the creation of an enabling business environment where transaction costs can be minimised will assist PPPs to be successful. In this way, government can also improve the efficiency of service delivery by attracting private investors and thereby also ensure technological improvements, as well as better managerial capacity.

POTENTIAL USERS OF THE RESEARCH

The following uses/applications by different role-players in the agricultural fraternity are envisaged:

- Policymakers in irrigation-water management as well as other agriculture-related regulations can benefit from the modelling capabilities contained in the models developed.
- Management groups of WUAs can constructively apply these models in the development of their business plans and negotiation processes.
- PPP consortiums can base their planning strategies on the results of micro- and macro-economic model simulations as shown in this study.
- Farmers and the organised agricultural bodies to which they belong will find these models extremely useful as part of a larger range of DSS in negotiation with authorities on issues like land tax, water rates, etc.

DEGREE TO WHICH AIMS HAVE BEEN MET

This project has succeeded in quantifying the impact of market risk on the efficient use of irrigation water by means of the farm-level and regional-level DLP model developed. In addition to the multiplier effects quantified, selected macro-economic impacts are quantified by means of the CGE model calibrated to the SAM database with disaggregated details for the agricultural activities in the NCP.

This project has succeeded in linking the micro- and macro-economic modelling frameworks in order to better estimate the macro-economic impacts of micro-economic shock and vice versa. Instead of the originally envisaged I/O model in the objectives of the original project proposal, a SAM (developed by the PROVIDE Project Team) was calibrated to a static CGE model designed and adopted for the NCP. In addition, economic multipliers were also calculated based on a similar, slightly more aggregated version of the SAM. The project has therefore succeeded in quantifying the impact of market risk on the efficient use of irrigation water, as well as the macro-economic impacts (including the multiplier analysis) accompanied by a shift in the production patterns in the NCP.

FUTURE RESEARCH NEEDS

- Regular updating of industry reports and models and the databases behind these as more recent data becomes available
- More detailed investigation of the virtual water concept to determine the potential benefits thereof for effective use of irrigation water in water-scarce countries like South Africa.
- The incorporation of a time dynamic in the macro-economic model used, which is of a static nature, in an effort to improve longer-term planning procedures

PROPOSED TECHNOLOGY TRANSFER ACTIONS

Finally, it is recommended that one of the first actions of the proposed TTP should be to inform decision-makers on all levels about the extremely useful role that models can play in farm planning and the formulation of agricultural policies. This effort should also extend to pointing out the interaction between the CGE model, the farm models, and the regional model. Terms of reference for the TTP should be developed in close collaboration with all stakeholders in agriculture in the NCP. As a minimum, it is proposed that the TTP provide at least for the following:

1. The establishment of MRMFs (even if it is only a pilot project) for at least grain and fruit. Following the establishment of the MRMFs it is proposed that the TTP team

go through an intensive exercise with these forums to run scenarios that they identify as critical for their industries.

2. An intensive model-implementation exercise with the Department of Agriculture of the Northern Cape. In this exercise, they should be asked to identify the issues they would want to analyse and, for example, to choose the top three.
3. A similar modelling exercise with the Department of Water Affairs and Forestry, as well as with organised agriculture.

Some of the main activities proposed for a formal Technology Transfer Project include:

1. Formal presentation of the results of this study to the national and NCP departments of Agriculture, as well as Water Affairs and Forestry.
2. Workshops in the form of a road show to present the results to the irrigation farmers, as well as the management of the WUAs in the NCP. The WUAs in the Free State Province operating in close proximity to the NCP should also be invited to attend. In addition, members of the management of organised agriculture and agri-businesses will also benefit from these sessions.
3. More specific empirical application of the models developed to assist WUAs in the compilation of their business plans and strategic planning sessions.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

According to Rosegrant (1995), the foremost challenge related to water scarcity in developing countries is the need to increase the efficiency of generally inefficient water use in agriculture, urban areas, and industry. Irrigated areas account for about 30 percent of agricultural production in South Africa, so growth in irrigated output per unit of land and water is essential. Improved efficiency in agricultural water use is required both to maintain productivity growth and to allow reallocation of water from agricultural to urban and industrial use.

Maximum productive efficiency can be said to exist when the factors of production are used in optimal proportions with optimal technology and are applied to those uses where total value product is maximised. The economic welfare of the owners of the factors of production is a function of the factors' productive efficiency, and, in turn, the economic welfare of the community is a function of the factor owners' welfare.

Theoretically, provided that there are no externalities, each factor will be optimally allocated (used) when that factor's marginal product values in various uses and among competing users are equal. One of the conditions for perfect competition is that factors are free to seek employment where they can bring maximum returns to their owners. If factors are immobile because of transfer restrictions, it is probable that marginal product values will be below optimum levels in current uses and that the observed market prices will reflect the lower productivity.

According to Kulshreshtha and Tewari (1991), the value of an economic good can be approximated by a measure of users' willingness to pay for the good rather than go without it. However, farmers are not direct users of water. Irrigation water has indirect utility as an

input to the production of other goods demanded by consumers. Willingness to pay for water would, therefore, depend upon increased output value over and above the extra output production cost. This concept is referred to as producer surplus. As product prices decrease, the derived demand for water tends to become more elastic. The long-run value of water is estimated as the residual after returns to long-run production factors are subtracted from short-run value estimates. Kulshreshta and Tewari found that only under high product price scenarios is there a long-run return to water, that is, greater than zero. For low-price scenarios, they found negative return to water, indicating that costs of fixed factors of production were not fully recovered.

The role of this proposed research project is obvious, given the risks involved (from a socio-economic point of view) in not reacting to market signals and the impact on the efficient water allocation. Lack of knowledge about the impact of market risks on efficient water allocation can be categorised in at least three ways. First, there is the economic impact of inefficient water allocation due to farmers' lack of knowledge about long-term market developments. This role involves the issues of forward and backward linkages to the local economy, economic feasibility, and social welfare. Only two studies had been done in South Africa to determine the contribution of irrigated agriculture to the regional economy in terms of output, income, distribution of income, and employment for irrigation areas. This was for the Ramah scheme (Kirsten, 1989; Kirsten & Van Zyl, 1990) and for the Vaalharts scheme (Viljoen, *et al.*, 1989). Second, there is the knowledge about the rules for reducing inefficiencies through a better understanding of the relationship between product prices, water value and alternative agricultural water uses. Third, this project will also develop proposals to increase water allocation efficiency within a high-risk marketing environment.

According to Backeberg and Oosthuizen (1991), knowledge of the comparative economic advantages and disadvantages of different schemes or regions is required before decisions are taken to develop new schemes or to rehabilitate a specific scheme in favour of another. In conjunction with scheme evaluation, the market potential of irrigation crops must be studied with reference to, for example, the infrastructure, population growth, projected supply and demand, and development policies in different regions (Kassier, Harrison, Tarr & Rhodes, 1988). According to Backeberg & Oosthuizen (1991), this especially applies to regions where agricultural products are processed locally and forward linkages are

expected. According to Groenewald (1991), crop selection and water allocation should be optimised simultaneously in irrigation planning. The major objective in economic cost-benefit analysis is to determine whether resource development will maximise or at least increase the national income of society as a whole. Project cost and benefits must finally be compared over time by discounting at a chosen interest rate and calculating various decision criteria such as benefit-cost ratio, net present value, and internal rate of return. That project alternative ought to be chosen which will maximise cash flow relative to capital resources used, so maximising value added at the same time and in turn maximising the contribution of capital to national income. Where resources are not allocated optimally due to producers' reaction to incomplete market information, inefficiencies arise, and this objective cannot be reached.

The table grape industry in South Africa grew by about more than 200% percent since the 1991/1992 season up to the 2005/2006 season.

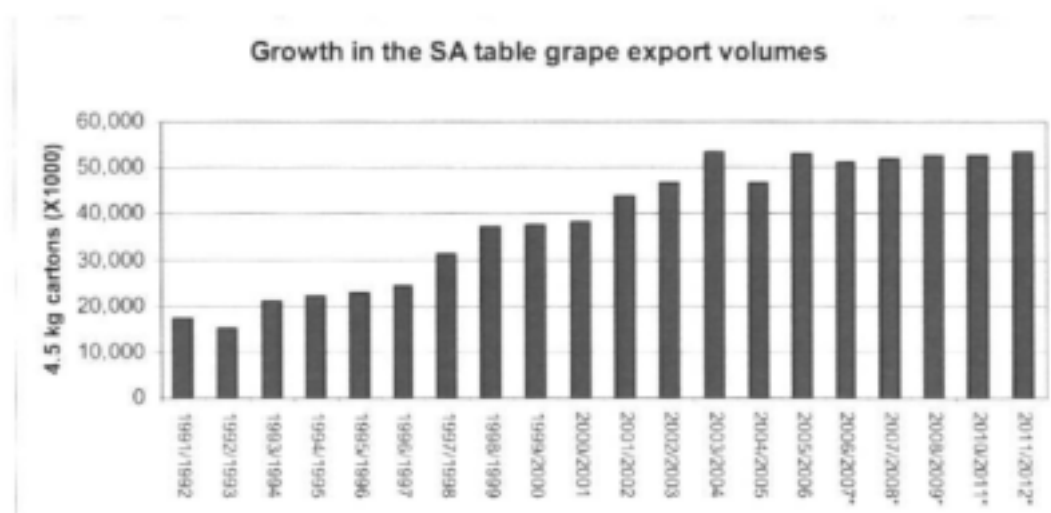


Figure 1.1: Growth in the table grape industry (1991-2012)

Note: * Estimate

Source: OABS (2006)

A large proportion of this growth came from the lower Orange River area. At present, the area produces about 30 to 32 percent of South Africa's export grapes. This area also represents about 30 percent of the total area planted with table grapes. During the

1997/1998 season, about 4.5 million 4.5 kg cartons of table grapes were exported from this region. This increased to about 7.5 million cartons during the 1998/1999 season and to more than 15 million during the 2005/2006 season. Industry turnover in the Northern Cape is about R650 million (measured in terms of the FOB value); about 6600 people are directly employed and 26400 dependent; R1.6 billion is invested in production and packaging infrastructure. It may seem there is a bright future for the industry, but the red lights have been flickering for a long time. According to European newspapers, about 25 percent of the world economy is in recession. At the same time, new plantings of Southern Hemisphere Table grapes are increasing at an alarming rate. From a resource allocation point of view, the question can rightfully be asked whether a scarce resource such as water is allocated optimally in the Orange River due to lack of market information on the side of producers. Plummeting table grape profitability will have a tremendous negative impact on the Northern Cape economy, where the livelihood of thousands of people depends on this industry. If farmers were to react rationally to market forces, they would probably diversify their farming operations. In the long-run, this would lead to more optimal allocation and more efficient use of resources.

This study will generate knowledge on the impact of market risk on the economic advantages or disadvantages of irrigation developments in the Orange River. The research effort will also contribute to providing solutions that will maximise or at least improve individual farmers' utility and general social welfare. The methodology and results will be available to use in other catchments where similar problems exist.

1.2 OBJECTIVES

This project's main objective is to quantify the impact of market risk on efficient irrigation water use and to determine the multiplier effects of irrigation accompanied by a shift in production patterns with reference to the middle and lower Orange River on the total Northern Cape economy.

Project sub-objectives are:

- To identify and quantify risk factors in irrigation agriculture.

- To develop a decision-making framework which farmers can use to reduce their risk.
- To compare present water use practices with optimal risk-reducing practices and to find reasons for deviations from the optimal.
- To develop a policy framework for irrigation agriculture that will reduce risks and improve the financial viability of individual farmers and irrigation schemes.

This volume of the report only addresses sub-objectives 1-4. The other sub-objectives are covered in Volume 2. They are:

- To identify and quantify the relevant products and economic sectors in the Northern Cape economy.
- To distinguish between the irrigation and non-irrigation agricultural sectors.
- To derive the relevant coefficients for the Northern Cape from the national input-output model by using the product balance approach.
- To develop a policy framework on effective water management for regions where irrigation agriculture makes a major contribution to the economy.

1.3 THE STUDY AREA

The study area includes the irrigation areas on the Northern Cape side of the Orange River from Vanderkloof Dam to Douglas as well as all the irrigation land from Douglas to Alexander Bay. The study also considers developments on the Namibian side of the River as well as 4000 ha of land identified by the Northern Cape Department of Agriculture for the establishment of new farms or the upliftment of existing farmers. Figure 1.2 shows the study area from Vanderkloof to Alexander Bay.

1.4 METHODOLOGY

The Orange River is an exceptionally good area to study the impact of possible inefficient water use due to the lack of efficient market signals. Irrigated agriculture and specific table grape production is the backbone of the Northern Cape economy. This makes the area particularly vulnerable to inefficiencies in water allocation and to agricultural market risks.

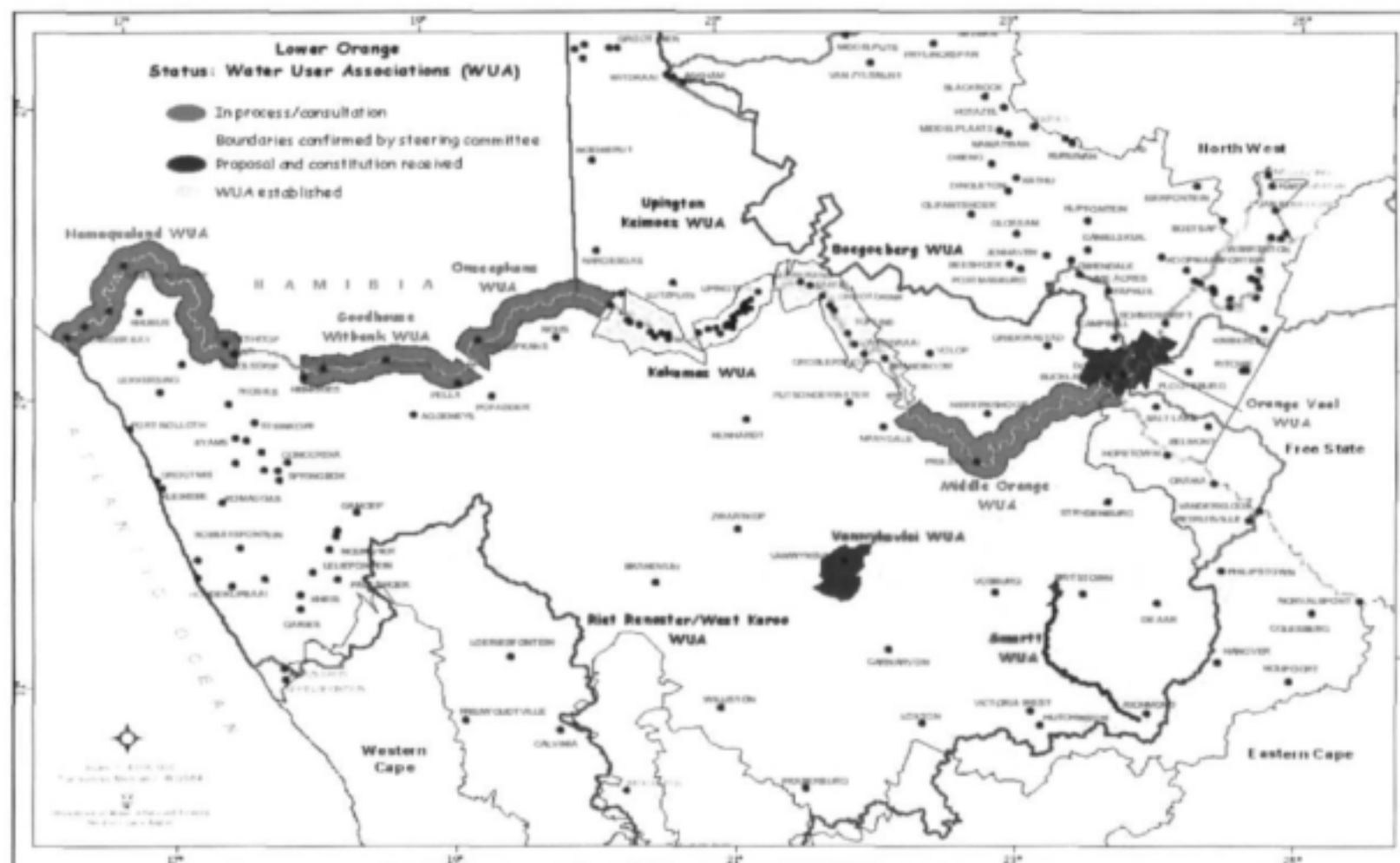


Figure 1.2: Location map

The abovementioned makes it possible to determine how changes in market prospects for agricultural products impact efficient water use, what structural changes will be necessary to increase efficiency, and how the rest of the local economy will be affected should inefficiencies exist. In order to complete the study successfully, certain processes were followed. For the micro-modelling part of the study (in this volume), they are the following:

- A literature study was conducted on the following aspects: in this volume, the theory of water use efficiency, water allocation, and responses in water demand because of product price changes, agricultural risk management, risk modelling methodology and risk measurement; in volume 2, methodologies to study the economic impact of backward and forward linkages of irrigated agriculture.
- An investigation into the present water allocation system, land use, and the long-term market prospects for the crops grown in the area.
- Division of the Orange River into homogenous areas for modelling and crop budget purposes.
- Compilation of different crop budgets for the homogenous areas under different market scenarios.
- A farm survey on a representative sample for homogeneous areas.
- Development of DLP's (Dynamic Linear Programming Models) for the different homogenous areas and irrigation systems.
- Calculation of the NPV (Net Present Values) of the cash balances with varying discount rates. The discount rates will reflect the risks involved in cultivating various crop combinations.

In volume 2, macro-modelling, the following steps were followed:

- Development of input-output matrices to calculate backward and forward linkages.
- Calculation of forward and backward linkages under different long-term market prospects. This will include scenarios where inefficiency exists as well as where structural changes and reallocations are made to increase efficient water allocation.

The research tools employed in the different micro modelling processes (this volume) were the following:

- Dynamic Linear Programming models
- crop budgets
- spatial equilibrium models.

Dynamic Linear Programming models are well documented as good research tools for measuring the impact of macro- and micro-economic variables on whole farm planning. Micro-combuds have specifically been developed by the Department of Agriculture to link up with planning models such as DLP's. Crop budgets for the different areas and irrigation systems were developed on the same basis as the Department of Agriculture's micro-combuds to ensure consistency for future research. With a spatial equilibrium model, optimal water resource allocation can be found and compared to the existing one.

1.5 DATA USED

In order to construct a mathematical programming model which accurately represents the Orange River system, various sources were consulted. A farm survey was conducted in the Orange River with a structural questionnaire using a representative sample of 217 farms representing six identified sub-regions of the river. Most of the data used to run the micro models were obtained from the farm survey.

Enterprise budgets were compiled based on the Micro-Combud (Micro Computerised Budget system) program methodology of the Department of Agriculture of the Western Cape. This system ensures that the budgets all comply with accepted agricultural and economic norms.

Price and yield data for long-term crops were obtained from Optimal Agricultural Business Systems (OABS). OABS collects and processes this data for the Deciduous Fruit Producers Trust (DFPT). Budgets for short-term crops of the Grickwaland-Wes coop were used and adapted to be comparable to Micro-Combud methodology.

Water use entitlements for the different reaches of the river were obtained from the Department of Water Affairs and Forestry. Water requirements were calculated with the SAPWAT (Crosby & Crosby, 1999 ; van Heerden & Crosby, 2001).

1.6 CHAPTER OUTLINE

The study is primarily concerned with the impact of risk on optimal water allocation and forward and backward linkages of irrigation on the total Northern Cape economy.

The present chapter is followed by an extensive literature review on issues relating to risk management. The chapter concerned deals with risk management strategies, risk management in South Africa, risk management and water allocation, risk measurement, and risk modelling methodology.

Chapter 3 presents a comprehensive description of the Northern Cape irrigation regions from Vaalharts to the Lower Orange River region, development projects in the irrigation region of the Northern Cape, and developments in Namibia impacting on South Africa.

In Chapter 4, an overview of the farm survey and data is presented including the sampling process, the survey results, a description of the typical farm, aggregation factors, enterprise budgets and other modelling data.

This is followed by a chapter on the marketing environment, market prospects, and risk factors for the most prominent crops in the region.

Chapter 6 is a description of the Lower Orange modelling framework including the typical farm models as well as the regional spatial equilibrium model.

In Chapter 7, a modelling framework is employed to study market risk scenarios. The final chapter consists of conclusions and recommendations regarding market risk-management strategies.

CHAPTER 2

LITERATURE REVIEW

2.1 BACKGROUND

There is an abundant literature on risk management in agriculture. The intention of this chapter is to give the reader a condensed summary of sources of risks in agriculture, common risk aversion strategies, and the methodology to include risk in mathematical models such as linear programming. Although this project concentrates on market risks, the chapter also covers other potential risks.

Risk and uncertainty are inescapable factors in agriculture. Types of risk include production risk related to weather, crop and livestock performance, pests and diseases, market risks, government-influenced institutional risks, and personal or human risk. All these risks constitute business risk which is further related to financial risk.

Farmers make decisions in a risky, ever-changing environment. The consequences of their decisions are generally not known when the decisions are made, and their outcome may be better or worse than expected. According to Patrick (2003), risky situations of concern are typically those in which:

- there is a high probability of adverse consequences, or
- potential adverse consequences would cause significant disruptions.

There are two reasons that risk matters in agriculture. First, most people dislike risk in the sense that they are averse to risk when faced with significantly risky incomes or wealth outcomes. A person who is risk-averse will be willing to forgo some expected return for a reduction in risk. Evidence of farmers' risk aversion is reflected in many of their actions, such as their willingness to buy certain kinds of insurance. Second is the issue of downside risk. This refers to those situations in which significant deviations from the 'norm' more

often lead to worse outcomes than to better ones. Crop yield, which depends on numerous variables such as rainfall and temperature, provides an obvious example. Broad variable deviation from expected values in either direction tends to have adverse effects (Wageningen University, 2002).

For Hardaker, Huirne and Anderson (1997), *risk management* is the systematic application of management policies, procedures, and practices to the tasks of risk identification, analysis, assessment, treatment, and monitoring. For any organisation, be it a large corporation, government agency, or family farm, risk management is, or should be, an integral part of good management. It is a way for an organisation to balance serious potential losses against the opportunities for profit. Risk management is not a set of procedures that are followed, once and for all, to "inoculate" the organisation against risk, since that is impossible in a turbulent world. Rather it is a continuous, adaptive process that needs to be integrated into all relevant aspects of the organisation's decision-making process.

After deregulation in 1997, the marketing environment in South Africa changed forever. Farmers operate in a globalised economy where they not only compete with their fellow farmers but also with other governments. In this environment, competition is strong, and only the best survive. There is no place in the market for farmers who cannot produce a quality product at a competitive price. Prices are not determined in South Africa: they are determined by global market forces. Existing farmers and potential investors in the Orange River irrigation region must realise this before they invest heavily in irrigation agriculture. In considering any investment in this region, farmers must ensure that they can produce a product competitively. They must first do the right things (effectiveness) and then do the right things right (efficiency).

When considering profitability, people are often seduced by the potential of fruit and vegetable production. Compared to most agronomic crops, these horticultural crops offer the opportunity to produce a substantial income per ha. With this income potential, however, come sizeable risks. These risks can be categorised as either impacting receipts or relating to production costs.

2.2 RISK MANAGEMENT

According to Miller, Boehlje and Dubbins (1998), farming has always been a risky business, and increased openness to world markets, growing international demand, and more global competition to supply these markets suggests even more risk.

2.2.1 Why do farmers not actively manage risks?

According to the USDA-RMA (2000), only about 5 percent of farmers in the USA are using the available tools to manage production and financial risks. They identified at least four reasons:

- **Resistance to change.** In what may be the ultimate irony, learning about risk management seems risky itself. It involves changing the way you approach decisions and the way you do business. If you believe that change is unnecessary, the risk management advice you've received in the past probably stung for a moment then blew past you like an arctic chill.
- **Too many decisions, not enough time.** The variety of risk management tools can be a curse as well as a blessing. Good tools incorrectly used or poorly understood can ruin an operation. Ongoing risk management and education will be necessary to stay competitive.
- **Old fears die hard.** Despite the fact that thousands of people use futures and options every day to protect themselves from price risk, distrust of the futures industry still runs deep in the hearts of many farmers. The crop insurance industry has also struggled to gain farmer confidence
- **The check is in the mail.** Last but not least, up until now the USA Federal farm program absorbed some of the harsh realities associated with farming. The Federal Government assumed part of the production risk by making annual disaster payments. For the most part, those have been replaced with subsidised crop insurance. In the past, part of the marketing risk was reduced by annual price support payments.

It has been shown by Dennis (2001) that a number of organisations in the UK claimed that private risk management tools are frequently "too expensive" or do not meet farmers' needs. There may be a number of reasons that private instruments might be perceived as expensive or otherwise inadequate. One possible explanation is that demand for risk management tools may be relatively low given farmers' present institutional operational environment. Another possible explanation is that farmers may misperceive risk. If misperception of risk is a reality, it is likely to have its root, once again, in inadequate information and training. These are explanations which relate to the *demand* for risk products.

Dennis (2001) believes that there might also be explanations relating to the *supply* of these instruments, especially with respect to insurance schemes. Asymmetric information (where the insured knows more about the potential risks to his business than the insurance company) is one issue. Another is systemic risk: that is, a situation in which a downside risk impacts on most of the industry in the same way. These problems make the provision of insurance coverage for a number of agricultural risks difficult and expensive. Asymmetric information involves problems of "adverse selection" and "moral hazard". Both problems lead to high monitoring and administrative costs for insurance companies. With systemic risks, multiple insureds can suffer losses at the same time. Insurance companies have problems pooling such risks themselves, and adequate reinsurance capacity is not usually available with large-scale systemic risk.

Risk has always been a part of agriculture. However, farming in South Africa has changed dramatically over the past few years, especially after deregulation in 1997. Increasingly, farmers are learning that there are new rules, new stakes, and, most of all, new risks. The nation's most successful farmers are now looking at a deliberate and knowledgeable approach to risk management as a vital part of their game plan. For them, risk management means farming with confidence in a rapidly changing world. It is the ability to deal with risks coupled with new, attractive farming opportunities. For producers, the reward for adopting risk management strategies may well be survival (Dean, 1999).

2.2.2 Understanding risk in agriculture

Farmers and other business people generally do not get into risky situations unless there is a probability of making money. It is to their advantage that these risky but potentially profitable situations be managed as carefully as possible. Effective risk management involves anticipating possible difficulties and planning to reduce their consequences, not just reacting to unfavourable events as they occur. The two primary aspects of risk management are:

- anticipating unfavourable events and acting to reduce the probability of their occurrence;
- taking actions to reduce the adverse consequences should unfavourable events occur. (Patrick, 2003)

Hardaker, Huirne, and Anderson (1997) distinguish between risk and uncertainty. One common distinction suggests that risk is imperfect knowledge where the probabilities of the possible outcomes are known, and uncertainty exists when these probabilities are not known. However, this is not a useful distinction, since cases where probabilities are objectively known are the exception rather than the rule in decision making. Hardaker *et al.* (1997) define uncertainty as imperfect knowledge and risk as uncertain consequences--particularly exposure to unfavourable consequences. Risk means many things to many people. A dictionary definition of risk is "exposure to the chance of injury or loss". Insurance defines risk as "the hazard or chance of loss".

While probabilities can often be extremely remote, it is now universally accepted that in almost all cases, zero risk is an unattainable goal. Although based on good intentions, the zero risk approach to risk management is fraught with difficulties. While risk can be reduced, it is impossible to reduce it to "zero" (MAF, 1996).

Kaplan and Garrick (1981) provide an excellent introduction to risk, both as a personal thing and a mathematical entity. They note that risk is "relative to the observer" and has to do with both uncertainty and damage. They provide a first-level mathematical definition of risk as a "set of triplets: $R = \{(s_i, p_i, x_i)\} \dots$ where s_i is a scenario identification or description, p_i is the probability of that scenario, and x_i is the consequence or evaluation

measure of that scenario, i.e. the measure of damage." They further note that risk is multidimensional, i.e. there are many possible damage measures.

Dean (1999) defined risk as "the perceived extent of possible loss". Risk is individual to a person or organisation because what one perceives as a major risk may be perceived by another as minor. Perception is very much a factor. To some, risk is defined as the chance of loss, but in reality, it is more. Risk also concerns how much could be lost. Probabilistic risk analysis can define risk as expected loss or even as a probability curve. This involves not just the chance of loss but, more specifically, the extent.

Patrick (2003) classifies individuals in the following risk-taking categories:

- Avoiders
- Daredevils
- Adventurers
- Calculators

"Avoiders" are the most cautious risk takers but do take some risks. They expect the worst to happen and will not take the slightest chance that they can avoid. They lose because they miss economic opportunities to profit. Farmers who are Avoiders may not be forced out of business, but they just manage to survive. Their farms usually disappear (being absorbed by a neighbouring farm) when they retire or die.

"Daredevils" are the opposite of the Avoiders and take many unnecessary chances. Daredevils close their eyes to risk, ignore facts, and go ahead. Daredevils commonly fall because they refuse to take precautions. Daredevils typically do not get involved in farming.

"Adventurers" are individuals who enjoy risks. To Adventurers, risks are challenging and exciting. Adventurers often look for the chance to take risks. Adventurers differ in their mental outlook. Some Adventurers enjoy the excitement of risk taking but keep the stakes to reasonable levels. Many farmers may be in this category with respect to their marketing plans. As long as financial survival is not at stake, they may enjoy the adventure of playing

the market. Many speculators are in this category. However, some Adventurers may get in over their heads. This may be from peer pressure or from a change in external conditions.

"Calculators" understand they must take some chances to get ahead but recognise that there are degrees of risk in every situation. Before making a decision or taking action, they gather information and analyse the odds. Calculators try to be realistic, recognise the risks and try to reduce risks to acceptable levels. Most farmers are Calculators. If they were not, adverse conditions of recent years would have eliminated them or changed their behaviour.

Risk tolerance is reflected in individual choices in risk management. Understanding choices and considering them all may cause an individual to change his/her management style to more closely reflect risk tolerance. The USDA-RMA (2000b) believes that risks can be managed in one of five ways, or in certain combinations of the five:

- **Retain** - With no protection from downside risk, as in holding an unpriced commodity.
- **Shift** - A contractual arrangement where someone else takes on some of the chance of a negative occurrence in exchange for a premium. The more risk you shift, the higher the cost.
- **Reduce** - Keeping fences in good repair to keep livestock off the highway and a marketing plan that locks in some level of guaranteed return are examples of reducing risk.
- **Self-insure** - Emergency reserves funded from previous years' profits.
- **Avoid** - Not selecting a particular enterprise...not pushing either end of planting windows...not increasing your debt-to-asset ratio beyond your comfort level.

Any risk must be evaluated for its frequency of occurrence and its possible negative consequences. As a general rule, formal insurance strategies are available for risks with low occurrences but with severe negative consequences. Examples include disability insurance, health insurance, hail damage, and life insurance.

2.2.3 Risk factors in agriculture

Dennis (2001) states that risk management involves choosing among alternatives that have uncertain outcomes and varying levels of expected returns. Various strategies and tools exist to assist producers to manage market risk. These all involve a reduction in average income or revenue over time in order to "purchase" a lower probability of an extremely low income or revenue in exceptional years.

Green, Gloy, and Nelson and White (2002) provide a useful basic profit equation in identifying risk:

Profits = Total revenue – Total Cost = (Amount produced x % Marketed x Product price) – (Input price x Inputs purchased)

Risk factors:

Amount produced = Production risks

% Marketed and product price = Marketing risks

Input price = Input price risks

Over time, the sources of risk have been categorised in a number of ways. However, according to a number of authors (e.g. Outlaw, 2003; USDA-RMA, 2000; USDA-ERS, 2001), the following categories for different sources of risk in agriculture can be used:

- **Production risk** derives from the uncertain natural growth processes of crops and livestock. Weather, disease, pests, and other factors affect both the quantity and quality of commodities produced. Also, the risk is associated with the **type of commodities** produced and farm size. What this means is that there is risk associated with producing a single commodity. Using an analogy it is much like placing all of your eggs in one basket. One method of dealing with this source of risk is by diversifying the operations which provides additional managerial flexibility. Also, **the size of the farm** operation can be a source of risk by limiting the feasible range of technology that could be adopted given financial and managerial constraints.

- **Price or market risk** refers to uncertainty about the prices producers will receive for commodities or the prices they must pay for inputs. The nature of price risk varies significantly from commodity to commodity.
- **Financial risk** involves the financing of the farm business, the assets it controls and its debt obligations. Financial risk is closely linked with cash flow risk. For the person who is highly leveraged and needs to borrow most, or all of their operating cash requirements, the two risks are comparable. Financial risk is the ability of the enterprise to generate sufficient profits at the end of the production cycle to cover both fixed and variable costs as well as living expenses and machinery replacement. Cash flow risk is more a matter of timing, whereas financial risk is a question of profitability. This type of risk has become more important with larger capital investments and the increased use of borrowed capital. The erratic nature of cash flows in farming operations, the variability of interest rates and periods of declining land values are three factors that have influenced financial risk. Rising interest rates, the prospect of loans being called by lenders, and restricted credit availability are also aspects of financial risk.
- **Institutional risk** results from uncertainties surrounding government actions. The government is also seen as a major source of risk in agriculture. Tax laws, labour legislation, regulations for chemical use, rules for animal waste disposal, and the level of price or income support payments are examples of government decisions that can have a major impact on the farm business.
- **Human or personal risk** refers to factors such as problems with human health or personal relationships that can affect the farm business. Rosenberg (2001) pointed out that work performed by people is critical to all agricultural production. The direct labour cost-per-ha in farm budgeting obscures the significance of countless decisions that farmers make in managing labour. Human resources risks involves the chance that essential tasks will not get done, the chance that the work will be done but poorly or not on time, thus raising unit labour costs or lowering product value, the risk of incurring high indirect labour expenses often associated with turnover, absenteeism, or mandatory benefits. Instability of the workforce increases total costs of finding, hiring, orienting, and supervising personnel. Workers have many legal grounds on which to base charges of employer wrongdoing, and defending against them is expensive, win or lose.

Outlaw (2003) states that the reward for managing risk is the enhanced probability of farm survival and the potential to realise a higher return on investment. It is important to remember that risk cannot be eliminated from farming. While risk complicates the decision-making process for the farmer, there are tools for reducing or managing the level of risk.

Miller, Boehlje and Dubbins (1998) suggest a very useful categorisation of risk. They identified two main sources of risks:

- Tactical or operational risks
- Strategic risks

Tactical or operational risks: Operational risks mainly consist of business risk and financial risk. Business risk is commonly defined as the inherent uncertainty of the financial performance of a farm independent of the way it is financed. Business risk includes those sources that would be present with 100 percent equity financing. The major sources in any production period are price, cost, productivity, and production uncertainty; a number of factors may affect this variability over time. Financial risk is defined as the added variability of net returns to owner's equity that results from the financial obligation associated with debt financing. These risks are basically those discussed in the previous paragraphs.

Strategic risks: Most of the risk analysis in the agricultural sector has focused on the tactical or operational risks associated with production and prices or debt use. Recently, however, strategic risk has been receiving more emphasis. The focus of strategic risk is the sensitivity of the strategic direction and the ultimate value of a company to uncertainties in the business climate. These uncertainties include: 1) political, government policy, macro-economic, social, and natural contingencies, and 2) industry dynamics involving input markets, product markets, competitive and technological uncertainties. Some examples of strategic risks are summarised in the next figure. Tactical or operational risk is easier to manage than strategic risk, in part because of the information available to measure these risks, and in part because of the availability of accepted tools and techniques to transfer risk to others, such as insurance and futures markets (Miller, Boehlje and Dubbins, 1998).

Most strategic risks cannot be managed or transferred through conventional futures or insurance instruments or markets. Strategic risk is multidimensional, so managers cannot assume simple one-to-one mapping between exposures and hedging or insurance instruments. Creative strategies must be developed to manage strategic risk exposure; approaches include flexibility, adaptability, and diversification. In essence, managing strategic risk requires the development of backup or contingency plans. One of the better planning techniques is "what- if" analysis (i.e. what is my best response if a particular event occurs?). One of the strategic risks farmers are facing because of agricultural industrialisation is contractual or relationship risk. The expanding use of contractual agreements and other forms of negotiation-based linkages between the various stages within the agricultural production and distribution system, combined with the decline in impersonal, market-based transactions, results in price risk being replaced by relationship or contractual risk for many businesses. A grower may have a contract that guarantees a price for the crop, but what if the processor goes bankrupt? What if the processor finds suppliers in other areas who can satisfy their needs at a lower price? What if I lose my contract? Another strategic risk that seems to have increased in recent years is regulatory risk. Farm firms are facing increasing regulation in all aspects of their business transactions. Added to the traditional areas of regulation concerned with transportation, taxation, and labor use are two rapidly growing regulatory areas: food safety and the environment. Strategic risk analyses would ask, for example, what if the regulations change and my waste handling and disposal system no longer complies with the new regulation? Developing a contingency plan for these risks will be increasingly important for the long-run survivability of many farm businesses (Miller, Boehlje and Dubbins, 1998).

2.2.4 Risk-managing strategies

Dennis (2001) points out that risk-managing strategies might be considered to fall into two categories. One set of strategies, "business diversification", has long been employed by producers. In this case, foregoing economies of scale associated with specialisation is the price paid for a more certain income stream. Diversification into non-agricultural on-farm activities such as tourism, or off-farm income sources such as paid employment, is also popular. However, there is a further category of risk management instruments: measures which involve sharing risks with others. These tools are provided mainly through private

financial markets. They include forward contracts, futures and options contracts, crop insurance, and revenue and income stabilisation schemes.

2.2.4.1 Managing production risk

Receipts are the gross returns (price times yield) from production. For perennial horticultural crops (tree fruits and nuts, small fruits), receipts may be zero for several years, while planting is in the pre-productive stage. Both yield and price variability will affect receipts. The producer's ability to deal with both types of variability will impact the enterprise's profitability. Large yields are not the important yardstick; the important thing for profitability is having sufficient high quality product sales.

Every year, horticultural producers face yield risk in the form of adverse weather and pest damage. In a perennial crop, yield risk can take the form of year-to-year variability, or more serious damage, which reduces the long-term production potential of the planting. Although yield risk is important, it usually has readily identifiable causes and remedies.

Producers can reduce the effects of yield risk through irrigation (see Cuykendall and White, 1998, Cuykendall, et al. 1999), pest management practices, and site and cultivar selection. In addition, multi-peril crop insurance is available for many fruit and vegetable crops grown. While it is important to minimise the effect of yield risk and its impact on profitability, producers are usually much more equipped to deal with this type of risk than those associated with marketing.

2.2.4.2 Marketing risk

The nature of agricultural market risk has changed over the past few years. While commodity prices have always been volatile and there have always been economic incentives for learning to manage risk, many changes in the agricultural marketplace have made these incentives even more compelling. Governments often reduced the impact of commodity price volatility with programs designed to stabilise price, yield, or revenue. Some governments have even managed grain stocks to maintain price levels. Many of these programs have been wound down or modified because of two main factors: reduced overall levels of support under most stabilisation programs and increased agricultural trade

liberalisation. The bottom line is that price variability occurs in the market, and producers must now become more self-reliant in risk management to remain competitive (CFBMC, 2002).

Marketing plays a crucial role in crop production and should be planned well in advance of harvest. In fact, farmers should be thinking of marketing prior to planting. This is particularly important for perennial crops where decisions about which varieties to plant are made several years prior to the first crop.

According to Lutgen (1996), market risk in agriculture is caused by two conditions. First, there is the time lag between the start and completion of the production cycle. During the production cycle, supply and demand conditions are constantly changing, causing prices to be in a continual state of change. Situations might also develop (transportation problems, labour strikes, elevator closures, etc.) which could eliminate market outlets. If commodities are stored, the risk continues until the date of sale. The nature of the market itself creates the second condition of market risk. Because of the large number of agriculturists producing similar products, they cannot have much individual influence on the market price. The individual producer has very little market power.

Oultaw (2003) pointed out that price risk in the major commodities is commonly managed with the aid of futures and options markets as long as they are used for managing price risk rather than speculation. Forward pricing through futures and cash contracts are methods of reducing market risk by entering into a commitment prior to the physical delivery of the commodity to market.

Cuykendall and White (1998) believe that knowledge of *what* the market requires (in terms of form and quality) and *when* to market is the key to success. Why do "good" producers go out of business, while others in less ideal production circumstances thrive? Often the difference is marketing acumen. Developing a marketing strategy requires careful evaluation of the supply and demand for your product and investigation of market alternatives. The successful marketer must strive to produce products which satisfy basic customer needs and wants rather than simply selling the products he/she produces. Strategic marketing planning requires specification of target markets, or the individuals or businesses identified as the most desirable customers. The selection of target markets in

turn drives decisions about products (including varieties and packaging), promotion, pricing, location, and distribution strategies.

Price and quality are synonymous in crop production and even more so for the production of export horticultural crops. Unfortunately, it is not always easy to know what is meant by "high quality", and quality judgment often varies from year to year. Grade standards do not exist for all crops, and those that have them are often not very specific. Often there is only one recognised quality grade, which means produce of "good average quality". Buyers, however, often have additional criteria by which they judge produce quality including flavour, ripeness, aroma, cleanliness, and the absence of pest damage and foreign material (Cuykendall and White, 1998).

Beurskens (1994) believes that conservative market risk management programs are founded in several fundamental concepts:

- The marketplace is always right (our job is to understand why it's right, rather than why it's wrong).
- There is no place for price speculation in agribusiness.
- The group is always smarter than the individual.
- The more we share, the bigger the pie gets.
- The better our customer understands our business, the better customers they become. (the opposite of "keep the customer dumb")
- Knowledge is wasted unless it is used.

Managing market risk must be a key element in marketing and is increasing in importance as we move to a global economy and reduced government support programs. Market risk management must be based upon strong business principles and philosophies which build a foundation to support the discipline necessary to adhere to managing rather than creating risk. Market risk management starts with strong discipline and attempts to optimise rather than maximise returns.

2.2.4.3 Cost of production and cash flow risk

The problem with price or gross margin per unit is that the numbers involved are often relatively small and therefore does not address the problem of managing cash flow. All enterprises have cash inflow from operations and cash outflow for production costs. The difference between inflow and outflow is known as net cash flow. At its simplest level, cash flow risk is the risk of not meeting financial obligations as they become due. The business may be profitable over the production period, but the producer may not have the cash available when accounts payable or loan payments become due (CFBMC, 2002).

Horticultural crop production is not for the financially faint of heart. For certain vegetable crops, pre-harvest costs may amount to several thousand Rand per ha. For perennial crops, substantial initial investments are required, and many years may go by before the crop breaks even. For most perennial crops, the pre-productive costs for land preparation and establishment are often many times the cost of annual horticultural crops. This is the period when growers are most exposed to financial risk. Growers must realistically assess their ability to absorb losses during this period and not rely on single enterprises for current and future income.

Naturally, growers complain when the costs of fertilizers and pesticides increase, and they are often tempted to reduce these costs by cutting applications. In the whole scheme of things, however, these costs are minor. It makes little economic sense to jeopardise profitability by trying to save a few Rand here and there. Once the crop is established, by far the major cost in horticultural crops is harvesting and marketing the crop. Labour management and costs are the primary concern given the new labour laws in South Africa. Investing in production practices which reduce yield and quality variability is rarely a waste of money.

Good labour management is a key to horticultural crop profitability. Because of the perishable nature of these products, hand picking is often the only alternative. Understanding the labour market and planning for adequate and experienced labour is critical to having a high-quality, ready-to-market crop. Growers must understand the laws applicable to agricultural labour use. These laws include those relating to migrant and seasonal workers, child labour, wages and hours, unemployment compensation, family and

medical leave, worker's compensation, worker protection (pesticide exposure, safe workplace, field sanitation), and migrant housing. Communicating your firm's personnel policies is a key element in effective human resource management.

2.2.4.4 Crop budgeting

Understanding the magnitude of the financial risks and the nature of cash flows in crop production requires the preparation of enterprise budgets. Enterprise budgets represent estimates of the receipts (income), costs, and profitability associated with the production of agricultural products. Budgets are used to (USDA-RMA, 2000c):

- enumerate the receipts (income) received for an enterprise,
- enumerate the inputs and production practices required by an enterprise,
- evaluate the efficiency of farm enterprises,
- estimate benefits and costs for major changes in production practices,
- provide the basis for a total farm plan,
- estimate break-even price and/or yield for market planning purposes
- support applications for credit.

Enterprise budgets should contain receipts (income) for every product and by-product of the enterprise. Prices should reflect the markets faced and the productivity of the enterprise, given the specific resource situation (land, labour, equipment, etc.).

Total costs are the sum of variable and fixed costs. Although a grower's aim is to earn a profit above total costs, this is not always possible. Because of yield or marketing conditions beyond the grower's control, income received is sometimes less than the total costs of production. Should a grower continue to produce under these circumstances? The answer may be yes if: (1) returns are above variable costs, and (2) it is a short-term condition. If fixed costs are not covered in the long run, however, reinvestment in capital items (like tractors, implements, buildings, and equipment) cannot be made, resulting in depletion of existing capital stock (USDA-RMA, 2000c).

2.2.4.5 Managing strategic risk

According to Miller, Boehlje and Dubbins (1998), strategic risks arise on the farm when: 1) strategy is unclear, 2) strategy is clear but implementation is ineffective, and 3) strategy is clear and effectively implemented but no longer relevant. Any one of these conditions can lead to undesirable consequences for the farm business. Strategy that is clear and effectively implemented but no longer relevant can occur when a manager:

- loses touch with the forces outside the farm gate that shape the industry and the business environment
- misreads the signals coming from outside the farm gate
- is not willing or able to change in response to industry dynamics.

The agriculture of the future will be an industry in which the pace and magnitude of change continues to escalate. The producer who watches the changes occur will struggle. The producers who slow down to think about the external forces driving their particular agricultural sector, spend time analysing the strengths and weaknesses of their business, develop strategic alternatives for their business, and consider what-if scenarios will be in a good position to take advantage of the opportunities in agriculture. However, they will need to invest time, energy, and resources in thinking creatively, honestly, and strategically. In addition, they will need to draw upon high-quality outside resources. Successful managers will be able to identify people who can form a team to evaluate opportunities and strategies for individual farm businesses. Agricultural professionals who can help producers develop strategic management approaches that take advantage of opportunities in the rapidly changing agricultural business environment will be invaluable. The customers of most agricultural professionals are facing a radically different agriculture from that which existed several years ago. How agriculturalists adapt to provide radically different services will also determine how well they survive (Miller, Boehlje and Dubbins; 1998).

It should therefore be clear that there is a need to either develop new analytical tools or to implement existing analytical tools to enable agricultural managers to make better risk management decisions. In this regard, models such as whole farm typical farm models and

Computable General Equilibrium models (CGE) can make extremely useful contributions to provide answers to "what if" questions.

Finally, it should be obvious that government and industry bodies also play a role in reducing agricultural risk, since not only producers but also farm workers, rural communities, and regional economies are threatened by risk (because of the forward and backward linkages between agriculture and the rest of the economy). In this regard, investment in information systems and training farmers in strategic planning and risk management can play an important role.

2.2.5 Risk and competitiveness

What does risk have to do with competitiveness? According to Dean (1999), each decision may result in loss. Each decision to introduce a new product into the marketplace can result in varying degrees of loss or gain. To be entrepreneurial is to accept risk, that is, the possibility of loss. A good entrepreneur's forte, however, is to make decisions which maximise possible gain and minimise possible loss. This has to do with risk management. Risk analysis has to do with the analytical process used to estimate the extent of possible loss. So does risk assessment which provides a rationale for the decision maker.

To become and remain competitive requires the use of risk methodology as a guide for decisions which could ultimately mean survival or demise. Decomposing the risk of designing for competitive advantage into the primary components of value, which are cost, quality, and timeliness, risk can be estimated by the extent to which final cost is expected to exceed planned cost, by the extent to which expected quality will fall short of planned quality, and by the extent to which expected market introduction will fall short of the planned introduction date.

According to Dean (1999), risk as estimated here can be both positive and negative, is a dynamic measure over the life of a project, and is multidimensional. It can be turned into a one-dimensional measure by weighting the cost, quality, and timeliness risks and summing. Risk is a cumulative effect of those things which went better than planned and those things which went worse than planned. The expected value minus the planned value is a projection of risk onto the basic dimensions of competitive advantage.

2.3 AGRICULTURAL RISK MANAGEMENT IN SOUTH AFRICA

According to Crane (2001), South African agriculture is experiencing an important transition. This transition is being driven by the desire of the South African government to be fully integrated into global markets and to ensure a healthy domestic agricultural sector. South African leaders seek to actively include their entire farming population in the world economy through membership in the World Trade Organisation (WTO). To achieve this, domestic farm programs such as risk protection and disaster relief need to comply with WTO guidelines.

As is the case in other countries in similar latitudes, South Africa is periodically afflicted by drastic and prolonged droughts, which often end in severe floods. Drought is also a major contributing factor to the danger of fire damaging crop production and destroying farm improvements such as fences, irrigation equipment, buildings, stored commodities, and feed for livestock.

To accomplish the goal of providing effective and affordable protection to farmers against the potential financially devastating impact of adverse weather events and stay within WTO parameters, the government is moving forward with the development of an agricultural risk management strategy that includes crop insurance as a major tool in managing crop production risk.

Insurance is viewed as an important risk management tool because of the benefits to both individual producers and the general economy as a whole. By using insurance to protect against uncertain losses, the private sector becomes more involved in risk sharing and the burden on the public sector of shouldering the risk of uncertain events is reduced.

In general, crop insurance is an effective tool for managing the risks inherent in the production of agricultural commodities. Effectively managing these production risks stabilises farm operations and provides greater access to capital and increases financial stability. As individual producers become more economically stable, rural communities and associated agricultural businesses become stronger, leading to increased national economic health.

Perhaps the greatest benefit of a planned, insurance-based risk management program for individual farmers is the potential for improving access to credit, particularly for crops with high initial investments. This is also particularly true for the South African government as it restructures its agricultural subsidy system to conform to WTO requirements and coincide with other government priorities. As more and more production risk is transferred to individual farmers, there is also a cumulative affect, which serves to transfer additional risk to financial institutions that invest bank capital into the agricultural sector.

Currently, in South Africa, crop insurance, which is primarily limited to hail insurance and associated property and casualty risk, is available on major agricultural crops. However, universal availability of crop insurance is non-existent, and crop coverage is limited to selected crops and regions where risk can only be effectively managed through the investment of private capital. Needless to say, this leaves a large sector of agricultural risk under-insured or uninsured under the present system.

2.4 RISK MANAGEMENT AND WATER ALLOCATION/MISALLOCATION

According to Bate and Tren (2002), the variations in water rights under current arrangements may increase under the New Water Act (government Gazette, 1998), due to increased bureaucratic control over water allocation and the assessment of applications for renewal of individual water rights. This will create considerable uncertainty over the security of water entitlement and may preclude any trading of water licences. The reliability of each use allocation will be highly variable since they will not be held in perpetuity and will not give a guaranteed assurance of supply or quality. In addition, any water use allocation will be temporally controlled, limited, or prohibited.

Therefore, farmers may lack the incentive to exchange water licences and may not invest in water-saving technology and other production inputs if there is uncertainty about ownership. Investments in the establishment of horticultural crops such as deciduous fruits are substantial (up to R250 000 for table grapes). If licences are insecure, the risks associated with such investments will be substantially increased. Furthermore, farmers' creditworthiness will diminish and make investment even harder. Incentives will be towards using less expensive technologies and growing short-term crops (Armitage and Nieuwoudt, 1999).

However, Gillitt and Nieuwoudt (2004) have found that a water market in the Lower Orange River has facilitated a transfer of water use from relatively lower value crops to relatively higher value crops and also promoted the use of more advanced irrigation technology. Their results confirm that farmers who are more risk-averse are likely to invest less in the future as can be expected from theory. Policies that increase risk in agriculture will have a significant negative effect on future investment in irrigation.

Gillitt and Nieuwoudt (2004) have also found that that irrigation farmers in the Lower Orange River area are highly risk-averse (down-side). They showed that farmers who feel that water licenses are not secure expect to invest less in the future. The latter effect is thus amplified as farmers appear to be highly risk-averse. This has important policy implications, and measures should be taken to improve the perceived security of water licenses. This could be achieved by keeping farmers more informed about the practical implications of the New Water Act (NWA) (Act 36 of 1998) and, specifically, water licenses.

According to Rosegrant (1995), the foremost challenge related to water scarcity in developing countries is the need to increase efficiency in general inefficient water use in agriculture, urban areas, and industry. Irrigated areas account for about 30 percent of agricultural production in South Africa, so growth in irrigated output per unit of land and water is essential. Improved efficiency in agricultural water use is required both to maintain productivity growth and to allow reallocation of water from agricultural to urban and industrial use. Maximum productive efficiency can be said to exist when the factors of production are used in optimal proportions with optimal technology and are applied to those uses where total value product is maximised. The economic welfare of the owners of the factors of production is a function of the productive efficiency of the factors; in turn, the economic welfare of the community is a function of the welfare of the factor owners. Economic welfare can therefore only be maximised if the owners of the production factors take market risks into account when making their production decisions. The welfare generation capacity of irrigation schemes are therefore directly derived from the optimal allocation of water use, which in turn derive directly from good market information.

Kulshreshtha and Tewari (1991) have found that only under high product/price scenarios is there a long-run return to water, that is, greater than zero. For low-price scenarios, they found negative returns to water, indicating that costs of fixed factors of production were not fully recovered. This stresses the importance of risk management to minimise low income in poorer years.

The new water law in South Africa emphasises that water must be allocated to its highest use value. For irrigation farmers, this means that they must restructure their farming operations in order to produce high value crops. However, high-value long-term crops often are also inherently riskier to produce. This is because of the high capital outlay and the time factor. It often takes between four and seven years for these crops to come into production. There is also a high market risk because of changes in consumer preferences and world economic growth patterns. The author believes that if it were possible to provide farmers with long-term crop market analysis, their perceptual risk would decrease, probably inducing structural changes to less risky high-value crops. This would lead to the more efficient utilisation of expensive irrigation water, so increasing community welfare.

2.5 RISK MODELLING METHODOLOGY

"We need the approach that is the antithesis of analysis, namely, synthesis. We are steeped in the analytical tradition. Essentially: take a living thing apart to discover what life is; you will not find a component called life-and behold the life thing is dead. If our only scientific tool is the analytic reduction of a system to its component parts, so that the very nature of the system itself as a viable entity is lost, so that its synergies are denatured, so that it is nothing but a bag of bits, then we do not deserve the name of scientist in the world of complex systems and complicated syntax."

- Beer¹

Using mathematical models to study the complex risk behaviour of the farming system is extremely useful. Meuwissen and Van Asseldonk and Huirne (2002) believe that whole-farm risk management approaches, i.e. approaches in which multiple risks and farm activities are considered simultaneously, seem more efficient than "single risk and

¹As referenced by Taylor (1990:52)

commodity strategies". Some kind of whole-farm planning modelling methodology is therefore appropriate to analyse risk behaviour. The following sections will deal with measuring variability, formulating expectations, and whole farm planning methodology and will conclude with a section on the inclusion of risk in these models.

2.5.1 Measuring variability

Patrick (2003) pointed out that outcome variability is generally associated with risk, and typically riskier situations have greater outcome variability. The average outcome is the most frequent or most likely if outcomes are normally distributed, but the average does not provide information about variability. The range--the highest and lowest values--combined with the average does provide some information about variability. However, it is difficult to make comparisons of variability between crops or prices.

The coefficient of variation is a statistical measure of variability based on all of the values for yields or prices, not just the high, low, and average. The coefficient of variation is based on the standard deviation, which is computed as

$$\sqrt{\frac{\sum (x - \bar{x})^2}{N}}$$

where x is the actual values, $\bar{x}$ is the average or mean value, and N is the number of observations. The coefficient of variation is simply the standard deviation divided by the average and multiplied by 100 to express it as a percentage. The coefficients of variation can be used to make comparisons of variability among crop yields or prices. The lower the coefficient of variation, the lower the variability.

2.5.2 Formulating Expectations

Expectations about the future are factors in decision-making. For instance, expected prices for wheat and maize have some impact on farmers' planting decisions. Investment decisions implicitly or explicitly involve expectations about future prices, costs, yields, and a number of other factors. No doubt the past has a significant impact on most expectations for the future. However, exactly how individuals form their expectations is unknown.

Furthermore, all individuals probably use somewhat different procedures. Extreme events are sometimes remembered and given excessive weight in expectations.

Hardaker et al. (1997) pointed out that basing future expectations on the past implicitly assumes that the factors responsible for past events will continue in the future. Long-run expectations based on recent changes can be especially misleading. Formulating expectations involves judgement. Short-run expectations are generally more precise than long-run expectations because more information is available. Expectations may be changed and revised as additional information becomes available.

Dean (1999) believes that formulating expectations is an important phase of the decision-making process. Most farmers rely heavily on personal experience but supplement it with other information. Futures prices and outlook information as well as an historical view can be helpful in formulating price expectations. Technical materials and discussion with other farmers can play a major role in formulating other expectations. Expert opinions can also be important. However, expectations are personal, and each individual has his or her own.

Chapter 5 and Appendix A of this report provides information to assist decision makers to formulate expectations and to identify risk factors.

2.5.3 General whole farm modelling methodology

The objective with the following sections is not to give a detailed discussion of the mathematical methodologies that are being used in whole farm planning models but rather to give a simplistic conceptual overview of the whole farm planning concept.

2.5.4 Background

The rapid development of computer science and technology makes it possible to develop large scale planning models on a micro-computer. *P.C. Magazine*² describes this progress in technology as follows:

² According to Kleyn (1995:592)

" If jet craft technology progressed as fast as computer technology we would be able to buy a 747 aeroplane, smaller than a peanut, costing less than a rand and capable of taking you on a trip to the moon on one litre of fuel."

Until as recently as the early 1990s, it was not possible to develop large dynamic linear programming models (DLP). This technique proved to be a useful holistic farm planning technique. Unfortunately, it required a very large computer capacity, so it was not very popular with agricultural economists. Those who did apply this method were obliged to use a mainframe computer, which was a frustrating and cumbersome procedure.

Louw (1996) developed the first microcomputer whole-farm linear planning model in South Africa (called OPTIMA). The objective with OPTIMA was to establish a holistic, user-friendly farm-planning model to contribute to improved farm planning, extension, and the formulation of agricultural policy. During 2000, the basic model was converted from spreadsheet to algebraic formulation. This increased the capacity and flexibility of the model substantially. The purpose of this section is not to give a comprehensive discussion of the mathematics of linear programming. However, it is important for the reader to have a basic understanding of the methodology that will be employed in this research in order to understand the results of these models.

The next section will deal with the principles of long-term planning methodologies. This is followed by a short description of the linear programming technique and concluded with a section on the relevance of the technique to this research problem.

2.5.5 Principles of long-term planning methodologies

The economic assessment of irrigation farms should be done by using the systems approach to problem solving. This means following a holistic approach. Although the different enterprises are analysed individually, it must always be done within the context of the whole farm. The agricultural economist therefore has to consider both the present and the future: the short and the long run. He should aid in rendering the present system effective, as well as in improving it for a better future. He has to identify the limited resources and find the ways to optimise their yield. The main objective of planning an economic farm/scheme/region is to establish the best choice between alternative uses of

limited resources to maximise return on capital investment. Economic planning has five objectives (Backeberg, 1988):

- Establish which plan reflects the best use of land, water, capital, and human resources.
- Establish the financial implications of the plan based on expected future cash flow.
- Establish the capital required and the time when needed from own and borrowed sources.
- Analyse the complexity of marketing, financial, and production management and the demands it will put on management capability.
- Analyse the financial incentive to put the plan into operation.

This information makes it possible to put forward the implications of alternative choices. The aim is to increase the existing return on capital. The plan put forward is not a guarantee for success but undoubtedly aids better decision-making. For economic planning purposes, it is necessary to compile a long-term whole farm budget. This plan is a written plan of resource use and must give an indication of the physical inputs and outputs as well as financial expenses and income for the farm as a whole. Several different methods can be used for planning, but every method must satisfy the following requirements:

- The method must be realistic and practical.
- It must be in line with the real objectives of the entrepreneur.
- The method must not be unnecessarily expensive or time-consuming.
- The result must be easy to understand and communicate.

These requirements must be met because the objective of planning can only be reached if the plan can be implemented successfully (Louw, 1996).

The human element is the starting point: what objectives do farmers have, can the farm comply with them, and what are the financial consequences? Technology determines what is possible, economic analysis shows what is feasible, and financial analysis shows how much money is needed and when. Analysis and planning therefore evaluate current performance as well as potential changes to this performance (Louw, 1996). This is

precisely the objective of this modelling exercise: to evaluate the current irrigation farming structure and compare it with a farming structure aimed at risk minimisation. The basic concepts discussed here are the foundation for understanding the modelling framework discussed in the following section.

2.5.6 Dynamic linear programming

The reason for developing whole farm planning models with this technique was to enable agricultural economists to provide policy makers as well as farmers with an holistic (whole farm) answer to practical farm problems. It often happened in the past that soil scientists, animal scientists, economists and other experts gave the farmer or policy maker their own isolated point of view on development or extension aspects without telling them the whole truth.

According to Dalton (1982), linear programming (LP) is a well-understood method that has been applied to many complicated problems. Variances of the method enable researchers to handle risk, the effect of time, indivisibility, and inter-relationships between activities and resources. A common characteristic is the allocation of scarce resources to activities to maximise an objective. Conceptually, there is no difference between planning a region or an individual farm. The practical application of LP depends on the feasibility of specifying the planning problem as a set of mathematical equations and solving them.

LP in its simplest form is normally static (only one time period) and is not suitable for simulating the complexity of biological processes typical of agriculture. The farm system is a biological-economic system and therefore dynamic. A variant of the LP method is dynamic linear programming. Various authors (e.g. Backeberg, 1984; Minnaar, 1990; De Jager, 1991; Nowers, 1991; Symington, 1993; Louw, 1996) have found that the DLP method is practical in simulating the farm system.

The time-dependent processes of biological systems such as the farming system necessitate a dynamic approach to modelling. Biological processes change over time, making it impossible to accurately describe these systems without reference to the time dimension. According to Rae (1977), the only difference between static and dynamic LP is that all

resources, activities and input-output coefficients in DLP refer to a specific time period within the planning horizon.

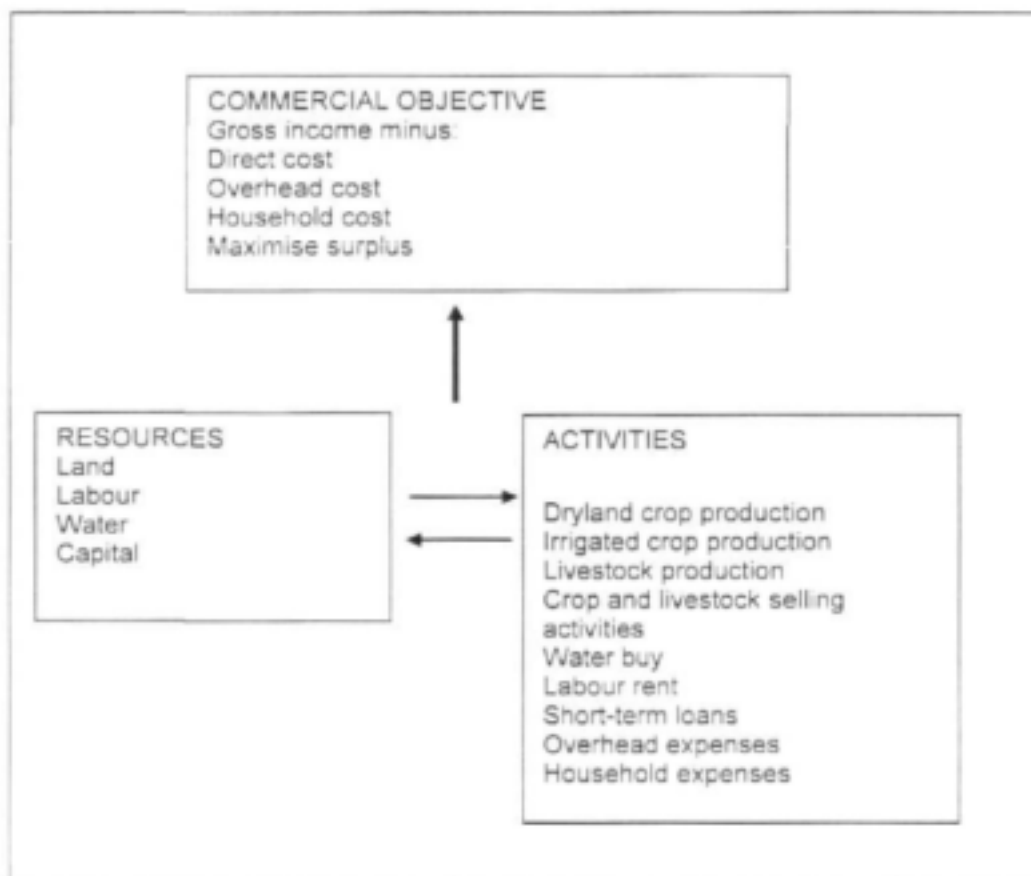


Figure 2.1: Conceptual framework for representative farm models

2.5.7 Essential parts of a whole farm planning model

The essential parts of a whole farm planning model consist of:

- An objective function
- Resources restrictions
- Activities

2.5.7.1 The objective function

In most cases, farmers' principal objective is to make a decent living from farming activities. The approach would be to specify the farmer's basic or minimum consumption requirements and add these to the fixed cash costs of each period, so making financing of

these requirements compulsory. Any surplus cash could then be reinvested in the business or invested off-farm, and the compounded (future) value of surplus cash, plus terminal values, could be maximised at the end of the planning period.

2.5.7.2 Resource restrictions

The following resource restrictions are normally included in mathematical modelling:

- Land
- Labour
- Water
- System delivery capacities
- Capital
- Crop rotations

These resources are normally fixed. It is only possible to acquire more of them at a cost.

2.5.7.3 Farm activities

Farm activities represent the use of scarce resources. The DLP approach optimises the use of resources through activities that will maximise farmers' objective (in quantitative terms). The activities compete for the same resources to generate cash to pay for operating expenses, interest on loans, and household expenses. Any cash surpluses are available as reserves and to earn interest. These activities normally include:

- crop and livestock production,
- renting or buying inputs (such as water, labour etc.),
- investing reserve funds,
- repaying loans,
- paying overhead expenses,
- paying household expenses,
- paying tax, and
- providing for depreciation.

2.6 PROBLEMATIC WITH RISK MEASUREMENT

According to Hardaker (2000), even supposed experts use the term *risk* in several different ways. These differences cause considerable confusion, especially when systematic efforts are made to measure and evaluate risk. Among the many usages of the word, three common interpretations are:

- the chance of a bad outcome;
- the variability of outcomes, i.e. the converse of stability; and
- uncertainty of outcomes.

Although seemingly similar, these three definitions imply quite different ways of measuring risk. Hardaker (2000) is of the opinion that while the first two meanings are in common usage, clarity is best served by defining risk, at least for formal analysis, as the uncertainty of outcomes.

It has been shown by Hardaker (2000) that it is necessary to specify at least two parameters (probability and "what is a bad outcome?") to apply *the chance of a bad outcome* as a measure of risk. For the second interpretation, *variability of outcomes*, it is necessary to measure the variability by some statistic of dispersion of outcome distribution such as the variance (V) or standard deviation (SD) equal to the positive square root of variance. Thus people who think of risk as dispersion of outcomes commonly link V or SD with the mean or expected value. Finally, adopting the third definition of risk requires the entire distribution of outcomes to be specified. Complete specification requires the probability density function or the cumulative distribution function.

Hardaker (2000) believes that the weakness of the first two definitions of risk with their associated measures is that neither tells the whole story when a choice has to be made among risky alternatives. In regard to the first definition, it is clear from observing behaviour that not all risks with bad outcomes are rejected. Describing risk only in terms of probability in the lower tail of outcome distribution does not provide full information for proper risk assessment and so may be seriously misleading.

A similar argument shows the limitation of variance alone as a measure for risk evaluation. Hardaker (2000) explains this by considering two normal distributions of outcomes of net income with identical variances but different means. Everyone will prefer the outcome with the higher mean. Moreover, many would describe the distribution located further to the right as the less risky of the two since the chance of getting less than any specified level is lower for this distribution than for the one with the lower mean. On the other hand, using variance as the measure of risk suggests that the two distributions are equally risky. Clearly, such confusion can be avoided by interpreting measures of stability dispersion simply as what they are and not regarding them as stand-alone measures for risk. If risk is defined as variance but is always interpreted in conjunction with the mean, this definition might seem to be similar to defining risk as the distribution of outcomes. However, the inherent problem of defining risk as variance still remains. Therefore, it seems to be unwise and potentially confusing to describe every prospect with lower variance as less risky.

Hardaker (2000) goes on to argue that the third definition has no single statistic that can be used to measure risk, making it impossible to compare distributions in terms of riskiness. What this third view implies is that notions of "more" or "less" risk are unsatisfactory, and careful analysts will confine themselves to describing risky prospects as "preferred" versus "not preferred", or as "risk efficient" versus "not risk efficient".

Hardaker (2000) has pointed out that to evaluate or assess a risk, one must be able to consider the whole range of outcomes, good and bad, and their associated probabilities. There is a good reason that none of the statistical measures of a distribution can provide a full description of the entailed risk. Risk assessment requires both probabilities and preferences for outcomes. Chances of bad versus good outcomes can only be evaluated and compared in light of the decision makers' relative preferences for such outcomes. Risk preference is reflected in the decision makers' utility function for consequences. The shape of such a utility function specifies an individual's attitude to risk.

According to Hardaker (2000), several attempts have been made to estimate farmers' utility functions in order to put the Subjective Expected Utility (SEU) hypothesis to work in the analysis of risky prospects in agriculture. Usually, the results have been rather unconvincing. There is evidence that the functions obtained are vulnerable to interviewer bias and bias from the way questions are framed.

In the past, it has been commonly assumed that all farmers are indifferent to risk. In the absence of any other information at all, Hardaker (2000) argues that a sensible way might be to assume a relative risk aversion coefficient of 1.0. However, Anderson and Dillon (1992) proposed a rough and ready classification of degree of risk aversion, based on the magnitude of the relative risk aversion coefficient. Their classification is:

$r_r(W) = 0.5$: hardly risk-averse at all;

$r_r(W) = 1.0$: somewhat risk-averse (normal);

$r_r(W) = 2.0$: rather risk-averse;

$r_r(W) = 3.0$: very risk-averse;

$r_r(W) = 4.0$: extremely risk-averse;

where $r_r(W)$ is the Relative Risk Aversion Coefficient.

Hardaker (2000) believes that such approximations might be made for some target group of farmers leading to an estimate of the range of r_a (assumed risk aversions) that might be plausible. This range can be used in risk analysis. However, Hardaker (2000) pointed out that in assessing risky choices expressed in terms of losses and gain, it is incorrect to apply the same relative risk aversion coefficient as for wealth. At least two types of risky choices affecting farm income can be imagined. One is where next year's income (or some single future year's income) is uncertain. This type of uncertainty contrasts with longer term uncertainty, as when a farmer may be contemplating a major investment perhaps associated with a dramatic change in the farm system. Here the uncertainty is about the long-run level of income.

Also, it has been shown by Hardaker et al. (1997) that the cost of risk may be a small proportion of the expected value of some risky prospect that constitutes only a part of the risk faced by the farm household. Many such marginal risks in diversified agricultural systems may have near-zero values of proportional risk premiums (PRP) so that choices can be made on expected values alone. At least, this seems likely in such matters as choosing among alternative crop varieties for use on that part of the farm where alternatives may have broadly similar yield-stability characteristics but significantly different mean yields.

Hardaker (2000) believes that since the cost of risk may be relatively small in many practical choice situations, it can be argued that agricultural economists have paid too much attention to risk aversion, at least relative to efforts to get good specifications of the probability distributions of outcomes. If these distributions are mis-specified, the estimate of expected payoff (E) will be biased, which may matter more than the error in calculating the approximate risk premium (RP) due to using the wrong risk aversion coefficient. Moreover, the focus on risk aversion and the cost of risk may have been a source of confusion in that attention has been directed to reducing the cost of risk rather than on finding the most risk-efficient option (erroneously minimising RP rather than maximising expected payoff).

According to Hardaker (2000), risk aversion may lead farmers to use resources less intensively than would be the case if they were indifferent to risk. However, from a social welfare perspective, most risks faced by individual farmers or groups of farmers are very unimportant since national income from other sources will be large and the relevant correlation will be small because of the diversified nature of the rest of the economy. It therefore becomes a potentially legitimate role of public policy to consider the scope of reducing the cost of risk to farmers in order to reduce the social welfare loss from farm-level risk aversion.

Both the SEU hypothesis and common sense lead to the conclusion that the right probabilities to use for decision analysis are the decision makers' subjective probabilities. A subjective probability may be defined as an individual's degree of belief in a given proposition. According to Hardaker (2000), probabilities that have been derived based on thoughtful analysis of all relevant information can be described as "public" probabilities", in the sense that many people might be willing to accept them as reasonable. Such public probabilities are the ones that could sensibly be used in analysis of, say, the risk of technology adoption in a given farming system.

2.7 INCLUSION OF RISK IN MATHEMATICAL MODELS

Simplified programming and linear programming are usually based on expected (i.e. mean) rather than sure activity net returns or gross margins. Ideally, the plans they generate would suit risk-neutral farmers but not necessarily the risk-averse majority of farmers. According

to McConnell and Dillon (1997), a variety of approaches have been developed to overcome this deficiency. First was quadratic risk programming, a form of non-linear mathematical programming, based on the strong assumption that utility is maximised in terms of the mean and variance of the probability distribution of total net revenue. Such problems are now readily solved using software such as GAMS (Brooke, Kendrick and Meeraus, 1992), which incorporates the powerful non-linear programming package MINOS.

Earlier, lack of non-linear software led to the development of linear approximations to quadratic programming such as MOTAD, Target MOTAD and mean-Gini programming (Hardaker, Huirne and Anderson 1997). Today, with the general availability of such software as GAMS, these earlier approaches to risk programming have been superseded by non-linear mathematical programming models which (1) directly maximise expected utility given knowledge of the decision maker's utility function or (2) maximise expected utility for specified degrees of risk aversion (Patten, Hardaker and Pannell 1988; Hardaker, Huirne and Anderson 1997). The latter method, known as *utility-efficient programming*, is obviously more feasible than the former. Both, however, necessitate knowledge of the probability distributions of total net returns from alternative allocations of farm-system resources.

The following sections discuss some of these methods.

2.7.1 Mean-variance (EV) analysis

Risk analysis is conducted through mean-variance (EV) analysis, which evaluates decisions based on their expected outcomes E and variances V . EV analysis has been used heavily in literature using risk modelling. Boisvert and McCarl (1990) offer a review of this procedure and identify 39 articles that use this approach to analyse mainly production and financial risk, with some dealing with market risk. The procedure was founded on research conducted by Markowitz in 1952 analysing portfolio selection (Stull and Dillon and Shearer and Isaacs and Riggins, 2001).

The EV framework is a widely used procedure for analysing a mix of risky sets. It is strongly considered more a deductive or analytical than an empirical tool (Robison and Barry, 1987). It is founded on the notion that given any two distributions with equal means,

a risk-averse individual will prefer the distribution with the smallest variance. In **comparison** to expected utility (EU) analysis, Meyer (1987) finds that EV analysis is consistent with the EU framework if the cumulative density function (CDF) of the random variables differs only by location and scale. It is thus sufficient when using returns (gross or net) when they are ranked as linear functions of one another. This being said, the ability to use means and variances to make assessments lends itself to the simplicity and resulting widespread use of EV analysis (Hardaker, Huirne and Anderson, 1997). The procedure for incorporating risk aversion into this analysis relies upon the seminal work of McCarl and Bessler (1989).

The Pratt risk-aversion coefficient is calculated according to varying risk levels. The procedure used generates a risk-adjusted gross revenue that is equal to the mean of the gross revenues minus a normal Z value times a standard error (Dillon, 1992). The process basically adjusts gross revenue to varying risk levels, where a highly risk-averse scenario would result in a lower gross revenue level acceptable to the individual than compared to a lower risk-averse scenario. The Pratt risk-aversion coefficient becomes larger as risk aversion increases, thus penalising gross revenues more for a higher risk aversion level. The Pratt risk-aversion coefficient is simply calculated with the following formula:

$$F = 2Z S_y$$

where

F is the risk-aversion coefficient,

Z is the standardized normal Z value of the level of significance,

And S_y is the relevant standard deviation.

The risk-aversion coefficient will become larger as the risk aversion level rises, thus penalising gross revenues, which raises the likelihood of a cell being enrolled in a filter strip. Risk aversion levels are used to represent levels of aversion from risk neutrality to a high risk aversion level.

2.7.2 MOTAD and Target MOTAD

To include the risk factor, this variability must be measured in some way. The best known method of solving this problem is MOTAD (Hazell and Norton, 1986), which provides an estimate of variability using absolute deviations from the average, observed in a determined temporal horizon. The advantage of using MOTAD appears to be that it refers directly to the farmer's observations and can be used even with little data and asymmetric distributions. To implement this in modelling, risk is inserted as a possible objective in the model, where profit is maximised and risk is minimised, both with their respective weights in the objective function. In a farm situation, the model can be solved and a calculation of risk presented to a farmer who only maximises long-term profit.

According to Watts and Held and Helmers (1984), mean – variance – analysis (EV) and MOTAD (minimisation of total absolute deviation) have become common methods of incorporating risk into decision analysis. MOTAD was developed by Hazel as a linear alternative to Markowitz EV analysis. EV analysis has been widely criticised. Markowitz, according to Watts et al. (1984), had reservations about using variance (as opposed to semi-variance), since variance considers both very high and very low returns as undesirable.

Conversely, semi-variance focuses on low returns. In a MOTAD model, risk is measured as linear deviations from the mean. Risk is implicitly undesirable, hence minimised. The trade-off occurs between mean income (E) and deviations (A). The E-A frontier is developed by parametrically running the model with regard to mean income and minimising deviations from the mean income.

Table 2.1 represents the gross margin data for four crops over a six-year period. Watts et al. (1984) point out that since deviations are measured from mean income, total negative deviations must equal total positive deviations.

Therefore, though less intuitively appealing, the objective function (as indicated in Table 2.2) which minimises positive deviations will yield an identical optimum solution to the other two objective functions. Comparing risk based upon different risk reference points (as in the case with MOTAD, since the reference point is the mean) is undesirable, if not erroneous and misleading.

Table 2.1: Gross margin data required

	Crop activities			
	X ₁	X ₂	X ₃	X ₄
	Gross margins (Rand per ha)			
Year 1 Gross Margin	292	-128	420	579
Year 2 Gross Margin	179	560	187	639
Year 3 Gross Margin	114	648	366	379
Year 4 Gross Margin	247	544	249	924
Year 5 Gross Margin	426	182	322	5
Year 6 Gross Margin	259	850	159	569
Average	253	443	284	516

Table 2.2: Comparison of risk between two hypothetical farm plans

Farm plan	A			B	
Year	Income (Rand)	Deviation from mean (Rand)	Deviation from X ₃ mean (Rand)	Income (Rand)	Deviation from mean (Rand)
	X ₁			X ₃	
Year 1 Gross Margin	292	39	-8	420	136
Year 2 Gross Margin	179	-74	105	187	-97
Year 3 Gross Margin	114	-139	170	366	82
Year 4 Gross Margin	247	-6	37	249	-35
Year 5 Gross Margin	426	173	-142	322	38
Year 6 Gross Margin	259	6	25	159	-125
Expected income (mean)	253			284	
Σ Neg. Dev		219	150		257
Σ Pos. Dev		219	300		257

Assume farm plans A and B (Table 2.2) both lie on the E-A frontier derived by MOTAD. Farm plan B has a higher income and greater risk, as measured by deviations from the mean. Therefore, the E-A criteria would not provide a ranking of farm plans A and B. However, if a common risk reference point or TARGET is used to measure risk, a ranking may be obtained. Using a target of 284, plan A is less risky (in terms of negative deviations) than B. Use of a common target as a risk reference point will result in the ranking of such clearly dominant alternatives.

Table 2.3 represents a typical MOTAD formulation for a farm with 4 crop activities.

Table 2.3: MOTAD example

Motad	Crop activities (ha)					Negative deviation counters (Rand)						
Rows	X ₁	X ₂	X ₃	X ₄	Z ₁	Z ₂	Z ₃	Z ₄	Z ₅	Z ₆	RHS	
Objective function					1	1	1	1	1	1	Minimise	
Expected total gross margin (Rand)	253	443	284	516							= λ	
Land (ha)	1	1	1	1							≤ 200	
Labour (hours)	25	36	27	87							≤ 10000	
Rotational requirements (ha)	-1	1	-1	1							≤ 0	
Risk rows (Rand)												
Year 1 Gross Margin (Rand)	39	-570	136	63	1						≥ 0	
Year 2 Gross Margin (Rand)	-74	117	-97	123		1					≥ 0	
Year 3 Gross Margin (Rand)	-138	205	82	-137			1				≥ 0	
Year 4 Gross Margin (Rand)	-6	101	-35	408				1			≥ 0	
Year 5 Gross Margin (Rand)	173	-261	38	-150					1		≥ 0	
Year 6 Gross Margin (Rand)	6	408	-124	53						1	≥ 0	

Source: Adapted from Hazel and Norton (1986)

According to Watts et al. (1984), target MOTAD maximises mean income subject to a limit on the total negative deviations measured from a fixed target rather than from the mean (see Table 2.4). Since deviations are not measured from the mean, total negative deviations must not equal the total positive deviations. Therefore, Target MOTAD does not restrict (or minimise) positive as well as negative deviations. Furthermore, Target MOTAD allows for comparison between solutions using a common risk reference point, while in MOTAD, the risk reference point is equal to and moves with the mean.

Table 2.4: Target MOTAD example

Target motad	Crop activities (ha)					Negative deviations from Target (Rand)					
Rows	X ₁	X ₂	X ₃	X ₄	Z ₁	Z ₂	Z ₃	Z ₄	Z ₅	Z ₆	RHS
Objective function	253	443	284	516							Maximise
Land (ha)	1	1	1	1							≤ 200
Labour (hours)	25	36	27	87							≤ 10000
Rotational requirements (ha)	-1	1	-1	1							≤ 0
Expected short fall from target					0.17	0.17	0.17	0.17	0.17	0.17	= λ
Risk rows (Rand)											
Year 1 Gross Margin	292	-128	420	579	1						≥ 55000
Year 2 Gross Margin	179	560	187	639		1					≥ 55001
Year 3 Gross Margin	114	648	366	379			1				≥ 55002
Year 4 Gross Margin	247	544	249	924				1			≥ 55003
Year 5 Gross Margin	426	182	322	5					1		≥ 55004
Year 6 Gross Margin	259	850	159	569						1	≥ 55005

Source: Adapted from Taylor (1997).

Finally, Target MOTAD will never choose a dominated plan, regardless of the target selected. A plan is dominated if another plan exists which has higher income in every situation or year.

2.8 A CONCEPTUAL FRAMEWORK FOR INCORPORATING RISK IN A DLP MODEL

This section is based on the work of Grove (2006). As a linear alternative to expected value variance analysis (E,V), MOTAD dominated the way objective function risk is incorporated into linear programming models. MOTAD was developed to overcome the inability of quadratic programming solvers to solve large quadratic programming models. However, with advances in computer technology and the availability of modern non-linear solvers such as MINOS and CONOPT, even large quadratic programming models are solved easily. Thus the need to approximate the quadratic formulation with a linear alternative, MOTAD, has become obsolete.

Multi-period risk programming applications are nothing new to South Africa. However, the assumptions of these models are vague or non existent. More specifically, these researchers fail to detail the way gross margins and deviations from mean are discounted to take the time value of money into account as well as assumptions about inter-temporal correlation structures. For instance, Nowers (1991) applied a multi-period MOTAD formulation but cast the conceptual model within a single-period framework. The objective of this part of the progress report is to develop the conceptual framework to incorporate risk into a multi-period quadratic programming framework. To develop the conceptual framework, it is important to note how the expected value and the variance of a linear combination of random variables over multiple years are calculated taking the time value of money into account.

The following equation is used to calculate the expected present value of the farm plan as the sum of discounted mean gross margins occurring in different time periods (Bussey, 1978:382):

$$E[P_f] = \sum_{t=1}^T \frac{E[Y_t]}{(1+i)^{t-1}} \quad (1)$$

The variance of the farm plan is calculated as the sum of appropriately discounted variance and covariance matrixes as follows (Bussey, 1978:384):

$$V[P] = \sum_0^n \frac{\sigma_t^2}{(1+i)^{2t}} + 2 \sum_{\tau=0}^{n-1} \sum_{\theta=1}^n \frac{Cov(Y_\tau Y_\theta)}{(1+i)^{\tau+\theta}} \quad (2)$$

Recognising that Y_θ and Y_τ are correlated gross margins in periods τ and θ , the covariance between Y_θ and Y_τ is defined by the following relationship $Cov(Y_\theta, Y_\tau) = \rho_{\theta\tau} \sigma_\theta \sigma_\tau$ ($\theta \neq \tau$) where $\rho_{\theta\tau}$ is the simple correlation coefficient and σ_θ and σ_τ are the standard deviations in the respective periods. Thus, correlation matrixes such as those used in long-term simulation models to correlate random variables can be used to estimate the covariance matrix.

An important property of equation (2) is that if you want to model independence between years, the correlation matrix becomes zero, and only the first part of equation (2) is applicable. Note, however, that the discount factor is raised to the power of $2t$ and not t . Extending standard single period (E,V) formulations to a multi-period model using the logic of equations (1) to calculate the present value of expected gross margins and equation (2) to discount the variance to present value results in the following GAMS code.

```
MINVARCOV.. SUM((j,t,k,u)$ (SAMEAS (t,u) AND SAMEAS (j,k))
               (X(j,t)*X(j,t)*covar(j,t,j,t))/((1+r)**(ORD(t)-1)**2))
               + SUM((j,t,k,u)$ (NOT SAMEAS (t,u) OR NOT SAMEAS (j,k))
               (X(j,t)*X(k,u)*covar(j,t,k,u))/((1+r)**(ORD(t)+ORD(u)-2)))
=E= VARIANCE;
TARGET.. SUM((j,t), egm(j,t)*X(j,t)/((1+r)**(ORD(t)-1))) =E= lambda ;
```

The objective of the code is to minimise the present value of VARIANCE given a specified target gross margin (lambda) while optimising the activity levels ($X(j,t)$) of each enterprise (j) in each period (t). Critical input to the model is the expected gross margins ($egm(j,t)$) and the variance-covariance matrix ($covar(j,t,j,t)$). Table 1 shows an example of the data contained in the $covar(j,t,j,t)$ matrix with variance if $(j,t) = (j,t)$ and the covariance if $(j,t) \neq (j,t)$.

Table 2.5: Example of parameter table cover (j,t,j,t)

	X1.t1	X2.t1	X1.t2	X2.t2
X1.t1	11264	1424	-20548	-15627
X2.t1	1424	10585	-27305	-10984
X1.t2	-20548	-27305	125145	29297
X2.t2	-15627	-10984	29297	93652

Obtaining the data to estimate the full variance-covariance matrix may be troublesome. However, Professor James Richardson of Texas A&M University (USA) has developed procedures to appropriately correlate random variables both intra- and inter-temporally. These correlated random variables are then used to simulate sequences of all the random variables for each iteration (state of nature). Once these values are simulated, it is possible to calculate the variance-covariance necessary for use in the E,V programming model. Another alternative is to assume and test a Markovian autoregressive model to estimate the autocorrelation matrix. Based on discussions with Prof. James Richardson, it was decided to use the indirect method of calculating the variance-covariance from appropriately correlated simulated output data.

The procedures used to appropriately correlate random variables intra- and inter-temporally are summarised below. First, the random components of the stochastic variables are isolated and specified as percentage deviations from the deterministic component. Calculate the intra- and inter-temporal correlation matrices. Given limited historical data, Richardson (2003) suggests calculating only a one-year lagged autocorrelation coefficient. Next, correlated standard normal deviates (CSND) are generated taking only intra-temporal correlations into account through the multiplication of the Cholesky decomposed intra-temporal correlation matrix with an array of independent standard normal deviates. These CSND are adjusted to account for the inter-temporal correlations during a second matrix multiplication similar to the process described above. To simulate the random variables using the inverse transformation method, the appropriately correlated standard normal deviates are transformed into uniformly distributed variables using the error function. Appendix B contains a printout of an Excel example demonstrating the procedures above using standard formulations as with SIMETAR.

2.9 RESEARCH IMPLICATIONS

The various types of market risk are price, gross margin, cash flow, and financial risk. By not hedging, a producer is exposed to all these risks, be it a price decline for the commodities they sell or a price increase for the commodities they buy. In essence, they are cash market speculators. In many ways, producers who do not hedge are in the same situation as a futures market speculator.

The producer's costs of speculating are much greater due to the high costs incurred producing these commodities. The size of the actual investment in inputs and capital all increase the risk to the producer. While the futures market speculator may face losses in addition to brokerage commissions and interest on the margin, these can be limited by getting out of the market. It can be argued that farmers who are cash market speculators are in a riskier position than futures market speculators - farmers are literally betting the farm!

With the changes in both support programs and the nature of agricultural markets, producers have had to become more self-reliant in the area of risk management. Risk management is relevant for most operations as a way of limiting risk in terms of price, gross margin, cash flow, and financial stability. It is a means of maintaining farm viability and protecting existing levels of equity.

The literature review in this chapter is important to understand the context in which the modelling framework was developed. It was pointed out that during recent years, the marketing environment has become more risky and more volatile in terms of both operational and strategic risks. The chapter also highlighted the importance of external help / tools that producers and other decision makers should use in developing risk management strategies. It is therefore important to know what tools are available, the advantages and disadvantages of each tool, and how they can be used individually or together to manage risk. This will help producers to become more effective managers and allow them to continue to be competitive in the global marketplace.

The principal purpose of risk-return analysis lies in ranking alternative farm plans on the basis of risk and examining trade-offs between risk and mean income. However, analysing trade-offs between risk (defined as deviations from mean income) and mean income is

subject to question, since risk is not expressed in a pure sense, i.e. such a risk expression is not independent of but rather dependent on mean income. Furthermore, in most cases, the only possible way to reduce (or eliminate) risk in MOTAD (and quadratic programming) is to reduce (or eliminate) income. Yet, from a practical standpoint, it is not higher income per se that poses a threat. To the contrary, it is low income, yielding negative deviations from a fixed level of acceptable target income. While it seems perfectly normal to penalise negative deviations as a source of risk, it is very difficult to view positive deviations as a genuine source of risk. That is, do rational producers really attach as much dis-utility to high income years as they do to low income years? If not, the Target MOTAD model appears to be a more plausible approach for examining risk-return trade offs and, in addition, is more consistent with risk literature (Watts et al., 1984). Finally, Grove (2006) has pointed out that special additions to the methodology are necessary to use Motad methodology in multi-period models.

The implications for this research project are the following:

- Risk management in agriculture has become an important part of the management function for primary producers, industry bodies, and government alike.
- The use of analytical tools as part of a framework to aid decision makers in formulating risk management strategies can be extremely useful.
- However, decision makers will only use these analytical tools if the value of these tools can be proved to make better decisions.
- Water allocation and water use efficiency is an important component of the New Water Act (1998). It is therefore of paramount importance to consider the impact of market risk on efficient water allocation and water use efficiency.

The chapters that follow will discuss the risks for the major irrigation crops that are grown in the Northern Cape and how micro (in this Volume of the report) and macro (Volume 2 of the report) models can be used to quantify these risks and to develop strategies to reduce them.

3.1 INTRODUCTION

The Orange, South Africa's major river, rises in the Drakensberg in Lesotho, where it is known as the Senqu. From where the river leaves Lesotho, it flows westward for some 2200 km to finally flow into the Atlantic Ocean at Alexander Bay. At the source of the Orange River, the rain fall is approximately 2000 mm per annum and decreases as the river flows westward. At its mouth, the rainfall is less than 50 mm per annum. Evaporation, on the other hand, increases in a westerly direction (Conley & van Niekerk, 2000).

From Lesotho's border to below the Van der Kloof Dam, the river bed is deeply incised. Further downstream, the land is low-lying with large areas under irrigation. The total catchment of the Orange River (including the Vaal) extends over 973 000 square km, i.e. about 77% of the land area of RSA (1 268 535 square km). Approximately 366 000 square km (38%), however, is situated outside the country in Lesotho, Botswana, and Namibia (Conley & van Niekerk, 2000).

The Orange River Project (ORP) was one of the largest and most imaginative projects of its kind in South Africa. The ORP was built to utilise the unused water of the Orange River, which, without the Vaal River, represents some 14.1% of the total runoff in South Africa, and to meet the increasing demand for water in the process.

The main objectives of the project were: to stabilise river flow for the generation of hydro-electric power, to provide a reliable water supply for users in the Orange River basin, and to give a new lease of life to water-deficient areas in the Eastern Cape such as the Great Fish and Sundays River valleys.

Irrigation in the vast area downstream of the Vanderkloof Dam, which has turned thousands of hectares of arid land into highly productive agricultural land, was made possible by the construction of the Gariep and Vanderkloof dams. Old established irrigation schemes such as those at Buchuberg, Upington, Kakamas, and Vioolsdrif have also benefited because of the regulation of river flows which is now possible (Southern African places.co.za, 2006).

The Gariep Dam, near Colesberg, is the main storage structure within the Orange River. From here, the water is supplied in two directions, namely westward along the Orange River (via hydro-electric power generators) to the Vanderkloof Dam, and southward through the Orange-Fish Tunnel to the Eastern Cape (Southern African places.co.za, 2006).

The purpose of this chapter is to give the reader an overview of the Orange River and the part of the Vaalharts irrigation scheme which falls within the boundary of the Northern Cape (see Figure 1.2). In general, the discussion will focus on a description of the irrigation regions and a brief description of development regions (BEE projects).

3.2 VAALHARTS

The Vaalharts Valley, situated in the north-east corner of the Northern Cape bordering the North West Province, was started as an agricultural irrigation scheme during the 1930's. Due to the depression--the aftermath of the terrible drought of the late 20's--the scheme was initiated to create employment and settle farmers on irrigated land. It derived its name from the two rivers, the Vaal and the Harts, which flow through it.

A number of towns are dispersed along the valley, of which Vaalharts, Hartswater, and Jan Kempdorp are the largest. The towns are self-supportive with all modern amenities. The 38 kilometre poplar lane along the road to Hartswater is one of the longest poplar lanes in the world and was planted in 1937.

Vaalharts is still the largest irrigation scheme in South Africa. Main crops include lucerne, cotton, maize, ground-nuts, and, recently, grapes, citrus, and pecan nuts, while fruits such as apricots, watermelon, peaches, and olives for the export market are on the increase. As is the case elsewhere, agriculture diversified considerably during the last decade. Probably the

most prominent feature of diversification is the Wine Cellar, while the local co-op made history by producing a very popular charcoal made from compressed ground-nut shells (Southern Africa places.co.za, 2006).

Most of the Vaalharts irrigation scheme is in the Northern Cape. However, Taung falls within the boundaries of the North-West province and was excluded from the study.

3.3 DEVELOPMENTS FROM VANDERKLOOF TO DOUGLAS

Only the area from the Vanderkloof dam to Douglas (to the confluence of the Vaal and Orange Rivers) that falls within the boundaries of the Northern Cape is included in this study. The main towns in this region are Hopetown and to a lesser extent Orania. There is no canal system, and all water for irrigation is taken directly from the River. The entitlement is 10 000 m³ per ha. The area falls under the jurisdiction of the Free State region of the Department of Water Affairs and Forestry (DWAF). Almost 80% of the irrigated area is planted with maize and wheat. Lucerne is the most common medium- to long-term crop.

3.4 HISTORICAL DEVELOPMENT OF THE REGION: BOEGOEBERG TO AUGRABIES

The following sections (3.4 and 3.9) and its subsections are primarily based on NCDA (1996).

3.4.1 Boegoeberg government water scheme

During the economic depression of the early 1930s, the construction of the Boegoeberg dam was commissioned by government to relieve the unemployment problem at the time. The dam was completed at the end of 1931. The original canal of 121 km on the southern bank of the Orange River was later extended to the present 172 km main canal. Irrigation farmers at Gariep and Rouxville-West, north of the river, are served by the 48-kilometre-long branches of the main canal.

In the early 1970s, the Department of Water Affairs built a 40 km canal for the Northern Orange River Irrigation Board. This canal is connected to the main canal with a siphon.

3.4.2 Kakamas government water scheme

The Kakamas irrigation scheme was initiated in 1898 by the Dutch Reformed Church. Originally, the southern water-furrow was built on the southern bank of the Orange River. The north water-furrow and the Augrabies-Rhenosterkop-Noudonzees canal followed later. On the 1st of September 1964, the scheme was taken over and extended further by the government.

In 1992, the Kakamas canals were upgraded. The farmers in the region were not allowed to buy more water rights at that stage, but they were promised an opportunity to buy water rights in the future.

3.4.3 Upington Island – Main Board

This scheme was originally started with the Gifkloof weir, which was built with stone and concrete in 1908. It was taken over by the government in 1961. Extensions were completed during 1981. At present, this scheme serves the irrigation areas of Straussburg, Swartkopeiland, Kanoneiland, Blaauwsekop, Steynsvoor, Louisevale, Olyvenhoutsdrift South, the communities of Curries Camp, Geelkop, and Eksteenskuil as well as a private enterprise in Eksteenskuil.

3.4.4 Upington

This scheme is on the north side of the Orange River and was started with the construction of a weir at Uap in 1888. At present, it falls under the Upington Irrigation Board. It serves irrigation farmers from Uap up to the township Lemoendraai. The main canal is not concreted.

3.4.5 Keimoes

This scheme was constructed before the Kakamas irrigation scheme and serves the 9 irrigation districts of Keimoes, Brakboseiland, Rooikopeiland, Malanshoek, Skanskopeiland, Neilersdrift, Kousas, Onderstekomeiland, and Friersdale. The community of Soverby has its own weir in the river to supply the community with water.

3.4.6 Private development within the government water regulated area

The latest and biggest development of the so called "outside" or "pump" irrigation areas developed when an opportunity arose to buy additional water rights. Private developments took place beneath Augrabies Falls at Blouputs as well as in the Onseepkans irrigation board area. Irrigation water at Blouputs is obtained by direct abstraction from the river whereas a weir and canal serve Onseepkans.

3.5 IMPORTANCE OF WATER IN THE LOWER ORANGE RIVER AREA

3.5.1 Number of farming units

The number of estimated farming units (1996) in the **lower Orange River** region gives an indication of the importance of the region to the community. The number of farmers in the area during 1996 was as follows:

- 1600 commercial farmers
- 90 small farmers on own land
- 149 small farmers on rented land (government or private)

There are about 400 hectares of potential irrigation land at Riemvasmaak. Although no development work has been started yet, 200 families have been settled there.

3.5.2 Possibilities for development of small farmers

Garden Farmers

Several towns on the banks of the Orange River such as Groblershoop, Upington, Keimoes, and Kakamas offer the possibility of home garden development to ensure food security for the inhabitants. Apart from these municipal areas, the informal town settlements also offer the possibility of home garden development. The potential has not been developed to the fullest but offers the opportunity for future farmers to obtain knowledge and experience of vegetable growing under irrigation.

New farmers

Almost all the opportunities for development projects along the Orange River are connected to irrigation. Established small farmers in the lower Orange River irrigation area were involved in the agricultural development projects (Eerstekuil, Congregational church ground). These farmers are relatively well organised and anxious for development, as opposed to small farmers in the rest of the country. Some of these farmers have up to thirty years' experience in small-scale irrigation farming.

Small farmers struggle to survive because their land is usually very small (1 hectare) and is situated on the flood plain of the Orange River and thus exposed to flood damage. 5 hectares is the minimum perceived for a feasible unit. The literacy level of the small farmers is regarded as the highest in the country. The population is concentrated in centres along the river, facilitating and improving access to schools, clinics and other services. Training opportunities improved through the attempts of irrigation farmers to uplift labourers by means of literacy and management training.

The lower Orange River area offers the best opportunity for settlement of new farmers in the Northern Cape Province.

Around 160 000 seasonal farm labourers obtain new skills and training every year when they do seasonal work on commercial farms. The potential for small farmer support and development includes the following:

- Supporting existing farmers to be more effective and profitable. Although the high-risk approach of intensive farming is not necessarily applicable to small farmers, they can learn the principles of risk and agricultural production management by attending training periods on currently successful farms.
- Extension services from the Department of Agriculture, farmers, and private organisations should be co-ordinated to prevent confusion among small farmers. The Department of Agriculture should strengthen its extension services with highly trained officers.

The Congregational church grounds (Curries Camp and Soverby) have "outside land" available for potential irrigation development, but water will have to be pumped, and only high-income crops can be considered. A potential extension of 450 to 500 hectares will provide an additional 1000 employment opportunities (4500 to 5000 dependants at 3 to 5 individuals per family will benefit from this). The establishment of a vineyard on the Eerstekuil rural area can create an additional 1400 farm labourer jobs. At Riemvasmaak, a potential 133 permanent farm jobs can be created if 400 hectares of dry grapes are established or 1600 farm jobs if 400 hectares of export grapes are established.

The Agricultural Research Council (ARC) is also involved with extension services in the region.

3.5.3 Employment opportunities

The fundamental role of agriculture in the lower Orange River area during 1996 was highlighted by the following statistics:

- Permanent farm workers $\pm 25\ 000$
- Seasonal farm workers $\pm 160\ 000$

When dependants are included, $\pm 500\ 000$ people are directly supported by agriculture. Most of the seasonal workers are recruited in the Northern Cape and Northwestern Cape Province.

During 1996, it was estimated that one hectare of export grapes provides an income equal to the Northern Cape per capita income for 2.96 persons. It was estimated that an additional 31 380 hectares can be put under irrigation if enough water is available. It is clear that not only can an enormous amount of foreign exchange be earned, but employment opportunities could also double with expansion.

3.5.4 Economy

Almost 35% of agricultural production in the Northern Cape contributes 32% of foreign earnings. 25% of these earnings go directly to labour. The area has a healthy, self-

sustaining economy because more than 90% of earnings in the rural area are spent in the local economy, making improved services possible.

There is a possibility for expansion downstream of Upington, with limited expansion possibilities within economic pump distance and a very suitable climate for specialised crop production.

Thanks to water availability and the favourable climate, the area can react to world market opportunities. The local business sector is supported by these developments in the form of soil preparation services, transport services, nursery and plant material supplies, pipes and irrigation equipment, trellising material supply, etc.

Dates, nuts, vegetables, peaches, and citrus hold enormous potential possibilities.

3.5.5 Tourism

The tourism industry of the lower Orange River is connected to the adjacent areas. Tourists usually visit places like Gemsbok Park, Augrabies Falls and Namaqualand. Upington offers a base from which tourists can easily reach these destinations. The attractiveness of the area is directly connected to the availability of water in the Orange River.

3.5.6 Linkages of irrigation development

The towns in the region's infrastructure are almost exclusively developed and maintained by the irrigation farming industry. However, the whole region reaps the benefits. According to local authorities in the region, towns are totally dependent on agriculture for their existence. More than 70% of the secondary industry activities in the lower Orange River are connected through forward and backward linkages to agriculture, with little connection to the mining industry. Towns like Groblershoop, Upington, Keimoes, and Kakamas have a population of more than 100 000 people each. These towns do not have an alternative water source and are totally dependent on the availability of water from the Orange River. Also, towns like Pofadder, Steinkopf, Springbok, Concordia, and Port Nolloth are supplied with water directly from the Orange River.

There is strong interaction with the livestock industry as well. The local feedlot industry, which is mainly supplied with lucerne and grains grown from Orange River water, has a stabilising effect on the livestock industry. The 600 000 hectare Western Kalahari livestock production area depends on the municipality of Upington for domestic water as well as stock watering. The rural areas have no alternative water source. The Geelkoppan stock farming area also depends on water from the Orange River. The Mier area would also like to get water from the Kalahari pipeline, but the community's unfavourable economic position rules this out.

Optimal usage of national assets like airports, roads, railway lines and irrigation infrastructure, as well as extended specialised infrastructures such as cold stores, wine cellars, and grape juice plants, benefits the economy of the whole country. Mines like Aggeneys are served by water from the Orange River, as will be any potential future mine developments at Renosterkop (Augrabies and Keimoes).

3.6 IRRIGATION REGIONS, LAND AND WATER USE

Table 3.1 is an estimate of the total irrigation water entitlements in the Northern Cape and the unused water.

The most important water users along the lower Orange River are local authorities, municipalities, communities, mining industry, and agriculture. Irrigation water use is the main economic user in the region. It is estimated that total unused water use entitlements amount to approximately 14 410 ha or 10 percent of the total. The reader should note unused canal and river water could not be differentiated in the farm survey. Therefore it was assumed that the unused percentage is the same for canal and river entitlements. This may not necessarily be the case.

The hot, arid climate of the lower Orange River makes it a favourable area for the cultivation of a vast array of different crops. Interviews with farmers during 1996 (Department of Agriculture: Northern Cape, 1996) confirmed that a significant change towards export grapes was planned for the next 5 to 10 years. Soil with a high risk of cold and fluid damage is not suitable for this change. It is desirable that farmers reserve a part of their irrigated area for cultivation of seasonal crops. The advantage of this is that

facilitates water management during periods of irrigation water shortage when available water can be diverted to long-term crops with a higher income. The development of the "outside land" and new areas downstream from Kakamas, with an emphasis on export grapes and other export crops due to the use of micro and drip irrigation, has huge implications.

Table 3.1: Northern Cape irrigation regions and water right entitlements

Region	Area (ha)	Volume/ha (m ³ /ha)	Total volume (mill m ³)	Source	Estimated used (ha)	Weighted volume/ha (m ³ /ha)
Vaal						
Vaalharts North and Wes channel	29,181	9,140	266.7	Canal	0	
Ganspan	300	9,140	2.7	Canal	0	
Research farm	381	9,140	3.5	Canal	0	
KB canals (Bardeley West canals)	2,469	11,855	29.3	Canal	0	
Below Vaalharts weir to Debat	6,494	9,140	59.4	river	0	
Hans River, Spitskop Dam	1,663	7,700	12.8	River	0	
Sub-Total	40,488		374.4			
Vaalharts - Borehole extractions	9,750	8,000	78.0			9,004
Douglas to Prieska (Middle Orange)						
Debad to Douglas Weir - left hand	3,773	9,140	34.5	River	45	
Debad to Douglas Weir - right hand	2,780	9,140	25.4	River	33	
Atherton Canal	349	9,140	3.2	Canal	4	
Bucklands canal	1,280	9,140	11.7	Canal	15	
Louis Bosman canal	2,100	9,140	19.2	Canal	25	
Markdrift to confluence - Douglas side	680	9,140	6.2	River	8	
Markdrift to Boegoeberg	18,827	10,000	188.3	River	202	
Sub-total	27,789		268.5		333	9,661
Vanderkloof - Douglas - Rietriver						
Orange-Riet canal	3,980	11,000	43.8	Canal	505	
Ritchie - River abstraction	97	11,000	1.1	Canal	12	
Lower Riet River - River abstraction (Ritchie to Zoutpansdrift)	3,938	11,000	43.3	River	500	
Vanderkloof first 50 km NC part of the river	5,980	11,000	65.8	River	759	
From FS border to Markdrift	8,100	11,000	89.1	River	1,029	
Sub-total	22,095		243.0		2,806	11,000
Boegoeberg						
Boegoeberg Canal	7,680	15,000	115.2	Canal	77	
River abstraction	1,287	15,000	19.3	River	13	
Sub-total	8,967		134.5		90	15,000
Uplington - Kakamas						
Gifkloof weir to Neusberg - Canal	13,811	15,000	207.2	Canal	4,820	
Gifkloof weir to Neusberg - River	2,244	15,000	33.7	River	783	
Kakamas N&S + Augrabies (canal) 50%	4,083	15,000	61.2	Canal	1,425	
Sub-total	20,139		302.1		7,028	15,000
Augrabies / Blouputs						
Kakamas N&S + Augrabies (canal) 50%	4,083	15,000	61.2	Canal	1,245	
River abstr. Neusberg - Augrabies	2,489	15,000	37.0	River	753	
River abstraction Augrabies - border	767	15,000	11.5	River	234	
River abstraction (19a)	1,604	15,000	24.1	River	489	
Sub-total	8,923		133.8		2,721	15,000
Below Blouputs - Alexanderbay						
Namqweland - Vooltsdrift Namibia	976	15,000	14.6	River	293	
Onseepkans (canal)	314	15,000	4.7	Canal	94	
River abstr. Kambreek - Vooltsdrift	835	15,000	12.5	River	251	
Vooltsdrift South (canal)	600	15,000	9.0	Canal	180	
Fish to Mouth (River abstraction)	751	15,000	11.4	River	228	
Sub-Total	3,486		52.3		1,046	15,000
Namibia						
Vooltsdrift North, Aussenkjer, others (Namibia)	1,286	15,000	19.3	River	386	
Sub-Total	1,286		19.3		386	15,000
Total allocation (excluding boreholes)	142,922		1,605.9		14,410	11,236
Estimated percentage unused entitlement					10.1%	

Source: Mainly DWAF (2006) and estimations from survey data

Appropriate development and expansion can be highly significant for the economy and the accompanying upliftment of communities in the province. Indications are strong that expansion will benefit both province and country. During the 1996 interviews with farmers, it was found that generally, in South Africa as in most other countries, the main objective is to protect yields, ensure product quality, and maintain a reasonable income. Irrigation is one of the inputs that must be managed well for this objective to be reached.

Water restrictions, a series of official investigations, and the new Water Act of 1998 raised awareness of improved water management, and farmers now have new ideas of water management and water-saving practices. Interviews with farmers also revealed uncertainty around the meaning of concepts such as crop water demand, irrigation demand, and irrigation efficiency and how this relates to the water quota. Scientists, engineers, and farmers must understand that farming practices and water balance are interconnected.

Irrigation systems play an important role in efficient irrigation water use. The amount of water needed for fluid and drip irrigation differs considerably due to evaporation. Figure 3.1 presents the gross crop water requirements for a combination of crops in the lower Orange River under different irrigation technologies.

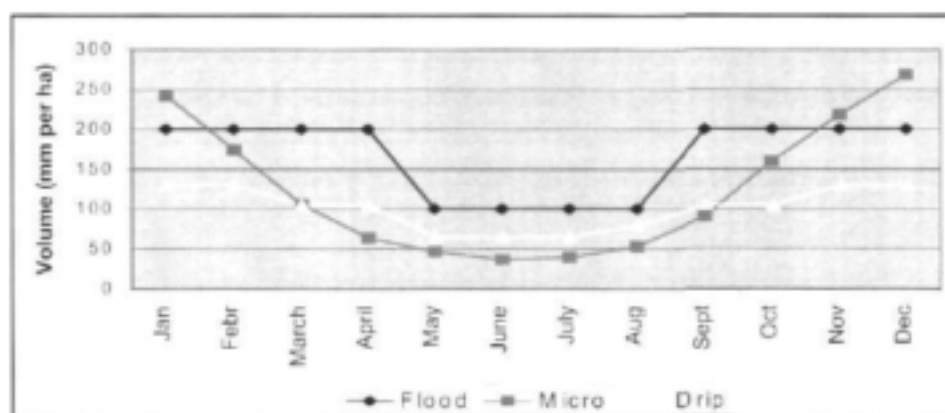


Figure 3.1: Gross crop water requirements for different irrigation systems

Source: Department of Agriculture Northern Cape, 1996.

The efficiency gains of more sophisticated (but also more expensive) irrigation systems are clear. The drip system is the most efficient, followed by micro. Flood irrigation is regarded as more inefficient compared to sprinkle, micro, and drip irrigation. However, this is purely

from a technical point of view and does not consider the costs of more efficient irrigation systems. The latter irrigation systems are also much more management intensive. Also, land above the canals tends to consist mainly of new developments irrigated with pump systems.

It is generally accepted that atmospheric demand increases from east to west down the river. This is only partly true. The maximum average demand, as pointed out by the A-pan or automatic weather stations (short grass reference), stays relatively constant over a huge area stretching from Boegoeberg up to the Namibian border and including the adjacent grazing areas. The equivalent A-pan evaporation for January, as calculated by the Department of Agricultural engineering, University of Natal, is 12.4 mm at Opwag and 12.8 mm at Kakamas. The actual long-term averages noted for January are 12.8 mm and 13.5 mm. There are actually significant local differences. The most important difference is between the green belt and "outer soils". The demand at Kakamas, where the weather station is situated outside the alluvial soils, is a little higher than the equivalent A-pan average for the area. The readings at the weather station in Upington, situated outside the alluvial soils, show less evaporation, as expected. One can accept that Boegoeberg, Upington, and Keimoes weather stations represent the green belt where flood irrigation is dominant. Opwag and Kakamas are typical of the "outer soils" where drip and micro irrigation are applied. The long-term average Penman-Monteith reference evaporation for January and December at Upington island is 6.9 mm/day; the reading at Kakamas (Water Affairs and Forestry), which is situated outside the flood plain, is 8.7 mm/day. The crop water requirements that will be used in this study will also be verified through other existing sources.

With the exception of 4000 ha irrigated mechanically, flood irrigation is the most common irrigation method on alluvial soils. The alluvial soils were deposited by the floodwaters of many centuries, so soil texture and composition will obviously vary. The clay contents differ between 10% and 30%, which can be explained by looking at the flow of water when the Orange River is in flood.

This variation in soil type must be taken into consideration when planning a flood irrigation system. The soil in the flood plain has a natural gradient towards the river and along the flow of the river. The strength of the current and the riverbed length and gradient must be

balanced to ensure efficient irrigation. This is complicated further by the soil variations. Also, soil preparation is critical for fertility.

During recent years, the tendency has been to systematically upgrade the efficiency of flood irrigation through various measures such as laser controlled land leveling. In this regard, farmers reported water savings of up to 30%.

In practice, farmers irrigate according to a schedule that fits the farming programme. In the case of flood irrigation, small administrations (e.g. 20 mm) are not possible, unlike with drip and micro irrigation. Consequently, a farmer will plan a number of irrigation administrations through the year, according to the demand of the production strategy. It is not easy to change this trusted recipe because the effect on the following years' yield is usually unpredictable.

3.7 DEVELOPMENT PROJECTS IN THE LOWER ORANGE RIVER

3.7.1 Background

According to the Department of Agriculture, Land Reform, Environment and Conservation (DALEC, 2003a), it is the Department's mission to establish a sustainable environmental framework that seeks to unlock potential and provide food security through the provision of efficient and effective service support. The Department is committed to promoting participation by youth, women, and men in the agricultural sector. The policies and objectives of the DALEC must be noted since they will most probably be the driving force behind these development projects.

3.7.2 Farmer Settlement Policy Considerations

Allocation of State land for production purposes to emerging farmers will be based on:

- Resource base capacity;
- Household food security
- Productive value of land;
- Commercial motive;

- Technology considerations; and
- Economic viability

3.7.3 Settlement Models

The following settlement models were identified by DALEC (2003):

- **State Land – Model 1:** State assistance for land improvement and development planning, facilitating the development process and finally leasing or selling to target beneficiaries.
- **State / Private Sector / Beneficiary Approach – Model 2:** Joint ventures of various natures can be entered into between the state, private sector and beneficiaries with the eventual aim of releasing developed land to beneficiaries.
- **Allocation of Water Rights as Means of Farmer Settlement on Private Land – Model 3:** Using the allocated 4000 hectares of water rights in the Orange River system in the Northern Cape as a method to give emerging farmers access to farming land.

The Orange River Re-Planning Study (ORRS) was commissioned in late 1994 in order to determine a strategy for the most beneficial utilisation and optimal development of Orange River water resources. Although the ORRS report was only finalised in 1999, early findings suggested the possibility of abstracting additional water along the lower Orange River for the purpose of emerging farmer development.

In November 1998, the then Minister of Water Affairs and Forestry Prof. Kader Asmal announced that an additional 4000 hectares of water rights (to the value of R40m) would be made available along the lower Orange River for this purpose. Agreement was subsequently reached between the national Minister and the Provincial MEC for Agriculture, Nature Conservation and Land Reform that the provincial government would champion a process by which these new water rights would be allocated in support of emerging commercial farmer development.

In April 2000, the Gariep Spatial Development Initiative (GDSI) was launched with the purpose of identifying, scoping, and appraising new opportunities for investment on a

sectoral basis in the lower Orange River area. In agriculture, the Gariep SDI was tasked with identifying prospects for the expansion of commercial farmer development, which has been afforded a high policy priority by government.

3.7.4 Objectives

The objectives of the model should be to increase levels of permanent employment and empowerment of disadvantaged communities through an increase in primary agricultural production and agro-processing activities. These projects should be planned to ensure empowerment and generate and sustain a meaningful annual income for the participants. Environmental, social, institutional, and economic sustainability must be aimed at. The targeted area should be along the middle and lower Orange River and should largely be achieved through the production of perennial and high value crops with an affinity for export.

3.7.5 Principles

Models 2 and 3 handle the settlement of emerging farmers mostly on irrigable land, where the outcome will be determined by the support given by various role players like commercial farmers and financiers. In model 2, the land is the property of the state and/or community, and in the case of model 3, development takes place on private/state/communal irrigable land without any present water rights.

It is foreseen that these types of equity schemes will not be used to develop grazing land because of its low income potential. The following principles and criteria will be used for these developed models.

3.7.5.1 Efficient use of water

Although efficient water use is critical for South Africa, the aim of this policy document is the settlement of emerging farmers and the creation of permanent jobs. To achieve this aim, high value crops should be promoted where possible.

3.7.5.2 Environmental sustainability

Environmental sustainability has a number of elements. The one that is most relevant to the development process is the maintenance of the natural resource base's productivity. In particular, projects must ensure that the actions of present generations do not undermine the capacity of the natural resource base to provide benefits for future generations. Of particular concern is the maintenance of agricultural and pastoral productivity as rural populations increase pressure on the natural resource base. Ecological sustainability also refers to the maintenance of ecological processes, such as the cycling of nutrients and water, which are basic life support system elements. The functioning of these systems must be protected so that the survival of communities of people, flora, and fauna is not endangered. The business plan must include measures to ensure that sustained soil fertility will be maintained and water logging and salination prevented / or dealt with, should such problems arise. Measures should be implemented to minimise pollution and waste production.

3.7.5.3 Social sustainability and participation

Social sustainability and participation refers to the extent to which desirable change has taken root in a society and is accepted by the population to the extent that it will be supported and maintained by them without external support. The crucial point is that innovations due to project activities should be appropriate for the recipient society. This does not only imply that they should be affordable and attractive as a result of the immediate gains that they offer, but also that they should be easily accepted by the community and incorporated within their way of thinking. To be sustainable, innovations must become part of a society's norms and values of a society and support the people's goals. This has implications for the way in which innovations are developed, as they should be developed by the community itself, where possible, rather than imposed or introduced from the outside. This means that participation is a crucial element for ensuring social sustainability. Meaningful participation requires that the recipient community not only contributes labour to a project but is also involved in the design and management of the project activities and has control over them.

3.7.5.4 Institutional sustainability

This refers to the long-term survival of institutions, which can ensure that activities developed through projects continue and evolve as conditions change. The institutions involved may be village and community ones or parts of a government administrative structure. Institutional sustainability also refers to the strengths and characteristics of the institutions in a community and their ability to continue to operate effectively and provide sustainable services or functions to the community. The task team should be convinced that the institutional backup does exist for the proposed projects or that shortcomings are properly addressed.

3.7.5.5 Economic and financial sustainability

This aspect of sustainability refers to the ability of project-initiated activities to cover the costs involved and produce a net economic benefit. This net benefit should be sufficient to make it worthwhile for the people involved to continue to undertake the activities with their resources and without external support. Hence, a project can be defined as sustainable if investment in the project results in a long-term flow of economic benefits to the project beneficiaries without a further flow of external funds being required. The task team should concentrate on the financial feasibility of the project. The number of shareholders must not exceed the maximum number of households that can make a living out of the surplus funds annually available to the shareholders. Apart from the number of beneficiaries, the proposals should also calculate the income stream and indicate all other non-cash benefits to individual beneficiaries over time.

3.7.5.6 Job creation

The number, quality, and level of permanent and seasonal jobs must be indicated, as well as how the beneficiaries of the communities would participate in management and decision making. This will include methods and measures to facilitate enhanced participation in management and decision making.

3.7.5.7 Land reform / economic empowerment

Projects should address the principles of land reform in collaboration with the commercial sector. The extent to which these communities will be empowered will be very important and must be clearly indicated. Ownership and management must be indicated and transferred, partially or in total, at some stage. The point of community take-over should be described and must happen within realistic economic and financial guidelines, within an acceptable period. The composition of portfolios, explanation and guarantees of development capital, and the value of contribution of each party should be quantified.

3.7.5.8 Agro-processing

Any additional value adding / further processing of produce will be taken into consideration. If part of the project, the creation of more jobs and/or raising the income of people already involved should be quantified.

3.7.5.9 Water rights

Projects should indicate the financial value of water rights and how it will be distributed at the point of take-over. Preference will be given to proposals where emerging farmers retain a maximum quantity of water rights.

3.7.5.10 Risk assessment / Reasonable security of investment

The internal risks in the project, e.g. growing a specific crop, fluctuation of market prices, etc., should be indicated and quantified in the proposals. The financial history of the partner(s) is also important. The project should also indicate how the share interests of different parties will be protected, e.g. if the entity is liquidated. To minimise the risk for the settlement policy under this model, the task team should also give consideration to diversity. The more diverse the enterprises and projects, the lower the risk of failure under this model if an industry collapsed or experienced economic difficulty. The same would apply if the projects were spread along the Orange River.

3.7.5.11 Human resources development

The development (training, skills development, etc.) of the historically disadvantaged group, and how it should be done and financed, must be indicated.

3.7.5.12 Access to social services

All beneficiaries must have access to social services. Linkages to available services must be indicated and how shortcomings will be addressed.

3.7.5.13 Development and growth considerations

Apart from the risk in awarding all the water rights for one industry or in one geographic area, consideration should also be given to development and growth opportunities along the Orange River area qualifying for water rights. A natural spread of these projects within the boundaries of natural and economic forces would be ideal and must be taken into account by the task team.

3.7.5.14 Strategy

Although the additional water rights made available as a result of the ORRS represent a substantial development opportunity, it is imperative that the deployment of these rights be planned for maximum success. Project developments such as Vioolsdrift, Goodhouse, Henkries, Witbank, and Eksteenskuil are all functioning at a sub-optimal level. However, they provide possible nodes or focal points where existing agglomerations of irrigation infrastructure, utilities, agricultural skills, etc. offer expansion opportunities. In most cases, this will entail a parallel process of project rehabilitation and redevelopment. Subsequent expansions may well be facilitated through the deployment of part of the additional 4000 hectares of water rights. Similarly, albeit from a different basis, large-scale private sector irrigated agricultural development as well as land restitution cases such as Riemvasmaak and the Congregational Church land near Keimoes offer the prospect of integrated development built around existing agricultural capacity.

3.8 SPECIFIC DEVELOPMENT PROJECTS

This section is based on the "ORANGE RIVER EMERGING FARMER SETTLEMENT PROGRAMME (OREFSP)" studying the Northern Cape (DALNC, 2006). The primary aim of the Orange River Emerging Farmer Settlement Program centres on economic growth, the development of communities, and economic empowerment through the development of irrigation land into intensive agricultural production units. Figure 3.2 shows the location of 20 existing or potential development projects³. Table 3.1 is a summary of the most important projects that have been identified by the DALNC. These projects have either already been implemented or are in the planning process. Some of them already have water use rights, while others will need to apply for the 4000 ha of surplus water rights set aside for this purpose.

Table 3.2: Current and potential development projects in the Northern Cape

Map no.	Project	Total area (ha)	Irrigable area (ha)	Current and/or potential land utilisation	Phase
2	Karoo Water Project		800	Pecan nuts, Vegetables, Lucerne, Maize, Wheat, Ground nuts, Cotton	Planning
3	Wimbledon	5504	Unknown	Current use is for game farming. Potential to irrigate some of the land	Planning
4	Bucklands	1719	850	Not indicated in the report	Stagnant
5	Sonskyn emerging farmers	100	55	Lucerne, Maize, Wheat, Ground nuts,	Planning
6	Thumelo youth project	176	170	Wine and table grapes, raisins and Luc	Partly operational
7	Sanddraai / Arbeidsgenot	90	90	33ha planted with Lucerne under pivot irrigation. Along with this is 4.5ha Merlot (wine grapes) and 20ha Pecan	Partly operational
8	Eiland female farmer project	17	17	Cotton and lucerne	Partly operational
9	OASiS hydroponics	?	?	Hydroponics vegetable production (two	Implementation
10	Blocuso	11139	289	Lucerne, wine grapes and table grapes	Implementation
11	Eksteenskui		621	Lucerne, wine grapes, raisins, vegetat	Partly operational
12	Kakamas Lucerne		1000	Lucerne	Planning
13	Riemvasmaak		800	Table grapes, other irrigation crops	Planning
14	Onseepkans (CSIR)		80	Essential oil crop, rose geranium, and the medicinal plant, <i>Hoodia gordonii</i> .	Partly operational
15	Onseepkans (Private)		50	Cash crops	Planning
16	Pella		85	Lucerne and table grapes	Planning
17	Witbank		185	20 ha lucerne	Partly operational
18	Abbessas		322	Cash crops	Planning
19	Goodhouse		550	High value crops	Planning
20	Henkries		25	20 ha dates and 5 ha mangoes	Partly operational
21	Sanddrift		150	Lucerne	Planning
Total area (ha)		18745	6139		

³ Please note that there is no no.1 project, since the index to the report was numbered according to the map and the first section was the introduction.

A number of agencies have been identified for the partial funding or financing of these projects. These include:

- Government agencies through:
 - CASP Funds
 - Department of Water Affairs and Forestry
 - ASGISA
- Land Bank
- Development Bank of SA

Finally, at the time of writing, it could not be established how many applications have been received for the 4000 ha of water rights (this is surplus water) set aside for development projects and how much has already been allocated. However, rough indications are that approximately 313 ha have already been allocated (Blocuso and Sonskyn), 800 ha are currently under review to be granted (Karoo), and applications have been made for a major proportion of the balance.

3.9 DEVELOPMENTS IN NAMIBIA IMPACTING ON IRRIGATION IN SA

The developments that will impact on irrigation in South Africa will mainly come from Aussenkehr Farm. According to SAT (2003), the farm is situated in Namibia on the north bank of the Orange River, 50 km west of the border post at Noordoewer. It was formerly an angora goat farm and belongs to Mr Dusan Vasiljevic, who bought it in the 1980s. The first development of table grapes started in 1988, and large-scale development commenced in 1997. The area currently has 1100 hectares under table grapes. The initiatives are jointly managed by the Grape Valley Management Company and consist of a consortium of companies which are:

- International Fruit Company
- Exotic International Namibia Pty Ltd
- Nivex Enterprises Pty Ltd.
- Namibian Grape Export Pty Ltd.
- Orange River Vineyard Investments
- Grape Valley Packers

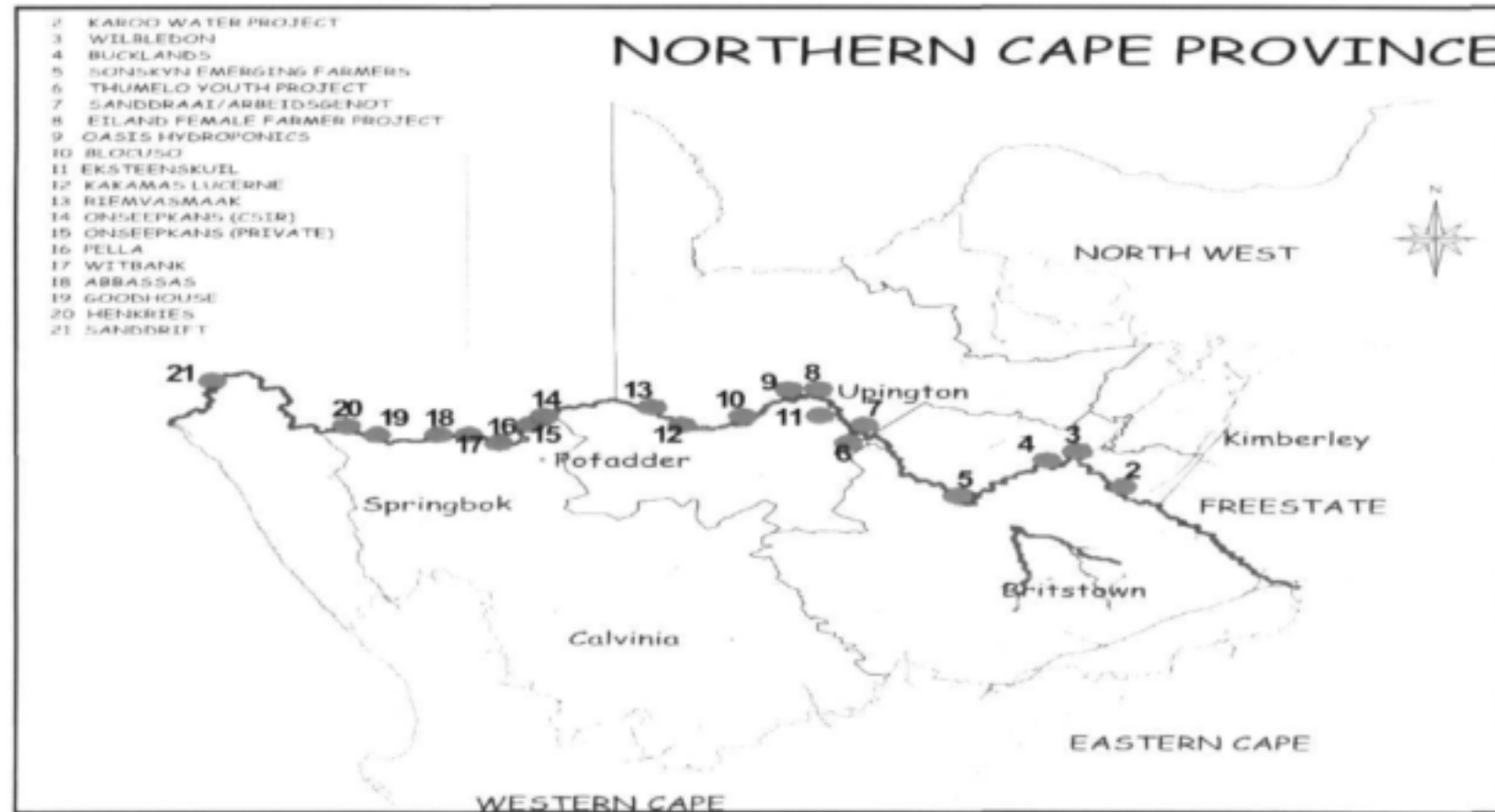


Figure 3.2: Current and potential development projects in the Northern Cape

Grape Valley Management Company manages all the production units co-owned by Dusjan Vasiljevic and other shareholders. All the land at Aussenkehr belongs to Mr Vasiljevic, with the exception of the Namibian Grape Company and the Namibian Development Company. This land was sold to the Namibian government, and these ventures are managed by the government of Namibia.

The infrastructure at Aussenkehr is breathtaking. One of the packing sheds is the biggest packing shed in the southern hemisphere and has the potential to pack 50 000 cartons per day. This is one of 8 sheds at Aussenkehr, and during the last season, the region harvested 1.8 million cartons in 8 weeks.

There is also a large punnet packing section. It has 6 pre-cooling rooms, each pre-cooling 36 pallets, and a holding store which accommodates 100 pallets. The Grape Valley Management Company has recently received EurepGAP accreditation and is in the process of applying for Tesco's Nature's Choice and HACCP accreditations.

A pumping station with the capacity to pump 45 million litres (45000 m³ per hour) supplies the table grape vineyards at Aussenkehr. Soil requires intensive and constant management. The alkaline soil has a pH of 8.5, and the water is also alkaline. The soil near the river is rich and becomes progressively poorer away from the banks.

The workers are mostly from Ovamboland, Kavango, and Caprivi in Northern Namibia. At the height of the harvest season, Aussenkehr has a population of 14 000 people. They travel great distances to come and work on the grape farms and are willing, industrious, and eager to be trained. The workers build their own reed dwellings, and the village is neat and clean. The Grape Valley Management Company provides water and sanitation. Although there are numerous shebeens in the village, employers do not have a problem with intoxication on duty, and Aussenkehr has no problem with crime or theft.

Aussenkehr has a small supermarket which provides sufficient supplies for workers and management. A school for workers' children was provided and is run by the Grape Valley Management Company, and they have also built a clinic and police station.

A new site for a proposed 2000 ha table grape development has been identified. It is seven km north of the river and is 1-2°C warmer than the riverside plantings. The infrastructure to supply this development with water will cost R120 million and require a pipeline with a 1.8 m diameter. The developers are approaching the Namibian Government (Namwater) for assistance with this scheme. A properly proclaimed and laid out town is planned for development. There are already plans for a service station, a supermarket, and a bank to open in the region.

The Namibian Grape Company is an investment of the Namibian Pension Fund. They are the largest producers of table grapes in the area and have a good infrastructure but are hampered by management problems, and profitability is a concern. For example, a recent mainline burst took 4 weeks to repair, and the entire crop was lost.

The Namibian development Company has established 20 new farmers on 5 hectares each. Each new farmer has 2 ha of table grapes. Dates and lucerne are also cultivated. The forthcoming harvest will be the first year that these young vineyards will bear, and they will be packed in the NDC's packing shed.

It is clear from the above background that Namibia (based on present developments alone) is going to have a substantial impact on the South African table grape industry, not only in the Orange River region but also in the other producing regions. Namibian grapes are in the market at least two weeks before Blouputs (earliest area in the Orange River). The prices which are determined early in the season normally also dictate what happens later in the season, e.g. high prices early in the season lead to a higher price for the remainder of the season.

Previously, this was not a problem due to the relatively small volumes produced. However, with the current and planned developments, it is expected that Namibian production will reach at least 5 million cartons within the next three to four years. The relatively small volumes will therefore become relatively large volumes, considering that the entire Orange River production at present is approximately 14 million cartons.

3.10 IMPLICATIONS FOR MODELLING

The objective of this chapter was to give the reader a detailed overview of the irrigation regions included in this project. From a modelling perspective, it is necessary to consider the following implications:

- The objective is to model all the irrigation regions in the Northern Cape to capture total current and potential future agricultural production. This is necessary to capture the total irrigation water usage and the total output from irrigation agriculture with the view of linking the output from the micro models to that of the macro model and visa versa.
- It is necessary to divide the region into regions that make sense and are practical from a modelling viewpoint. The first logical division of the irrigation regions would have been the areas of the Water User Associations (WUA's). However, there is still much uncertainty regarding the geographical areas of the WUA's, and it was decided to consider other practical considerations such as crop combinations and stretches of the river. The choice of irrigation regions used in the modelling exercise is discussed in Chapter 4.
- Since there is much uncertainty regarding the 4 000 ha allocated for development projects, it was decided to treat this area as part of the total water allocation for the Northern Cape, and the theoretical land use for this area is therefore considered to be the average current land use. However, it will be very simple to deduct this area for specific development projects and to analyse them as specific projects within the modelling framework as more information becomes available.
- The area below Blouputs is a long stretch of the Orange River and only contributes to approximately 3.33 percent (4 471 ha) of total current water use entitlement. It was therefore considered that carrying out a regional survey will not add value to the outcome of the modelling exercise.
- All the major crops that are currently grown in the Northern Cape irrigation regions should be considered in the models and in the market analysis.

Finally, it is useful to have reference groups to discuss modelling results and farm survey data. For this purpose, three reference groups were established: the north-eastern regions

(Vaalharts, Douglas/Prieska, Vanderkloof/Riet River) where short-term crops dominate, the middle section of the river where mixed farming is dominant (Boegoeberg and Upington/Kakamas), and one for the regions where table grapes dominate (Augrabies / Blouputs).

CHAPTER 4

FARM SURVEY AND DATA

4.1 INTRODUCTION

The objective of this chapter is to describe the farm survey results and all the data to be used in the modelling exercise. The next section gives an overview of the sampling method, followed by the farm survey results and a description of the typical farms. Next, the aggregation factors and aggregated irrigated regions are described. Finally, the crop budgets, input coefficients and a chapter summary are presented.

4.2 SAMPLING METHOD

A farm survey was conducted during 2002 to assess the resources, land use, and financial position of farmers in the Lower Orange River and in the Vaalharts irrigation regions. The questionnaire is shown in Appendix A.

Stratified random sampling with the unequal sampling fractions method was adopted for the survey (Snedecor and Cochran (1982). Stratification enables the population to be divided into subpopulations or strata that are less variable than the original population; different parts of the population can be sampled at different rates when this seems advisable. There are several reasons for choosing this method:

- Differences between the strata means in the population do not contribute to the sampling error of the estimate of the population mean; it arises solely from variations among sampling units in the same stratum.
- If strata can be used to divide a heterogeneous population into fairly homogeneous parts, a substantial gain in precision over simple random sampling can be expected.

- In stratified sampling, the size of sample to be taken from any stratum can be chosen separately. This freedom of choice provides scope for efficient resource allocation to strata sampling.
- When different parts of the population present different problems of listing and sampling, stratification enables these problems to be handled separately.

Originally, it was envisaged to use the following sub-regions:

- Van der Kloof Dam to Douglas
- Douglas to Boegoeberg
- Boegoeberg to Upington
- Upington to Blouputs
- Blouputs to Klein Pella
- Klein Pella to Alexander Bay.

However, to capture all the irrigation regions in the Northern Cape, it was also necessary to include the Vaalharts irrigation region up to the Vaalharts weir, Barkley West, the reach below Vaalharts weir to Debat, and the Harts River from Spitskop Dam to the confluence of the Vaal River. Also, the steering committee requested the research team to work with Water User Association regions as far as possible. After a discussion with DWAF officials, it was decided not to follow this route since most of the Water User Associations (WUA) boundaries (regions) are still under negotiation or negotiations have not even started. The second problem is that the areas used in previous studies (DWAF, 1998b) did not necessarily correspond with the proposed WUA regions. In the 2002 survey, the area below Blouputs was not surveyed, and it was decided to treat this area in the modelling framework as the average for this Orange River. Discussions with farmers and officials of farmer co-ops assisted in identifying areas with relatively homogeneous farm structures along different reaches of the river. Therefore, given all the practical problems regarding the proposed WUA regions, the following irrigation regions were included:

- Vaal region (Vaal): The Vaalharts region (excluding Taung) plus the Vaal River below the Vaalharts weir up to the De Bad. Also included are the Barkly West canals plus the area of the Harts River below Spitskop Dam. The total area represents

approximately 40 488 ha of river and canal abstractions plus approximately 9 750 ha borehole abstractions. The total irrigation area (in terms of water entitlement) is therefore 50 238 ha or 35.15% of the total irrigation entitlement in the Northern Cape (see Figure 1.2 for the location map).

- Vanderkloof-Douglas-Riet River region (VdkDR): The irrigation region from Vanderkloof Dam on the Northern Cape side for a distance of approximately 50km downstream of Vanderkloof Dam and then the irrigation regions on both sides of the Orange River up to Marksdrift. Also included are the Orange-Riet canal, the Ritchie irrigation board, and the area from Ritchie to Zoutpansdrift. The total irrigation region is approximately 22 095 ha or 15.46% of the total water entitlements.
- Douglas - Prieska region (DP): This region includes the area from De Bad to the Douglas weir, the Atherton, Buckland, and Louis Bosman canal, the area from Marksdrift to the confluence of the Orange River on the Douglas side of the Orange River, and the area from the Orange-Vaal confluence to Boegoeberg Dam. The total irrigation water entitlement area is approximately 27 789 ha or 19.44% of the total.
- Boegoeberg region (Boegoe): The region below Boegoeberg Dam up to the Gifkloof weir near Upington. The area represents approximately 8 967 ha or 6.27% of the total irrigation water entitlement.
- Upington-Kakamas region (UpKaka): The region from Gifkloof weir to Kakamas including 50% of the Kakamas North and South canals and 50% of the Augrabies canal. The area represents 20 139 ha or 14.09% of the total irrigation water entitlement area.
- Augrabies – Blouputs region (AugBlou): The irrigation region including Augrabies, Blouputs, and Marchand. In this region, there is some overlapping with the Kakamas region, and it was decided to split the Kakamas North and South Canal and the Augrabies canal 50:50 between the UpKaka region and the AugBlou region. The region represents 8 923 ha or 6.24% of the total irrigation entitlement area.
- The irrigation regions below Blouputs to Alexander Bay (BBlou). This area includes most of the proposed Onseepkans WUA region, Goodhouse/Witbank, and the Namaqualand WUA regions. This area was not surveyed due to the extremely high cost of surveys and low concentration of farming activities. The area represents 4 771 ha (3.34%) of the total irrigation entitlement area of the Northern Cape. For

modelling purposes, it was decided to use the average survey results for the lower Orange River to simulate farming activities in this region.

The total irrigation entitlements in the study region is summarised in table 4.1.

Table 4.1: Summary of water entitlements in the study region

Region	Area entitlement (ha)	Average volume per ha (m ³)**	Total volume (million m ³)	% of total volume	Number of typical farms
Vaal*	50,238	9,000	452.1	28.2%	4
VdkDR	22,095	11,000	243.0	15.1%	4
DP	27,789	9,660	268.4	16.7%	4
Boegoe	8,967	15,000	134.5	8.4%	3
UpKaka	20,139	15,000	302.1	18.8%	4
AugBlou	8,923	15,000	133.8	8.3%	2
Bblou	4,771	15,000	71.6	4.5%	1
Total	142,921		1605.6	100.0%	22

*Including boreholes (9750 ha x 8000m³ per ha)

** Weighted average for the region (see table 3.1)

Source: DWAF (2006)

The purpose of the survey was not to determine the exact situation of water distribution within these regions. The "borders" between these regions are therefore "soft" borders. It was stated previously that the main purpose was to gather information to compile typical farms in each region so as to establish the difference in farm structure, since this largely determine the impact of market risks on the various systems. A rather simple method of stratified random sampling was employed using the total water right entitlement in each of the above regions and setting a target of covering at least 15-20%, but as high as possible a percentage, of the total irrigated area in each of the regions. Farmers were selected randomly from information provided by the Department of Water Affairs and Forestry. However, there is some deviation from the target for the following reasons:

- Since it was not originally envisaged to include the Vaalharts region in the study, the project team worked on secondary data from a previous study that was conducted in the area during 2002. Also, the land use is relatively homogeneous, and it was therefore decided that the 58 farmers (8% of the total water right entitlement for this region) that were surveyed adequately represent this region.

- The Upington – Kakamas region has many relatively small farming units. It was therefore not unexpected that although 29% (63 units) of the farming units that were surveyed are in this area, only 15.7% of the total water entitlement was covered. However, the authors are confident that these farming units adequately represent the farming structure of the region.
- The Augrabies - Blouputs region was also regarded as an exception at the time, since the farm structure in the region is relatively more homogeneous than the other regions and since information on farm structure, production costs, and marketing arrangements is more readily available compared to the other regions.

4.3 SURVEY RESULTS

4.3.1 Regional results

The main objective of the farm survey is to establish the difference in farm structure between different sub-regions of the river. The data being presented in the following sections were obtained from a survey of 217 farmers. Table 4.2 shows the number of farmers in each of the regions which participated in the survey.

Table 4.2: Number of farmers

Region	Number of farmers	Contribution to total farmers	Irrigation area surveyed (ha)	Total entitlement (ha)	Percentage surveyed of total entitlement
Vaal	37	17.1%	3,981	50,238	7.9%
VdKDR	28	12.9%	6,989	22,095	31.6%
DougPrieska	34	15.7%	8,991	27,789	32.4%
Boegoe	39	18.0%	1,852	8,967	20.7%
UpKakam	63	29.0%	3,171	20,139	15.7%
AugBlou	16	7.4%	1,054	8,923	11.8%
Total	217	100.0%	26,037	138,150	18.8%

The reader should be aware that many farmers farm on more than one farming unit. For the purpose of this study, a whole farm approach is adopted, so the number of farmers that participated is not that important. Table 4.3 - Table 4.6 show a condensed summary of the most important parameters regarding the survey results. It is clear from Table 4.3 that there are substantial differences in farm structure between the sub-regions. Short-term crops dominate the Vaal, Vanderkloof-Douglas-Riet, and Douglas-Prieska regions. In the

Boegoeberg region, farm structure starts to change to long-term crops, although short-term crops still make a substantial contribution. Moving towards Upington-Kakamas, long-term crops start to dominate, while long-term crops are grown almost exclusively in the Augrabies-Blouputs region.

Table 4.3: Summary of important structural and financial parameters

ITEM	Vaal	VOKOR	OP	Boegoe	UpKaka	AugBlou	Bblou*
Long-term crops (ha)	900	546	430	1 366	2 863	1 011	4 151
Short-term crops (ha)	4 860	10 337	16 047	705	68	2	565
Total irrigated (ha)	5 761	10 883	16 477	2 061	3 049	1 013	4 716
Capital investment per ha irrigated (Rand)	35 257	33 233	32 388	55 937	133 501	221 670	137 036
Gross income per ha (Rand)	8 658	12 255	11 978	17 002	41 540	91 034	49 859
Direct costs per ha (Rand)	4 470	7 279	6 389	9 905	24 044	44 199	26 050
Total gross margin/ha (Rand)	4 188	4 976	5 589	7 097	17 496	46 834	23 809
Overheads per ha (Rand)	2 455	2 458	2 687	4 014	6 510	8 850	6 458
Depreciation cost per ha (Rand)	908	601	442	924	1 782	2 235	1 647
NFI per ha (Rand)	826	1 917	2 460	2 159	9 204	35 749	8 719
Water entitlement per ha (m ³ /ha)	9 000	11 000	9 660	15 000	15 000	15 000	15 000
NFI per m ³ (Rand/m ³)	0.09	0.17	0.25	0.14	0.61	2.38	1.05

* Not surveyed

A rough calculation of the Net Farm Income per m³ was also made. Table 4.3 represents some economic parameters for the various regions and gives an indication of the Gross Income (GI), Direct Allocatable Costs (DAC), and Net Disposable Income (NDI). The reader should note that depreciation is not accounted for accurately in the calculations below since the survey did not collect adequate information to allow for accurate depreciation calculations. However, assuming a 10-year lifespan for machinery and equipment and 25 years for fixed improvements, a rough estimate was made. The analysis clearly shows that the Augrabies-Blouputs region, where table grape production dominates, yields the highest return per m³ water (in 2002). However, it is also clear that capital investment and production costs (and therefore also the risk) are substantially higher than in the other regions. The Boegoe region returned the lowest Net Farm Income per volume of water in the regions where long-term crops are important. This was mainly the result of a depressed market for dried grapes (in 2002), which is the dominant crop in the region. It is also interesting to note that in the Vaal region (mainly Vaalharts), the NFI/m³ is the lowest of all the regions and substantially lower than the other regions where short-term crops dominate. This can be explained through the fact that farms are generally smaller in this region, so farmers cannot achieve the same economies of scale as in the Douglas-Prieska region, for example.

Table 4.4 shows the level of employment in the sub-regions. The regions with the highest contribution of long-term crops to total area also generate the highest employment.

Table 4.4: Employment (number of labourers)

ITEM	Vaal	VDKDR	DP	Boegoe	UpKaka	AugBlou	Bblou*	Total
Number of permanent labourers	432	337	302	346	1 229	904	1 932	5 482
Number of casual labourers - (perm equivalent)	367	437	180	679	2 840	1 292	3 749	9 545
Total number of labourers	799	774	482	1 025	4 069	2 196	5 681	15 027
Labourers per ha irrigated	0.14	0.07	0.03	0.50	1.33	2.17	1.20	0.34

* Not surveyed - average for Boegoe, Upkaka, Augblou and calculated for the total of 4771 ha

It is estimated that approximately 5 482 permanent and 9 545 permanent equivalent labourers are employed by the respondents. Table 4.5 represents an estimate of the total number of farm workers employed on irrigation farms in the Northern Cape. The estimate shows that approximately 60 000 permanent equivalent labourers are employed.

Table 4.5: Approximation of the total employment for Northern Cape irrigation agriculture

ITEM	Vaal	VDKDR	DP	Boegoe	UpKaka	AugBlou	Bblou*	Total
Number of permanent labourers	3 767	684	509	1 506	8 118	7 964	1 932	22 550
Number of casual labourers - (perm equivalent)	3 202	888	304	2 954	18 762	11 383	3 749	37 492
Total number of labourers	6 970	1 572	813	4 460	26 880	19 347	5 681	60 041
Labourers per ha irrigated	0.14	0.07	0.03	0.50	1.33	2.17	1.20	

* Not surveyed - average for Boegoe, Upkaka, Augblou and calculated for the total of 4771 ha

Table 4.6 represents the area that was covered by the survey. The objective of 15-20% of the total irrigated area was clearly reached, with the exception of the Upington-Kakamas and the Augrabies-Blouputs region, which were slightly below target. The high coverage in the Vanderkloof-Hopetown and Douglas regions can be explained by the fact that farms are substantially larger on average than in the other regions. It was therefore possible to cover a much larger area in the two weeks that were set aside for the survey in these regions.

The author is confident that the survey results are representative of the sub-regions and that the modelling results will adequately simulate the response of irrigation agricultural to external and internal impulses when aggregated to the whole region. Approximately 18% of the total irrigation water entitlement was covered by the survey. Figure 4.1 to Figure 4.6 represents the estimated land use for specific regions. There are evidently substantial differences in farm structure between the regions

Table 4.6: Area contribution of sub-regions to total area surveyed

ITEM	Vaal	VOKDR	DP	Boegoe	UpKaka	AugBlou	Bblou	Total
Canal abstraction (ha)	32,331	4,077	3,729	7,680	17,894	4,083	914	70,707
River abstraction (ha)	8,157	18,018	24,060	1,287	2,244	4,840	3,858	62,464
Borehole abstractions (ha)	9,750	0	0	0	0	0	0	9,750
Total irrigation entitlement (ha)	50,238	22,095	27,789	8,967	20,139	8,923	4,772	142,921
Percentage canal allocation	64%	18%	13%	86%	89%	46%	19%	49%
Percentage river allocation	16%	82%	87%	14%	11%	54%	81%	44%
Percentage from boreholes	19%	0%	0%	0%	0%	0%	0%	7%
Area surveyed (Below Blouputs excluded) (ha)	3981	8989	8991	1852	3171	1054	0	26037
Percentage of entitlement covered	8%	32%	32%	21%	16%	12%	0%	18%
Percentage of total irrigation irrigation area	35.2%	15.5%	19.4%	6.3%	14.1%	6.2%	3.3%	100.0%

Source: Survey and DWAF (2002, 2005)

It is clear from Figure 4.1 that wheat and maize represent approximately 53% of total land utilisation, followed by barley, groundnuts, and lucerne. Figure 4.2 represents the estimated land use in the Vanderkloof-Douglas-Riet River region. Almost 90% of the total area is used for maize and wheat production (in one year), followed by lucerne and some other minor crops.

It is clear from Figure 4.2 and Figure 4.3 that there is no major difference between the Vanderkloof and Douglas-Prieska regions.

The dominant crops are maize and wheat produced by crop rotation, where both crops can be produced on the same land in the same year. With the exception of Lucerne, there are virtually no long-term crops. Farm structure changes substantially in the Boegoeberg region (Figure 4.4). The region is characterised by a combination of short-term (34%) and long-term crops (66%). The major crop is dried grapes, which represents approximately 28% of total land utilisation.

In the area between Upington and Kakamas, farm structure changes towards a larger area with long-term crops (Figure 4.5). Only 3% of the total area ("other plus maize") is used for short-term crops. Table grapes use 27% of the total irrigation area. It is also clear that approximately 40% of the area is under dried grapes. This explains the much lower Net Farm Income compared to the Augrabies-Blouputs region. The Augrabies-Blouputs region (Figure 4.6) is characterised by table grapes as the dominant crop (67.2%). The second largest area is dried grapes.

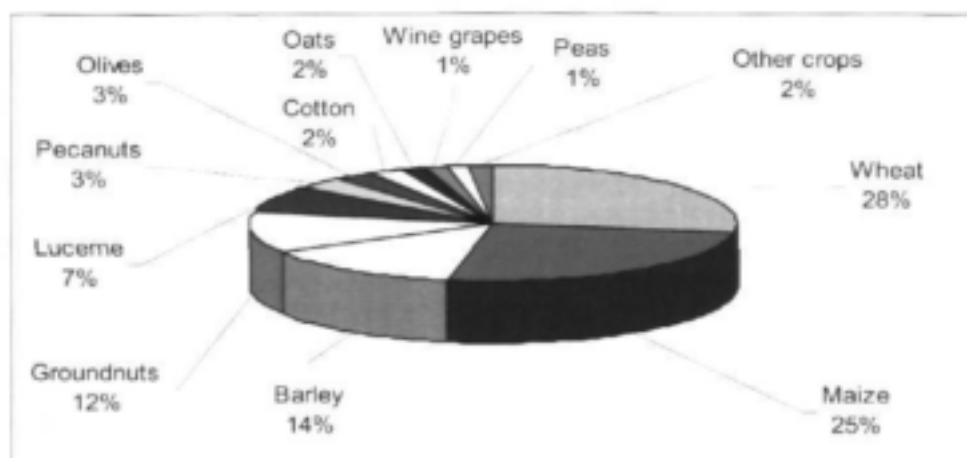


Figure 4.1: Vaalharts land use

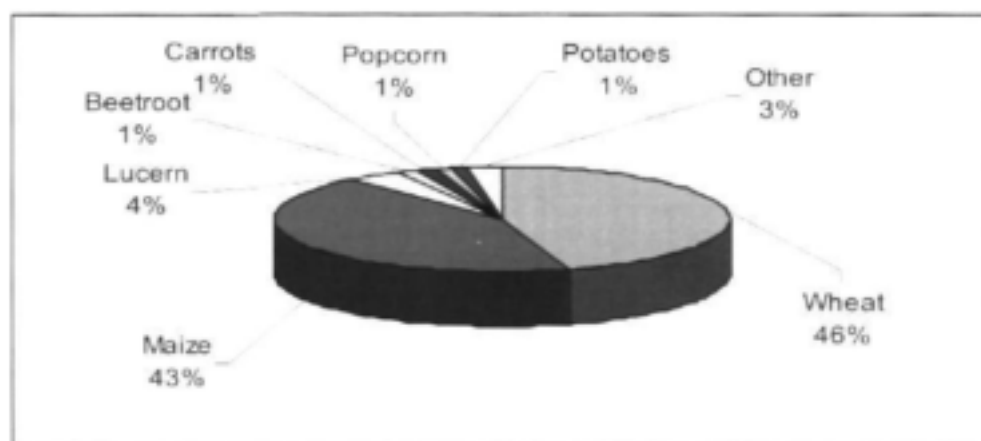


Figure 4.2: Vanderkloof-Douglas-Riet River land use

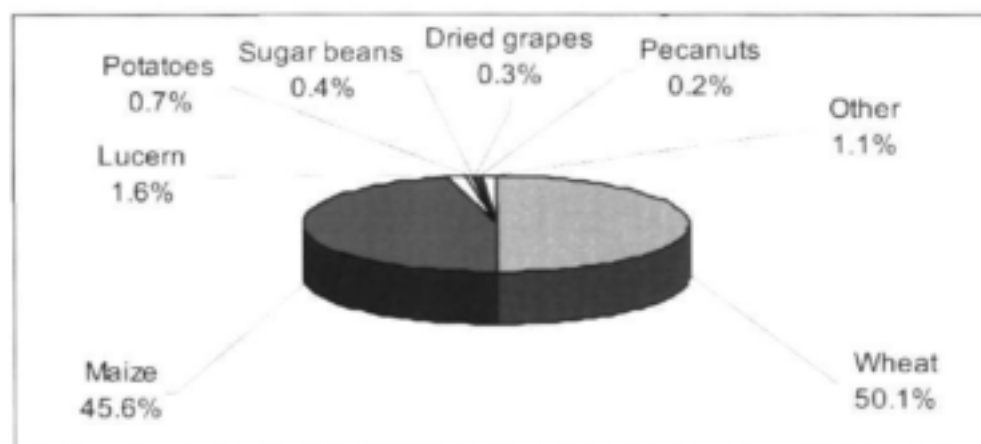


Figure 4.3: Douglas - Prieska land use

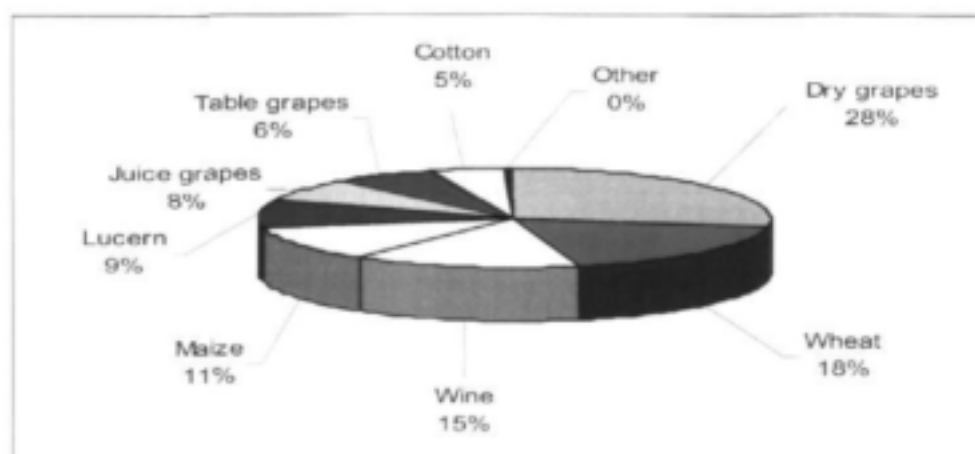


Figure 4.4: Boegoeberg land use

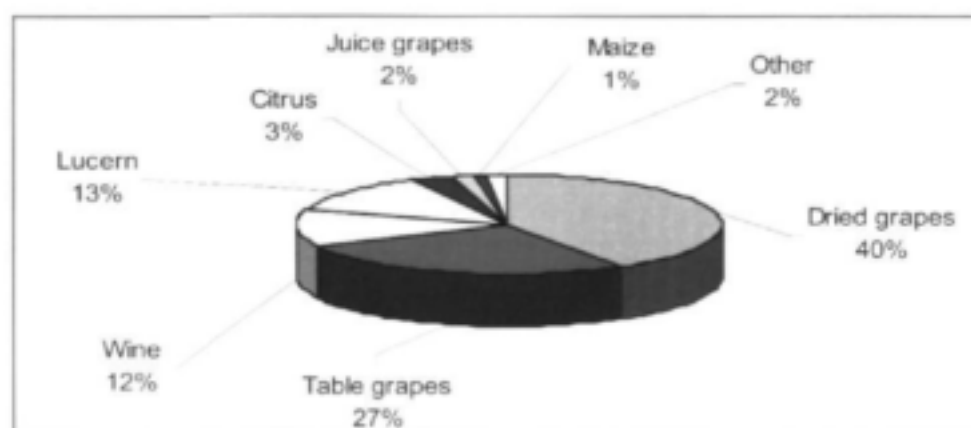


Figure 4.5: Upington-Kakamas land use

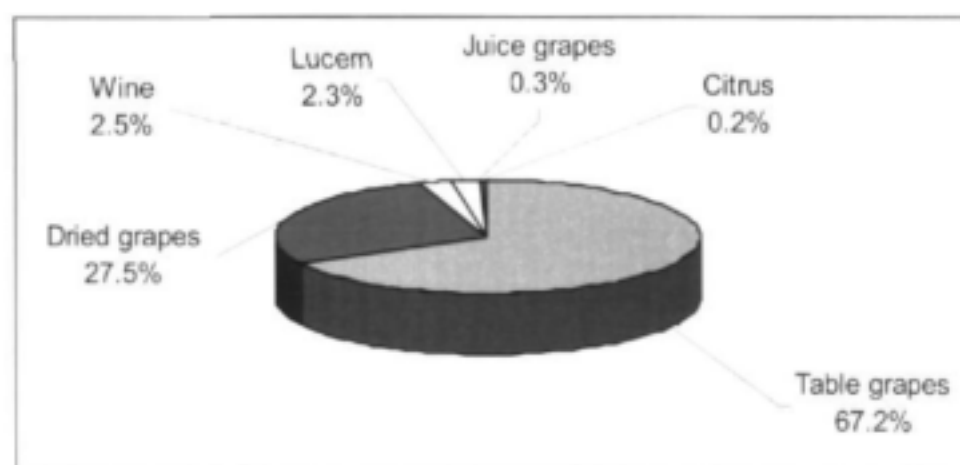


Figure 4.6: Augrabies-Blouputs land use

The survey results were also compared to previous results. Two sets of figures are available: from DWAF(1998a), which covers the whole river, and from the Northern Cape Department of Agriculture (1996), which only covers the area from Boegoeberg Dam to Alexander Bay. To render the figures of the 2002 survey comparable, only the survey results from Boegoeberg to Augrabies-Blouputs were considered. Figure 4.7 – Figure 4.9 represents the comparable results for each estimate. Clearly, substantial structural change has taken place since 1996. Unfortunately, the DWAF estimate did not distinguish between different kinds of grapes.

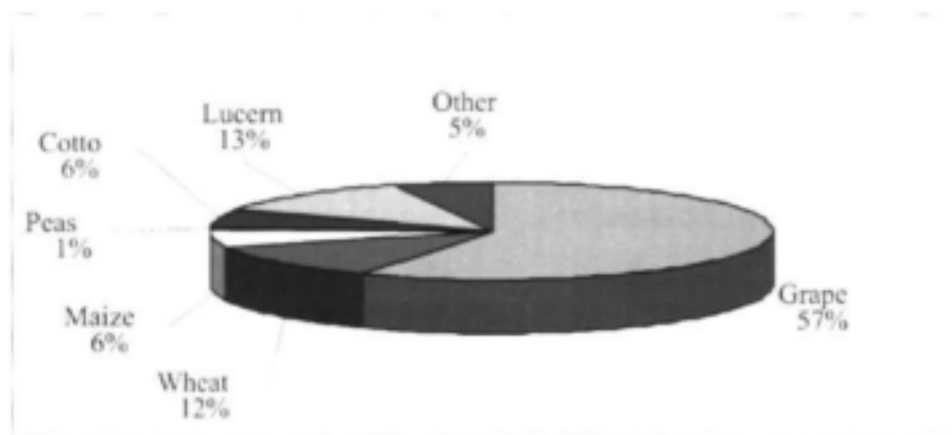


Figure 4.7: NCDA 1996 land use estimate

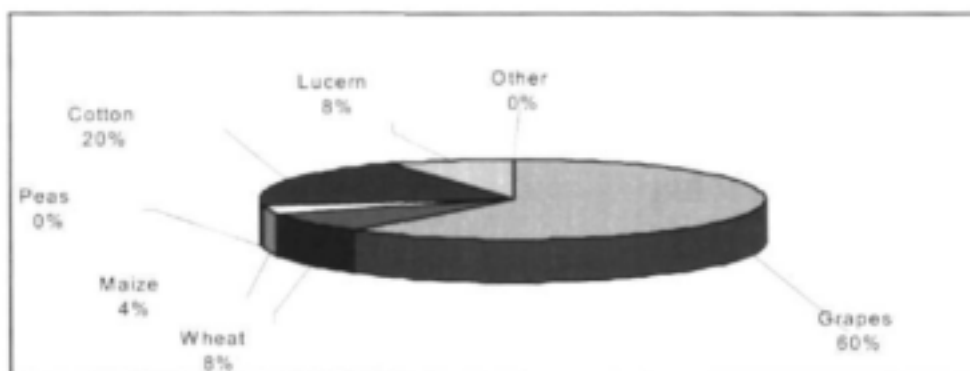


Figure 4.8: DWAF 1997 land use estimate

The 2002 survey result indicates approximately 20% growth in area contribution for grapes. In the following chapter, this growth will be explained when the table grape

industry is discussed. At this point of the report, the reader should just be aware that table grape production in the Orange River more than doubled from 1996-2003. This tendency had a huge impact on the region in terms of capital investment in new orchards, pack houses, cold storage facilities, transport, and the services industry. Obviously, then, a negative impact on the table grape industry will have region-wide impacts.

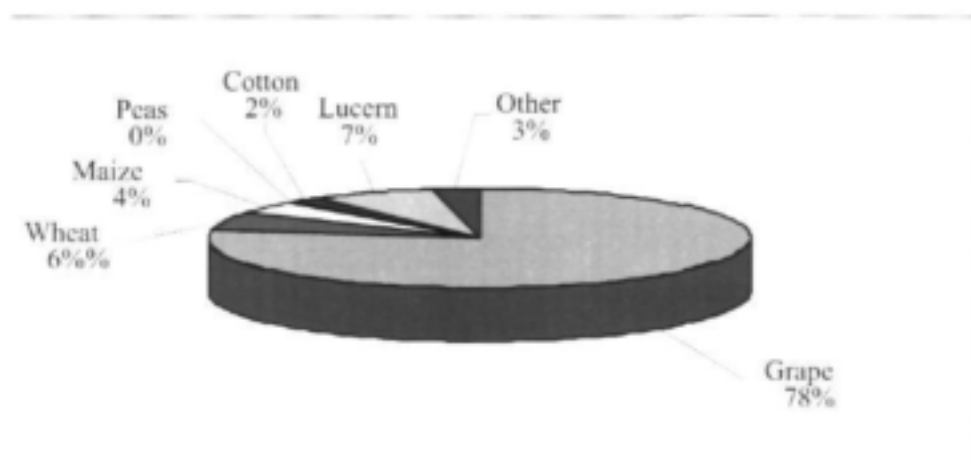


Figure 4.9: Survey results 2002 land use

The DWAF (1998) probably overestimated the cotton area since the 1996 NDCA estimate and the survey 2002 results are relatively of the same magnitude. Also, the 2002 survey results indicate a reduction of approximately 7 percent in the area of lucerne compared to the 1996 estimate. A casual observation in the area shows that the lucerne area has increased again since 2002 as farmers have struggled to cope with a negative marketing environment for almost all grape commodities and have experienced difficulty in re-establishing old orchards.

4.3.2 Typical farms

The large differences between individual farms make it impractical to use averages as criteria for creating typical farms for an area. It will be more realistic to create typical farms for each area based on the median and through discussions with farmers and agricultural experts in the region. The end result must be a farm that is representative / typical for a specific area in terms of land utilisation, debt, and capital investment. The survey data were used to establish the variance within a region in order to decide on the number of typical

farms per region. A large variance in the area irrigated and the land use structure led to the construction of more typical farms per region. Twenty-one typical farms based on farm size were thus constructed within the 6 irrigation regions covered in the survey, plus one typical farm for the area below Blouputs which is basically the average of the area from Boegoeberg to Blouputs. The detailed results are presented in tables 4.7 to 4.10. The following can be concluded from the survey results:

- Average farm size in the Vanderkloof-Douglas-Riet and Douglas-Prieska regions is much higher than in the other regions of the river.
- The size of farms below Boegoeberg does not vary substantially between typical farms of the same size (e.g. the medium representative farm in every region is the same size).
- Land use in the Vanderkloof-Hopetown and Douglas-Prieska regions is relatively homogeneous. The most important crops are maize and wheat on all the typical farms. However, it seems that larger farms tend to be more diversified than smaller farms.
- Pivot irrigation dominates the irrigation systems in the Vanderkloof-Douglas-Riet and Douglas-Prieska regions. Systems change substantially in Boegoeberg, where flood irrigation dominates. The area between Upington and Kakamas is also characterised by flood irrigation. However, the area under drip and micro irrigation increases mainly because most table grapes are cultivated with these systems. Micro and drip irrigation systems dominate in the Augrabies-Blouputs region, especially on the larger farms.
- The labour requirement per ha is substantially lower in the Vaalharts, Vanderkloof-Douglas-Riet, and Douglas-Prieska regions than along the rest of the river. Labour requirement is determined by farm structure. Differences in labour requirement per ha in the lower parts of the river can be explained by differences in table grape contribution to total land use. In the Augrabies-Blouputs region, where table grapes dominate, the labour requirement per ha is clearly much higher than in the other regions.
- With the exception of Vaalharts and Boegoeberg, there is no clear tendency for economies of scale to exist in terms of labour cost per ha. In both these regions, labour cost per ha irrigated is clearly much lower on large farms than on small farms.

- Comparison of capital investment per ha irrigated on typical farms in the Vanderkloof-Douglas-Riet and Douglas-Prieska regions clearly shows that economies of scale exist. Capital investment per ha irrigated is much higher on small farms than larger units. However, there seems to be a tendency in the opposite direction lower down the river. In the Boegoeberg region, there are no substantial differences, and in the Upington-Kakamas region, there is no tendency at all. The contribution of table grapes seems to dictate investment per ha. This tendency is clear in the Augrabies-Blouputs region. Some of the infrastructure required by table grape farmers can only be afforded by the larger farming units.
- The above observation is explained when liabilities per ha are considered. Although the liability figures are probably not very accurate, they explain the differences in capital investment. It is clear that with a few exceptions, they follow more or less the same trend. High capital investment per ha is accompanied in most cases by high liabilities per ha irrigated.
- Overhead expenses per ha clearly indicate economies of scale on the Vaalharts, Vanderkloof-Douglas-Riet, Douglas-Prieska and Boegoeberg typical farms, where the costs of small farms are substantially higher than large farms. Economies of scale are less clear in the lower parts of the river. This can also be explained by the impact of table grape contribution to irrigated area.
- Although the emphasis is not necessarily on livestock production in this study, livestock is an important industry in the Northern Cape and specifically in some regions. It should be clear from Table 4.7 that the areas with the most natural veldt are in the Vanderkloof-Douglas-Riet, and Douglas-Prieska regions. On many of these farms, the production of livestock contributes substantially to farm income. Livestock enterprises also play an important role in using crop rests and other own produced feed. During the survey, farmers also indicated that the livestock enterprise in combination with grain production makes their farms adapt more flexibly to grain price reduction. Although livestock is not so important in the farm structure in other regions, lucerne production makes an important contribution to livestock production in the Northern Cape. From the farm survey data, it is estimated that there approximately 10 000 ha of lucerne (approximately 180 000 ton) were produced in the Northern Cape in 2002. Although a large (unknown) proportion is sold outside of

the Northern Cape, farmers indicated that they use a lot of the lucerne on their own farms for livestock production.

The information contained in the description of the typical farms in this section will explain most of the results of the market and other risks scenarios that will be analysed in this project.

4.4 AGGREGATION FACTORS

Typical farms must be aggregated to represent the total irrigation region of the Northern Cape. Since no data for the total population of irrigation farmers in the Northern Cape is available, it was decided to aggregate typical farms to the total water entitlement area for each of the identified regions. Table 4.10 show the results of this exercise. Table 4.11 shows that the total water entitlement for the Northern Cape in terms of area (ha) is estimated to be 142 921 ha. The reader should know that it is very difficult to make an exact estimate of water entitlements per region since water entitlements (water use rights) are continuously traded between farmers and regions and therefore change frequently. It was therefore necessary to take a snapshot in time. The estimate in table 4.11 is therefore based on information obtained from DWAF and the Water User Associations (those already established at the time) during September 2005. However, the author is convinced that this information is adequately accurate within the context of this study.

The first step was to calculate the relative contribution of each representative farm to the total for a specific region. The second step is to use this ratio to aggregate to the area that was surveyed. Finally, this ratio is then used to aggregate to the total water rights entitlement per representative farm type, per sub-region, and for the total Northern Cape irrigation regions.

Table 4.7: Typical farms – land classification and land use (long-term crops)

	Vaal				Vanderkloof-Douglas-Riet				Douglas - Prieska				Beegoe			Upington-Kakamas				Augsrabies-Blouputs	
	Small <50	Medium 50-100	Large 100-150	XLarge >150	Small <100	Medium 100-200	Large 200-400	XLarge >400	Small <100ha	Medium 100-200	Large 200-300	XLarge >300	Small <30	Medium 30-50	Large >50	Small <25	Medium >25<50	Large >50<100	XLarge >100	Medium 30-60	Large 60-120
Land ownership																					
Irrigable (ha)	7.0	30.0	2.0	3.0	4.7	12.4	30.0	42.9	2.7	14.8	23.7	50.0	23.2	41.6	101.3	21.6	22.8	33.5	85.9	27.3	30.9
Actual irrigated (ha)	35.3	79.3	141.0	259.8	68.4	138.1	246.4	563.4	32.6	143.4	288.0	741.6	23.0	39.0	94.1	17.6	36.3	74.7	139.7	36.6	95.1
Dryland (ha)	0.0	0.0	4.7	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.9	2.4	13.3	28.7	0.0	0.0
Veget (ha)	49.8	15.5	20.4	25.0	1,023.6	499.0	1,170.6	1,734.0	518.6	2,005.6	2,327.3	2,039.7	7.8	24.1	29.8	297.3	198.8	409.8	200.7	783.9	621.3
Orch (ha)	3.1	3.7	6.0	8.0	4.0	10.1	44.2	128.0	5.4	92.2	54.3	1,305.5	5.1	14.4	32.8	2.5	4.8	61.9	61.7	2.2	5.4
Total farm size (ha)	95.2	108.5	174.1	295.8	1,092.7	659.7	1,484.9	2,458.3	559.7	2,256.0	2,693.3	4,136.7	36.1	80.2	163.9	326.1	245.6	576.0	496.2	850.0	76.7
Land use																					
Long-term crops (ha)																					
Red Wine	0.32	0.36	0.40	0.69	0.00	0.00	0.00	1.43	0.00	0.62	0.33	0.50	0.33	0.23	0.78	0.00	0.06	0.10	0.31	0.00	0.00
White Wine	1.27	1.45	1.62	2.75	0.00	0.00	0.00	4.00	0.79	0.58	0.56	0.75	4.66	6.84	13.85	1.24	2.97	4.76	15.71	0.38	2.75
Dry grapes					0.00	0.00	0.00	0.00	0.00	0.00	5.11	0.00	4.11	11.78	34.30	11.97	15.83	23.93	44.47	13.09	21.63
Juice grapes					0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.31	5.03	3.57	0.11	0.72	0.00	1.71	0.38	0.00
Table grapes	0.00	0.00	0.00	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.74	3.75	1.56	3.23	12.91	34.06	35.47	18.46	86.50
Citrus	0.00	0.18	2.89	2.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.68	0.11	0.00	0.44	1.53	9.47	2.50	2.25
Lucern	6.38	12.55	11.06	29.80	9.49	12.00	29.57	14.29	12.09	0.92	14.89	5.52	3.40	5.25	5.11	0.23	1.19	4.28	20.07	0.88	2.00
Flax					0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.86	0.00	0.00
Garlic					0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Olives	0.37	1.78	2.61	21.80	0.00	0.00	0.00	0.00	0.00	1.67	0.67	0.00	0.00	0.00	0.00	0.00	0.07	6.00	0.00	0.00	0.00
Pecanuts	1.83	5.64	9.52	5.54	0.00	1.43	0.00	0.00	0.00	0.42	0.11	4.30	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00
Plums	0.00	0.73	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other pastures					0.00	1.71	3.36	0.00	1.43	0.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total area long-term (ha)	10.16	22.69	27.31	55.02	9.40	16.14	32.93	20.29	14.90	5.33	21.67	11.07	18.71	32.96	59.28	16.98	34.35	68.76	128.08	36.68	96.13

Table 4.8: Typical farms – short term crops and irrigation systems

	Vaal				Vanderkloof-Douglas-Riet				Douglas - Prieska				Rogoo			Upington-Kakamas				Augsrabies-Blouputs	
	Small	Medium	Large	Xlarge	Small	Medium	Large	Xlarge	Small	Medium	Large	Xlarge	Small	Medium	Large	Small	Medium	Large	Xlarge	Small	Large
	<80	80-160	160-160	>160	<100	100-200	200-400	>400	<100ha	100-200	200-300	>300	<30	30-60	>60	<25	>25<60	>60<100	>100	30-60	60-120
Short-term crops (ha)																					
Wheat	14.3	17.4	49.2	149.3	41.4	103.4	167.3	268.3	9.4	133.8	251.4	708.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maize	14.0	20.2	62.8	99.2	43.1	85.1	171.6	260.0	8.1	135.5	181.8	712.5	2.3	6.3	24.7	0.1	0.0	1.9	0.0	0.0	0.0
Groundnuts	7.4	12.7	15.4	61.6																	
Barley	2.9	23.9	35.3	33.9																	
Popcorn					0.0	0.0	0.0	17.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sunflower					0.0	0.0	4.3	7.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Olives	1.5	3.1	3.2	4.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	3.3	18.9	0.0	0.0	0.0	0.0	0.0	0.0
Onions	0.3	0.0	0.0	0.0	0.0	0.0	0.0	3.6	0.3	0.0	1.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Cotton	0.6	0.0	1.7	21.2	0.0	0.0	0.0	4.3	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.5	0.3	0.6	1.4	0.3	0.0
Peas	0.0	0.0	1.7	11.4	0.0	0.0	1.4	0.0	2.1	0.0	1.1	0.0	0.0	0.5	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Sugarbeets					0.0	2.9	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Potatoes					0.0	5.7	0.0	11.0	1.7	3.8	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carrots					0.0	0.0	0.0	21.4	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Beetroot					0.0	0.0	0.0	21.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sweetmelon					0.0	0.7	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Watermelon	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total area short-term (ha)	41	78	169	381	85	199	345	836	22	276	436	1,441	2	10	44	1	1	3	1	0	0
Total short + long-term (ha)	51	101	197	436	94	214	378	857	37	282	458	1,452	21	43	103	18	35	71	130	36	95
Not currently irrigated																					
Irrigation system (ha)																				0.00	0.00
Drip	0.13	1.15	0.93	1.36	0.00	0.00	0.00	11.14	0.00	2.08	4.33	0.50	0.00	0.14	2.62	0.40	2.37	9.35	7.60	0.38	12.23
Micro	0.29	2.67	2.18	3.18	0.00	0.00	0.00	1.71	0.00	1.50	1.67	0.97	0.00	0.00	0.00	3.57	8.17	21.68	22.59	2.63	36.78
Sprinkle	1.58	0.37	15.64	6.00	2.00	8.86	0.43	6.00	0.00	34.00	2.67	6.72	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00
Flood	43.83	73.51	132.56	181.30	0.00	18.38	7.00	14.29	20.04	0.75	13.89	1.55	22.83	38.48	86.99	13.69	23.96	36.60	78.75	22.35	28.75
Central pivot	6.25	23.73	41.70	241.56	91.48	189.00	370.07	829.29	16.57	232.50	434.44	1,442.67	0.00	0.00	3.89	0.00	0.00	0.00	17.00	0.00	0.00
Other					0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (ha)	52.08	101.42	193.62	433.50	93.49	214.21	377.50	862.43	36.61	270.83	457.00	1,452.40	22.83	38.62	93.50	17.27	32.32	98.58	118.33	25.35	77.75
Entitlement from - Canal (ha)	32	68	134	243									23	39	72	21	38	50	183	53	44
Entitlement from - River (ha)					64	153	265	534	36	157	306	820	1	2	17	3	10	45	57	9	83
Tariff-channel (Rand per ha)	442	442	442	442									850	850	850	588	505	497	587	623	377
Tariff-river (Rand per ha)					167	167	167	167	152	152	152	152	85	85	85	3	25	79	69	10	230
Entitlement in this area m ³ /ha	9,000	9,000	9,000	9,000	11,000	11,000	11,000	11,000	9,660	9,660	9,660	9,660	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000
Actually irrigated / entitlement (%)	110%	118%	108%	107%	94%	90%	93%	104%	89%	92%	94%	90%	97%	96%	108%	74%	74%	78%	88%	89%	74%

Table 4.9: Typical farms – labour requirements and farm valuation

	Vaal			Vanderkloof-Eouglas-Riet			Eouglas - Prinska			Eouglas			Lipington-Nakamas			Augabies-Bloepan		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
Labour	<40	40-100	100-500	<100	100-200	200-400	<400	400-800	800-1600	<100	100-200	200-400	<100	100-200	200-400	<100	100-200	200-400
Permanent labour (hours/yr)	6 27	9 45	16 44	1 57	6 43	9 71	30 43	3 80	4 00	12 67	18 83	8 06	15 89	35 57	31 50	81 50	81 50	81 50
Permanent labour (pounds/yr)	1 070	2 266	3 909	337	782	590	13 364	291	1 266	1 648	3 305	5 140	3 240	7 894	27 894	5 314	33 440	33 440
Total labour costs (Rand)	58 666	907 288	168 554	217 143	20 529	75 440	571 134	588 089	45 769	52 786	269 665	147 892	220 929	118 487	270 825	765 749	1 543 232	334 620
Casual permanent labour equivalent (240 days)	3 02	8 32	10 70	25 45	1 41	3 26	2 11	55 77	1 67	3 10	6 25	12 52	13 53	10 27	30 58	82 86	116 23	139 36
Total labour costs (casual plus permanent)	10 29	17 77	27 14	48 66	2 68	9 69	11 82	86 20	5 53	7 68	18 92	21 25	29 53	45 21	116 04	151 80	53 64	226 66
Labour cost per ha irrigated	0 28	0 22	0 18	0 18	0 08	0 03	0 08	0 08	0 02	0 05	0 02	0 02	0 03	0 03	0 27	1 21	1 47	2 24
Labour cost per ha irrigated (Rand/ha)	1 717	1 340	1 147	880	260	202	325	640	1 467	591	370	263	4 173	3 863	2 267	7 753	8 938	12 827
Valuation of farm, total (Rand x 1000)																		
Land improvements	565 57	602 70	9 202 87	1 937 38	732 14	1 239 86	1 676 86	1 657 26	821 60	9 305 16	9 306 67	394 58	526 27	1 062 61	541 87	1 577 13	4 473 02	5 505 14
Vehicle, machinery, implements, livestock	242 33	429 03	688 16	1 844 68	537 57	1 309 43	2 277 86	4 294 05	331 21	9 814 36	9 814 36	252 03	469 34	700 13	376 07	659 29	2 403 43	1 939 42
Land	341 13	553 73	1 136 14	2 694 50	1 908 96	3 517 54	6 075 59	11 802 47	955 71	4 855 00	4 855 00	825 00	1 501 86	3 097 06	6 214 38	2 240 03	5 849 85	12 077 19
Total	1 153 42	1 605 46	11 023 17	6 097 34	3 578 68	6 059 77	10 552 37	16 963 74	1 750 52	24 922 82	24 922 82	1 382 62	2 498 04	4 860 79	7 232 32	4 469 34	12 738 20	19 228 54
Valuation of farm per ha irrigated (Rand/ha)																		
Land improvements	17 657	7 446	8 959	7 212	32 142	5 566	4 649	2 474	15 881	2 908	2 962	1 957	12 746	13 922	15 865	40 684	65 378	42 944
Vehicle, machinery, implements, livestock	7 405	6 563	5 087	8 835	11 736	6 886	5 354	5 236	8 714	6 296	6 305	4 153	11 771	2 071	20 020	38 587	34 893	11 670
Land	9 536	7 640	10 64	8 087	25 312	17 094	17 885	16 388	33 139	17 252	17 273	15 874	39 085	38 466	41 187	52 732	63 389	61 462
Total	34 642	21 258	23 133	23 134	49 192	29 530	28 497	23 797	57 733	29 436	27 540	22 034	63 086	63 086	73 988	135 249	131 659	156 188
Valuation of farm per ha farm (Rand/ha)																		
Land improvements	5 980	5 557	6 897	6 552	3 715	3 221	3 075	1 376	8 579	1 218	1 620	1 094	8 873	6 678	7 884	18 378	19 025	23 662
Vehicle, machinery, implements, livestock	2 540	4 878	3 843	6 271	8 968	4 203	4 930	2 534	5 179	2 733	3 268	2 020	7 251	6 714	4 886	11 852	8 793	10 408
Land	3 585	5 706	6 525	7 087	10 138	8 529	14 020	7 816	15 502	7 543	8 308	7 424	20 550	21 943	23 486	292 367	35 041	29 169
Total	12 105	15 541	17 363	19 910	26 821	15 953	22 614	11 726	29 261	11 494	13 146	10 545	42 674	35 335	36 256	322 587	63 659	58 682
Total depreciation (Rand)	42 185	60 429	102 925	225 814	123 042	187 452	294 140	517 687	51 647	214 376	238 878	68 644	113 370	93 282	128 114	419 263	384 767	160 943
Depreciation per ha irrigated (Rand)	1 104	0 39	730	870	1 330	848	781	586	1 411	361	740	480	1 101	1 579	1 101	3 575	5 884	2 401

Table 4.10: Representative farm – liabilities and overhead expenses

	Vaal				Vanderloof-Douglas-Riet				Douglas - Prietka				Boesgoe			Upton-Kakamas				Augsburg-Bloubaai	
	Small	Medium	Large	Xlarge	Small	Medium	Large	Xlarge	Small	Medium	Large	Xlarge	Small	Medium	Large	Small	Medium	Large	Xlarge	Medium	Large
	<50	50-100	100-150	>150	<100	100-200	200-400	>400	<100ha	100-200	200-300	>300	<30	30-60	>60	<25	>25<50	>50<100	>100	30-40	60-120
Liabilities (Rand)																					
Short-term	216 250	155 637	669 667	470 000	211 429	171 429	742 857	728 572	41 429	141 667	150 001	900 001	153 000	150 000	440 000	196 334	597 963	1 853 334	2 878 572	462 500	4 130 000
Medium term	6 250	59 480	263 722	276 570	139 571	431 143	210 000	585 714	235 920	966 700	1 152 000	404 000	15 125	8 200	61 400	53 768	55 169	195 833	335 286	14 658	0
Long-term	78 917	270 753	201 956	265 186	273 571	254 286	465 714	1 857 143	142 333	319 664	1 868 333	2 766 667	94 615	116 159	542 000	177 756	472 374	329 612	1 432 071	654 578	1 308 750
Total liabilities (Rand)	301 417	425 870	1 235 345	1 011 757	624 572	856 858	1 418 572	3 271 429	270 944	1 160 360	2 035 566	2 283 334	312 000	280 177	725 100	329 691	875 043	1 902 113	3 803 872	1 131 736	5 408 750
Total Mt and Lt Installments (Rand)	14 017	73 949	146 151	233 744	64 946	107 749	196 222	399 737	58 232	313 844	467 899	217 460	38 500	42 500	106 351	42 921	94 517	113 870	377 857	66 117	0
Mt+Lt installments per ha irrigated (Rand/ha)	397	933	1 037	900	892	504	281	467	1 864	1 114	1 021	150	1 829	986	1 033	2 425	2 708	1 598	2 918	1 840	0
Liabilities per ha irrigated (Rand/ha)	8 531	5 372	8 761	3 895	7 964	3 965	3 770	3 950	8 503	4 195	4 566	1 847	12 381	7 486	10 968	15 931	23 610	30 119	30 438	33 449	53 958
Overhead expenses (Rand)																					
Total overhead expenses	105 435	156 794	279 388	858 747	318 886	395 458	770 547	1 355 863	105 203	534 681	1 260 435	3 472 973	107 718	149 850	346 057	103 716	187 247	553 199	755 445	284 900	1 004 688
Overheads per ha irrigated	2 754	2 013	1 967	3 157	3 841	2 002	2 179	1 879	4 428	1 818	2 859	2 119	4 685	3 854	3 638	6 167	5 754	7 726	6 276	7 853	9 847
Labour costs per ha	1 717	1 348	1 147	880	260	380	325	645	1 497	191	310	203	4 173	3 863	2 267	5 523	7 432	8 638	7 753	8 978	12 827
Overheads including labour (per ha)	4 471	3 361	3 114	4 037	4 101	2 382	2 505	2 464	5 905	2 009	3 169	2 322	8 858	7 717	5 905	12 050	13 186	16 364	14 029	16 831	22 674
Overheads including depreciation (per ha)	5 685	4 199	3 844	4 906	5 411	3 230	3 286	3 049	7 316	2 770	3 968	2 802	10 634	9 296	7 006	15 666	16 857	22 249	17 000	21 309	29 874

4.5 ENTERPRISE BUDGETS AND OTHER MODELLING DATA

The approach with crop budgets was to attempt to capture differences between irrigation regions. The following notes are important:

- Farmers and experts had several opportunities to comment on these budgets during work sessions and individual conversations.
- GWK budgets are updated annually and are regarded as authoritative sources within the Northern Cape and specifically the middle Orange River.
- Wine budgets are annually updated by Vinpro.
- Optimal Agricultural Business Systems (OABS) updates table grape and raison budgets annually under contract for the Deciduous Fruit Producers Trust (DFPT).
- The Department of Agriculture of the Northern Cape lost the capacity to update budgets, and it is not clear if and when they will be able to regain this capacity.
- In order to update the model periodically, all the data must be updated every three to four years.

The complete Combud budgets are not available in electronic format. Unfortunately, not even the latest Combud version provides for user-friendly electronic budgets.

4.5.1 Crop gross margin budgets

Discussions with farmers and industry experts in the region established that the major differences between regions are appear not so much in terms of production cost (accept for differences in irrigation technology) but in yield, quality, and price (especially with table grapes). In some cases, Table 4.12 gives a summary of the most important relative yield differences between regions.

Table 4.12 clearly shows that the most significant differences are for table grapes because of the early late effect. Although yield decreases slightly towards the West, this region is earlier than the North Eastern regions, so the average price is substantially higher. In many cases, better quality has also been reported. The same is true for raisins with regard to quality and therefore average price. It is a fact that the Western regions produce better

quality raisins than the North Eastern regions. With regard to Lucerne, there are no clear differences, although farmers to the West claim that they can produce better quality lucerne since the area is drier than, for example, Douglas-Prieska and Vaalharts. Although there are differences in wheat and maize yields between Vaalharts, Vanderkloof-Douglas-Riet, and Douglas-Prieska, the author believes that these differences can be attributed to degrees of specialisation and irrigation technology. The slightly higher maize yield in the Douglas-Prieska and Vanderkloof-Douglas-Riet regions is mainly due to the fact that most of the crop is grown under flood irrigation in the Vaalharts region and that the Vaalharts region is more diversified than the other two regions. Table 4.13 is a summary of differences in direct variable costs for the different regions. Costs generally tend to be higher towards the west due to longer transport distances.

Table 4.12: Yield differences (yield unit/ha)

Crop	Unit	VaalH	VdKDR	DP	Boegoe	UpKaka	AugBlou
Wheat.g01	Ton	6.5	6.0	6.0	5.0	5.0	4.5
Groundn.g01	Ton	3.0	3.5	3.5			
Maize.g01	Ton	8.5	12.0	12.0	7.0	7.0	6.5
Cotton.g01	Kg	3 000.0	4 500.0	4 500.0	3 000.0	3 200.0	4 800.0
Drybean.g01	Ton	2.0	2.0	2.0			
Sunflower.g01	Ton	0.7	0.7	0.7			
Soyabean.g01	Ton	3.8	3.8	3.8			
Oats.g01	Ton	5.0	0.0		5.0	5.0	
Barley.g01	Ton	5.0	0.0	0.0	0.0	0.0	0.0
CarrotsS.g01	Ton	70.0	70.0	70.0			
Potatoes.g01	Ton	35.0	35.0	35.0			
Onions.g01	Kg	5 500.0	5 500.0	5 500.0			
Beetroot.g01	Ton	5.0					
Watermelon.g01	Kg	4 000.0	4 100.0	3 950.0			
Sweetmel.g01	Ton	1.0					
Lucern.g01	Ton	12.0	15.0	15.0	15.0	15.0	15.0
Lucern.g02	Ton	18.0	19.0	19.0	19.0	18.0	21.0
Pecan.(g12*g20)	Kg	2 100.0	1 890.0	2 163.0			
Olives.(g10*g20)	Ton	0.0	8.0	8.0			
Citrus.(g12*g20)	Kg	44 064.0	43 200.0	46 920.0		43 700.0	44 620.0
RWine.lrrig.(g4*g20)	Ton	15.0			15.0	15.0	15.0
WWine.lrrig.(g4*g20)	Ton	20.0	20.0	20.0	25.0	25.0	25.0
Drygrape.lrrig.(g04*g20)	Ton	0.0			25.0	25.0	25.0
Juigrape.lrrig.(p4*p20)	Ton	0.0			24.0	24.0	24.0
Tablegr.lrrig.(g3*g20)	Ton	0.0			18.5	18.0	18.0

g= Growth stage. For exa g= Growth stage. For example g3*g20 is the yield for full bearing from year 3-20

Table 4.13: Direct variable costs (Rand/ha)

Crop	VaalH	VdKDR	DP	Boegoe	UpKaka	AugBlou
Wheat.g01	4,864	4,320	4,999	5,164	5,364	5,364
Groundn.g01	5,276	4,551	6,184			
Maize.g01	5,056	5,737	5,684	5,230	5,930	5,930
Cotton.g01	6,102	6,393	8,705	6,175	6,819	6,175
Drybean.g01		4,889	6,007			
Sunflower.g01		3,418	4,357			
Soyabean.g01		2,591	3,445			
Oats.g01	4,372			4,563	4,713	4,477
Barley.g01	5,683					
CarrotsS.g01		4,713	4,949			
Potatoes.g01		39,608	41,827			
Onions.g01		35,770	37,145			
Beetroot.g01						
Watermelon.g01		11,942	12,200			
Sweetmel.g01						
Lucern.g01	4,990	5,283	5,870	5,283	5,636	6,222
Lucern.g02	4,651	4,925	5,472	4,925	5,636	5,800
Pecan.g01	27,393	28,306	29,524			
Pecan.(g12*g20)	13,865	13,603	13,603			
Olives.g01	23,468	29,623	31,104			
Olives.(g10*g20)	11,304	10,823	11,364			
Citrus.g01		21,351	20,710		20,334	22,620
Citrus.(g12*g20)		13,063	12,671		12,441	13,839
RWine.Irrig.g01				44,444	43,444	45,444
RWine.Irrig.(g4*g20)				8,154	8,954	8,654
VWine.Irrig.g01	36,494	40,764	41,987	42,654	40,767	41,578
VWine.Irrig.(g4*g20)	8,478	9,399	8,929	8,817	8,654	9,654
Drygrape.Irrig.g01				40,943	40,175	41,286
Drygrape.Irrig.(g04*g20)				8,384	8,854	9,900
Juigrape.Irrig.g01				43,366	41,366	42,366
Juigrape.Irrig.(p4*p20)				5,654	6,654	7,654
Tablegr.Irrig.g01				153,541	160,541	172,249
Tablegr.Irrig.(g3*g20)				70,902	80,902	91,353

4.5.2 Crop water requirements

The gross crop water requirements were calculated with the so-called SAPWAT model (Van Heerden, Crosby & Crosby, 2001). The objective of this section is not to give an overview of the SAPWAT methodology but only to present the results. The water requirements are presented in tables 4.14 to 4.21.

The most important implication from the SAPWAT crop water requirement estimates is that double cropping between small grain (mainly wheat) and maize is physically and biologically possible in most regions, but water allocation is inadequate. Chapter 7 refers to

this point again in more detail. It is also important to note that crop water requirements for some crops (mainly lucerne, dates, vine and citrus) in some regions exceeds water allocation per ha. For example, a farmer with 100 ha of water use entitlement in the Augrabies region will not be able to irrigate 100 ha of lucerne or grapes since lucerne's water requirement in this region varies between 16 800 - 25 800 m³ per ha and grapes' varies between 18 600 - 19 800 m³. It will therefore only be possible to produce 75-90 ha of lucerne. Therefore, it is not uncommon that farmers own more water use entitlements than the actual area they irrigate.

4.5.3 The Sultana factor

The Sultana or Thompson seedless grape variety accounts for approximately 40% of table grape production (55% to 33% depending on the season) in the Orange River. The relatively large variation in Sultanas exported as fresh table grapes is due to the variety's versatile nature. It is possible to change between table grapes, dried grapes, wine, and even juice depending on price expectations and climate. This dynamic therefore had to be provided for in the modelling structure.

It was therefore assumed that approximately 40% of the current area classified as "table grapes" would be handled by the introduction of a basic Sultana budget (basically the same as for establishing grapes for wine) which can be converted to raisins, wine, table grapes, or juice by simply adding the additional costs of preparing the grapes for one of these products.

Table 4.16: Gross crop water requirements: Douglas-Prieska (mm/ha)

CROP	CROPTION	IRRISYSTEM	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Barley	Standard	Flood : Border	0	0	0	0	0	120	120	180	240	60	0	0	720
Barley	Standard	Flood : Border	0	0	0	0	0	0	120	120	180	240	60	0	720
Cotton	Medium	Flood : Border	240	60	0	0	0	0	0	0	120	180	240	300	1140
Cotton	Medium	Flood : Border	240	240	300	60	0	0	0	0	0	0	180	240	1260
Fescue-grazing	Standard	Flood : Border	240	240	300	240	60	120	60	120	180	240	240	300	2340
Lucerne	Semi-dormant	Flood : Border	240	240	120	60	120	60	60	180	300	240	240	300	2160
Maize-early-plant	Short variety	Flood : Border	300	60	0	0	0	0	0	0	0	180	240	240	1020
Maize-late-plant	Short variety	Flood : Border	180	240	300	60	0	0	0	0	0	0	0	120	900
Pastures_perennial	Standard	Flood : Border	240	240	120	60	120	120	60	120	120	120	120	240	1680
Peas	Standard	Flood : Border	0	0	0	0	120	120	180	120	0	0	0	0	540
Vine-wine	Medium	Flood : Border	300	240	120	60	120	60	60	60	60	240	240	240	1800
Wheat-med	Early June	Flood : Border	0	0	0	0	0	120	120	120	240	240	0	0	840
Wheat-med	Late July	Flood : Border	0	0	0	0	0	0	60	120	180	300	120	0	780
Barley	Standard	Sprinkler : Centre pivot	0	0	0	0	0	45	90	165	120	45	0	0	465
Barley	Standard	Sprinkler : Centre pivot	0	0	0	0	0	0	75	135	150	150	90	0	600
Beans_Dry	Medium	Sprinkler : Centre pivot	45	120	150	30	0	0	0	0	0	0	0	0	345
Beans_Dry	Short	Sprinkler : Centre pivot	90	150	105	0	0	0	0	0	0	0	0	0	345
Carrot	Autumn plant	Sprinkler : Centre pivot	0	0	43	60	105	30	0	0	0	0	0	0	238
Carrot	Summer plant	Sprinkler : Centre pivot	0	60	75	105	60	0	0	0	0	0	0	0	300
Cotton	Medium	Sprinkler : Centre pivot	275	25	0	0	0	0	0	0	45	150	180	250	925
Cotton	Medium	Sprinkler : Centre pivot	150	150	150	30	0	0	0	0	0	0	75	150	705
Fescue-grazing	Standard	Sprinkler : Centre pivot	150	135	165	135	30	75	60	60	75	150	150	165	1350
Lucerne	Semi-dormant	Sprinkler : Centre pivot	200	200	60	60	60	45	30	105	150	165	200	200	1475
Maize-early-plant	Short variety	Sprinkler : Centre pivot	275	50	0	0	0	0	0	0	0	75	150	230	780
Maize-late-plant	Short variety	Sprinkler : Centre pivot	120	135	150	45	0	0	0	0	0	0	0	45	495
Onion	Trnsplnt Autumn	Sprinkler : Centre pivot	0	0	21	14	80	100	75	15	0	0	0	0	305
Onion	Trnsplnt Autumn	Sprinkler : Centre pivot	0	0	0	0	75	60	60	165	150	15	0	0	525
Pastures_perennial	Standard	Sprinkler : Centre pivot	150	150	60	60	60	75	60	60	150	165	150	150	1290

Table 4.17: Gross crop water requirements: Douglas-Prieska cont.

CROP	CROPTION	IRRISYSTEM	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Peas	Standard	Sprinkler : Centre pivot	0	0	0	0	75	60	150	15	0	0	0	0	300
Potato	Standard	Sprinkler : Centre pivot	90	150	150	75	0	0	0	0	0	0	0	0	465
Potato	Standard	Sprinkler : Centre pivot	0	0	0	0	0	0	0	100	210	275	195	0	780
Watermelon_early	Spring plant	Sprinkler : Centre pivot	0	0	0	0	0	0	0	0	0	170	200	180	550
Watermelon_early	Winter plant	Sprinkler : Centre pivot	0	0	0	0	0	0	0	135	175	180	60	0	550
Wheat-med	Early June	Sprinkler : Centre pivot	0	0	0	0	0	75	135	150	150	135	0	0	645
Wheat-med	Late July	Sprinkler : Centre pivot	0	0	0	0	0	0	15	60	135	165	60	0	435
Olives	Standard	Sprinkler : Drip	165	135	150	60	60	45	30	30	30	135	150	150	1140
PecanNuts	Standard	Sprinkler : Drip	10	10	20	10	20	10	20	10	90	200	200	200	800
Vine-wine	Medium	Sprinkler : Drip	125	100	40	15	30	15	15	15	30	95	100	100	680
Watermelon_early	Spring plant	Sprinkler : Drip	0	0	0	0	0	0	0	0	0	125	200	225	550
Watermelon_early	Winter plant	Sprinkler : Drip	0	0	0	0	0	0	0	105	180	200	80	0	565
Olives	Standard	Sprinkler : Micro spray	220	180	200	60	60	45	30	30	30	135	150	200	1340
PecanNuts	Standard	Sprinkler : Micro spray	60	60	75	60	45	30	30	30	135	200	200	200	1125
Vine-wine	Medium	Sprinkler : Micro spray	125	100	70	60	45	30	30	30	45	95	100	100	830
Barley	Standard	Sprinkler : Quick-coupling	0	0	0	0	0	120	120	180	240	60	0	0	720
Barley	Standard	Sprinkler : Quick-coupling	0	0	0	0	0	0	125	145	160	200	80	0	710
Beans_Dry	Medium	Sprinkler : Quick-coupling	75	115	160	65	0	0	0	0	0	0	0	0	415
Beans_Dry	Short	Sprinkler : Quick-coupling	140	160	120	0	0	0	0	0	0	0	0	0	420
Carrot	Autumn plant	Sprinkler : Quick-coupling	0	0	66	72	94	80	0	0	0	0	0	0	312
Carrot	Summer plant	Sprinkler : Quick-coupling	0	48	125	115	40	0	0	0	0	0	0	0	328
Onion	Trnsplnt Autumn	Sprinkler : Quick-coupling	0	0	36	24	48	112	100	25	0	0	0	0	345
Onion	Trnsplnt Autumn	Sprinkler : Quick-coupling	0	0	0	0	60	56	80	180	160	40	0	0	576
Peas	Standard	Sprinkler : Quick-coupling	0	0	0	0	60	64	135	65	0	0	0	0	325
Watermelon_early	Spring plant	Sprinkler : Quick-coupling	0	0	0	0	0	0	0	0	0	200	200	190	590
Watermelon_early	Winter plant	Sprinkler : Quick-coupling	0	0	0	0	0	0	0	170	160	160	80	0	570

Table 4.18: Gross crop water requirements: Boegoeberg (mm/ha)

CROP	CROPTION	IRRISYSTEM	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	IRRITOT
Citrus	Average	Flood : Border	300	240	240	120	180	120	120	180	240	300	240	240	2520
Cotton	Medium	Flood : Border	300	240	60	0	0	0	0	0	0	180	240	240	1260
Datepalm	Standard	Flood : Border	240	240	300	240	120	180	120	120	120	120	240	300	2340
Lucerne	Semi-dormant	Flood : Border	0	0	0	0	0	120	60	60	300	240	240	0	1020
Lucerne	Semi-dormant	Flood : Border	240	240	180	120	120	120	60	60	300	240	240	300	2220
Maize-early-plant	Short variety	Flood : Border	240	240	120	0	0	0	0	0	0	0	180	240	1020
Maize-late-plant	Short variety	Flood : Border	180	240	300	120	0	0	0	0	0	0	0	120	960
Oats	Standard	Flood : Border	0	0	0	0	0	120	120	180	300	120	0	0	840
Peas	Standard	Flood : Border	0	0	0	0	120	120	120	300	0	0	0	0	660
PecanNuts	Standard	Flood : Border	180	120	120	120	120	60	60	60	120	300	240	240	1740
Vine-table	Medium	Flood : Border	300	120	120	120	120	60	120	60	120	300	240	240	1920
Vine-wine	Medium	Flood : Border	300	240	120	120	120	60	60	60	120	300	240	240	1980
Wheat-med	Early June	Flood : Border	0	0	0	0	60	60	180	120	240	180	0	0	840
Wheat-med	Late June	Flood : Border	0	0	0	0	0	60	60	300	240	240	60	0	960
Cotton	Medium	Sprinkler : Centre pivot	275	185	30	0	0	0	0	0	0	75	250	250	1065
Lucerne	Semi-dormant	Sprinkler : Centre pivot	0	0	0	0	0	45	30	135	200	220	180	0	810
Lucerne	Semi-dormant	Sprinkler : Centre pivot	250	250	100	100	100	45	30	123	180	198	250	250	1876
Maize-early-plant	Short variety	Sprinkler : Centre pivot	250	220	45	0	0	0	0	0	0	0	75	250	840
Maize-late-plant	Short variety	Sprinkler : Centre pivot	180	225	250	95	0	0	0	0	0	0	0	45	795
Oats	Standard	Sprinkler : Centre pivot	0	0	0	0	0	75	135	150	150	90	0	0	600
Peas	Standard	Sprinkler : Centre pivot	0	0	0	0	45	60	105	150	15	0	0	0	375
Wheat-med	Early June	Sprinkler : Centre pivot	0	0	0	0	15	30	150	160	200	105	0	0	660
Wheat-med	Late June	Sprinkler : Centre pivot	0	0	0	0	0	30	75	150	160	275	25	0	715
Citrus	Average	Sprinkler : Drip	150	135	120	45	75	60	80	115	150	150	150	165	1395
Cotton	Medium	Sprinkler : Drip	275	185	30	0	0	0	0	0	0	75	200	215	980
Datepalm	Standard	Sprinkler : Drip	250	250	250	250	60	75	60	60	75	60	240	250	1880
PecanNuts	Standard	Sprinkler : Drip	60	60	75	60	20	10	20	10	170	200	200	200	1085
Vine-table	Medium	Sprinkler : Drip	200	85	60	60	30	15	30	15	45	175	200	220	1135
Vine-wine	Medium	Sprinkler : Drip	150	135	75	60	30	15	30	15	45	150	150	165	1020
Citrus	Average	Sprinkler : Micro spray	180	162	141	45	75	60	90	159	180	180	180	198	1650
Datepalm	Standard	Sprinkler : Micro spray	250	250	250	250	60	75	60	60	75	60	240	250	1880
PecanNuts	Standard	Sprinkler : Micro spray	80	80	100	80	45	30	30	30	175	200	200	200	1250
Vine-table	Medium	Sprinkler : Micro spray	200	120	80	80	45	30	30	30	75	195	200	200	1285
Vine-wine	Medium	Sprinkler : Micro sprinkler	150	150	45	15	45	30	30	30	75	165	150	150	1035

Table 4.19: Gross crop water requirements: Upington-Kakamas (mm/ha)

CROP	CROPTION	IRRISYSTEM	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Citrus	Average	Flood : Border	300	240	180	60	120	60	120	180	240	300	240	240	2280
Cotton	Medium	Flood : Border	300	240	60	0	0	0	0	0	0	300	240	240	1380
Cotton	Medium	Flood : Border	240	240	300	60	0	0	0	0	0	0	180	240	1260
Datepalm	Standard	Flood : Border	240	240	300	240	240	180	120	120	120	120	240	300	2460
Lucerne	Semi-dormant	Flood : Border	240	240	300	180	120	120	60	120	180	240	240	300	2340
Maize-late-plant	Short variety	Flood : Border	300	240	240	240	60	0	0	0	0	0	0	0	1080
Maize-late-plant	Short variety	Flood : Border	240	240	300	120	0	0	0	0	0	0	0	180	1080
Olives	Standard	Flood : Border	240	240	300	240	240	120	60	120	60	240	240	300	2400
Peas	Standard	Flood : Border	0	0	0	0	0	120	120	180	180	0	0	0	600
PecanNuts	Standard	Flood : Border	300	240	240	240	120	60	60	60	120	300	240	240	2220
Vine-table	Medium	Flood : Border	300	240	120	120	120	60	60	60	120	300	240	240	1980
Vine-wine	Medium	Flood : Border	300	240	120	120	60	60	60	60	120	300	240	240	1920
Wheat-med	Early July	Flood : Border	0	0	0	0	0	0	120	180	240	300	0	0	840
Wheat-med	Early June	Flood : Border	0	0	0	0	0	120	120	180	300	60	0	0	780
Maize-late-plant	Short variety	Sprinkler : Centre pivot	120	200	200	120	0	0	0	0	0	0	0	0	640
Maize-late-plant	Short variety	Sprinkler : Centre pivot	180	180	180	40	0	0	0	0	0	0	0	60	640
Wheat-med	Early July	Sprinkler : Centre pivot	0	0	0	0	0	0	75	135	185	185	0	0	580
Wheat-med	Early June	Sprinkler : Centre pivot	0	0	0	0	0	75	60	150	190	15	0	0	490
Citrus	Average	Sprinkler : Drip	165	135	120	30	75	60	60	105	150	150	150	150	1350
Datepalm	Standard	Sprinkler : Drip	200	200	200	200	80	100	80	80	100	80	200	200	1720
Olives	Standard	Sprinkler : Drip	220	180	200	60	60	45	30	30	30	135	150	200	1340
PecanNuts	Standard	Sprinkler : Drip	60	60	75	45	25	25	25	25	50	250	250	250	1140
Vine-table	Medium	Sprinkler : Drip	200	100	80	80	30	15	30	15	30	140	200	220	1140
Vine-wine	Medium	Sprinkler : Drip	150	135	45	30	30	15	15	15	35	120	150	165	905
Citrus	Average	Sprinkler : Micro spray	165	135	120	30	75	60	60	105	150	150	150	150	1350
Datepalm	Standard	Sprinkler : Micro spray	250	250	250	250	80	100	80	80	100	80	200	250	1970
Olives	Standard	Sprinkler : Micro spray	250	225	250	60	60	75	60	60	75	150	150	275	1690
PecanNuts	Standard	Sprinkler : Micro spray	120	108	132	96	45	30	30	30	135	250	250	262	1488
Vine-table	Medium	Sprinkler : Micro spray	200	100	80	80	45	30	30	30	50	140	200	220	1205
Vine-wine	Medium	Sprinkler : Micro spray	150	150	75	45	45	30	30	30	75	165	150	150	1095
Cotton	Medium	Sprinkler : Quick-coupling	500	350	50	0	0	0	0	0	0	150	200	300	1550
Cotton	Medium	Sprinkler : Quick-coupling	200	200	250	50	0	0	0	0	0	0	150	200	1050

Table 4.20: Gross crop water requirements: Augrabies-Blouputs (mm/ha)

CROP	CROPTION	IRRISYSTEM	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Citrus	Average	Flood Border	300	240	240	120	120	60	120	300	240	300	240	240	2520
Citrus	Average	Sprinkler Drip	165	135	120	30	45	30	30	105	150	150	150	150	1260
Citrus	Average	Sprinkler Micro spray	150	135	120	45	60	40	70	150	150	150	150	165	1385
Cotton	Medium	Flood Border	300	240	60	0	0	0	0	0	0	180	240	240	1260
Cotton	Medium	Flood Border	240	240	300	60	0	0	0	0	0	0	180	240	1260
Lucerne	Semi-dormant	Flood Border	240	240	300	240	240	120	60	60	300	240	240	300	2580
Vine-table	Medium	Flood Border	300	240	120	120	120	60	60	60	120	300	240	240	1980
Vine-table	Medium	Sprinkler Drip	150	135	75	60	30	15	30	15	45	150	150	165	1020
Vine-table	Medium	Sprinkler Micro spray	200	200	80	45	45	30	30	75	190	200	200	1325	
Vine-wine	Medium	Flood Border	300	240	120	120	120	60	60	60	60	240	240	240	1860
Vine-wine	Medium	Sprinkler Drip	150	135	45	30	30	15	30	15	30	105	150	165	900
Vine-wine	Medium	Sprinkler Micro spray	150	135	75	60	45	30	30	30	45	105	150	165	1020
Beans Green	Standard	Flood Border	0	0	180	120	120	0	0	0	0	0	0	0	420
Beans Green	Standard	Sprinkler Drip	0	0	75	60	60	0	0	0	0	0	0	0	195
Beans Green	Standard	Flood Border	0	0	0	0	0	0	0	0	180	240	240	0	660
Beans Green	Standard	Sprinkler Drip	0	0	0	0	0	0	0	0	70	120	200	0	390
Brinjals	Standard	Flood Border	0	0	180	120	60	120	60	0	0	0	0	0	540
Brinjals	Standard	Sprinkler Drip	0	0	60	50	60	60	15	0	0	0	0	0	245
Brinjals	Standard	Flood Border	120	0	0	0	0	0	0	0	120	180	240	300	960
Brinjals	Standard	Sprinkler Drip	120	0	0	0	0	0	0	0	45	115	230	260	770
Citrus	Average	Sprinkler Drip	150	135	120	45	30	15	15	15	135	150	150	165	1125
Citrus	Average	Sprinkler Micro spray	165	135	120	30	30	15	30	75	150	150	150	150	1200
Datepalm	Standard	Flood Border	240	240	300	240	120	120	60	120	60	120	120	300	2040
Datepalm	Standard	Sprinkler Drip	200	200	200	200	40	60	40	40	40	200	200	200	1460
Datepalm	Standard	Sprinkler Micro spray	250	250	250	250	40	60	40	40	40	40	200	250	1710
Green peppers	Standard	Flood Border	0	0	180	60	120	60	0	0	0	0	0	0	420
Green peppers	Standard	Sprinkler Drip	0	0	75	60	60	45	0	0	0	0	0	0	240
Green peppers	Standard	Flood Border	0	0	0	0	0	0	0	0	180	180	240	180	780
Green peppers	Standard	Sprinkler Drip	0	0	0	0	0	0	0	0	75	175	200	90	540
Lucerne	Semi-dormant	Flood Border	240	240	180	120	120	0	0	0	120	120	240	300	1680
Lucerne	Semi-dormant	Sprinkler Quick-coupling	200	200	150	100	100	0	0	0	250	200	200	250	1850
Maize-early-plant	Short variety	Flood Border	240	240	240	0	0	0	0	0	0	0	120	180	1520
Maize-early-plant	Short variety	Sprinkler Quick-coupling	240	240	220	0	0	0	0	0	0	0	100	170	970
Mango	Standard	Sprinkler Drip	75	60	60	75	45	0	30	50	200	200	130	60	985
Mango	Standard	Sprinkler Micro spray	75	60	60	60	60	0	30	105	200	220	130	60	1060
Oats	Standard	Flood Border	0	0	0	120	60	120	120	60	0	0	0	0	480
Oats	Standard	Sprinkler Quick-coupling	0	0	0	100	50	100	50	50	0	0	0	0	350
Pumpkin	Winter plant	Flood Border	0	0	0	0	0	0	0	120	120	180	300	180	900
Pumpkin	Winter plant	Sprinkler Drip	0	0	0	0	0	0	0	70	80	140	185	120	595
Squash-baby	Summer plant	Flood Border	60	240	120	120	120	0	0	0	0	0	0	0	660
Squash-baby	Summer plant	Sprinkler Drip	15	120	150	60	45	0	0	0	0	0	0	0	390
Tomato	Table	Flood Border	0	0	180	120	120	120	120	0	0	0	0	0	660
Tomato	Table	Sprinkler Drip	0	0	75	60	60	75	60	0	0	0	0	0	330
Tomato	Table	Flood Border	240	0	0	0	0	0	0	0	240	240	240	300	1260
Tomato	Table	Sprinkler Drip	250	0	0	0	0	0	0	0	90	165	150	240	895
Vine-table	Medium	Sprinkler Drip	150	90	80	80	0	0	0	0	20	120	150	185	855
Vine-table	Medium	Sprinkler Micro spray	200	100	80	80	15	15	15	15	35	140	200	220	1115
Watermelon_late	Winter plant	Flood Border	0	0	0	0	0	0	0	120	180	240	180	0	720
Watermelon_late	Winter plant	Sprinkler Drip	0	0	0	0	0	0	0	60	105	195	105	0	465

Table 4.21: Gross crop water requirements: Blouputs – Alexander bay (mm/ha)

CROP	CROPOPTION	IRRISYSTEM	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Beans_Green	Standard	Flood : Border	0	0	180	120	120	0	0	0	0	0	0	0	420
Beans_Green	Standard	Sprinkler : Drip	0	0	75	60	60	0	0	0	0	0	0	0	195
Beans_Green	Standard	Flood : Border	0	0	0	0	0	0	0	0	180	240	240	0	660
Beans_Green	Standard	Sprinkler : Drip	0	0	0	0	0	0	0	0	70	120	200	0	390
Brinjals	Standard	Flood : Border	0	0	180	120	60	120	60	0	0	0	0	0	540
Brinjals	Standard	Sprinkler : Drip	0	0	60	50	60	60	15	0	0	0	0	0	245
Brinjals	Standard	Flood : Border	120	0	0	0	0	0	0	0	120	180	240	300	960
Brinjals	Standard	Sprinkler : Drip	120	0	0	0	0	0	0	0	45	115	230	260	770
Citrus	Average	Sprinkler : Drip	150	135	120	45	30	15	15	15	135	150	150	165	1125
Citrus	Average	Sprinkler : Micro spray	165	135	120	30	30	15	30	75	150	150	150	150	1200
Datepalm	Standard	Flood : Border	240	240	300	240	120	120	60	120	60	120	120	300	2040
Datepalm	Standard	Sprinkler : Drip	200	200	200	200	40	60	40	40	40	40	200	200	1460
Datepalm	Standard	Sprinkler : Micro spray	250	250	250	250	40	60	40	40	40	40	200	250	1710
Green_peppers	Standard	Flood : Border	0	0	180	60	120	60	0	0	0	0	0	0	420
Green_peppers	Standard	Sprinkler : Drip	0	0	75	60	60	45	0	0	0	0	0	0	240
Green_peppers	Standard	Flood : Border	0	0	0	0	0	0	0	0	180	180	240	180	780
Green_peppers	Standard	Sprinkler : Drip	0	0	0	0	0	0	0	0	75	175	200	90	540
Lucerne	Semi-dormant	Flood : Border	240	240	180	120	120	0	0	0	120	120	240	300	1680
Lucerne	Semi-dormant	Sprinkler : Quick-coupling	200	200	150	100	100	0	0	0	250	200	200	250	1650
Maize-early-plant	Short variety	Flood : Border	240	240	240	0	0	0	0	0	0	0	120	180	1020
Maize-early-plant	Short variety	Sprinkler : Quick-coupling	240	240	220	0	0	0	0	0	0	0	100	170	970
Mango	Standard	Sprinkler : Drip	75	60	60	75	45	0	30	50	200	200	130	60	985
Mango	Standard	Sprinkler : Micro spray	75	60	60	60	60	0	30	105	200	220	130	60	1060
Oats	Standard	Flood : Border	0	0	0	120	60	120	120	60	0	0	0	0	480
Oats	Standard	Sprinkler : Quick-coupling	0	0	0	100	50	100	50	50	0	0	0	0	350
Pumpkin	Winter plant	Flood : Border	0	0	0	0	0	0	0	120	120	180	300	180	900
Pumpkin	Winter plant	Sprinkler : Drip	0	0	0	0	0	0	0	70	80	140	185	120	595
Squash-baby	Summer plant	Flood : Border	60	240	120	120	120	0	0	0	0	0	0	0	660
Squash-baby	Summer plant	Sprinkler : Drip	15	120	150	60	45	0	0	0	0	0	0	0	390
Tomato	Table	Flood : Border	0	0	180	120	120	120	0	0	0	0	0	0	660
Tomato	Table	Sprinkler : Drip	0	0	75	60	60	75	60	0	0	0	0	0	330
Tomato	Table	Flood : Border	240	0	0	0	0	0	0	0	240	240	240	300	1260
Tomato	Table	Sprinkler : Drip	250	0	0	0	0	0	0	0	90	165	150	240	895
Vine-table	Medium	Sprinkler : Drip	150	90	80	80	0	0	0	0	20	120	150	165	855
Vine-table	Medium	Sprinkler : Micro spray	200	100	80	80	15	15	15	15	35	140	200	220	1115
Watermelon_late	Winter plant	Flood : Border	0	0	0	0	0	0	0	120	180	240	180	0	720
Watermelon_late	Winter plant	Sprinkler : Drip	0	0	0	0	0	0	0	60	105	195	105	0	465

4.5.4 Base crop price levels

Table 4.22 presents the 2002 base crop price for each crop product. Since crop prices are determined on the international market, it should be obvious that only quality, time of season, and transport cost can make a difference to the farm gate price between regions.

For example, the price of wheat is exactly the same between Vaalharts and Upington. However, Upington is much further away from the South African market than Vaalharts. The average table grape price for the Orange River for the 2001/2002 season was R57 per 4.5 kg carton. However, there is approximately a R3 per 4.5 kg carton difference in average weighted price between Blouputs and Boegoeberg, which amounts to about R12 000 per ha difference in gross income.

Table 4.22: Base (2002) crop prices

Crop	Unit	VaalH	VdKDR	DP	Boegoe	UpKaka	AugBlou
Wheat.g01	Ton	1,500	1,500	1,500	1,450	1,450	1,400
Groundn.g01	Ton	3,913	3,913	3,913			
Maize.g01	Ton	1,300	1,300	1,300	1,250	1,250	1,200
Cotton.g01	Kg	3.9	3.9	3.9	3.9	3.9	3.7
Drybean.g01	Ton	5,000	5,000	5,000			
Sunflower.g01 -seed	Ton	13,000	13,000	13,000			
Soyabean.g01	Ton	2,250	2,250	2,250			
Oats.g01	Ton	1,000	1,000	1,000	950	950	
Barley.g01	Ton	1,650	1,650	1,650	1,650	1,650	1,650
CarrotsS.g01	Ton	140	140	140			
Potatoes.g01	Ton	2,168	2,168	2,168			
Onions.g01	Unit	15	15	15			
Watermelon.g01	Unit	4.5	4.5	4.5			
Lucern.g01	Ton	650	650	650	650	630	630
Pecan.(g12*g20)	Kg	16.5	16.5	16.5			
Olives.(g10*g20)	Ton	5,400	5,401	5,401			
Citrus.(g12*g20)	Kg	1.6	1.6	1.6		1.5	1.5
RWine.Irrig.(g4*g20)	Ton	1,200			1,200	1,250	1,150
WWine.Irrig.(g4*g20)	Ton	725	725	725	650	650	630
Drygrape.Irrig.(g04*g20)	Ton				850	894	894
Juigrpae.Irrig.(p4*p20)	Ton				460	460	450
Tablegr.Irrig.(g3*g20)	Ton				12,064	12,660	12,729

Source: Farm survey data, GWK, OABS (2002)

4.5.5 Livestock data

Although this project is primarily concerned with irrigated agriculture, some of irrigation farms, especially in the Vanderkloof-Douglas-Prieska and Douglas-Prieska regions, are also integrated with an extensive livestock farming unit or semi-intensive feedlot enterprise. Livestock was not modelled in great detail since it is relatively unimportant on most of the irrigation farms in the Vaalharts, Boegoeberg, Upington-Kakamas, and Blouputs regions where irrigation farming is a specialised business (see Table 4.23). Since livestock was included in the models in a relatively simple way, the same livestock enterprise budgets were used.

Table 4.23: Livestock budget summary

Livestock enterprise	Gross income per LSU (Rand)	Direct costs/LSU* (Rand)	Gross Margin/LSU (Rand)
Sheep	1273	215	1058
Beef	1196	412	784
Goats	1146	196	950

* Excluding fixed labour and other overhead costs

Imbedded in the models is a minimum cost feed ration module that satisfies the nutrient requirements of the livestock based on three quality measures:

- The bulk feed requirement per day per livestock unit
- The Total Digestible Nutrient requirement (TDI)
- The Total Protein requirement (TPR)

Table 4.24 is a summary of the feed demand per LSU. Table 4.25 shows the nutrient contents per unit of raw material.

Table 4.24: Feed demand per livestock unit (%)

Quality requirement	Sheep	Beef	Goats
Bulk	1	1	1
TDN	0.65	0.6	0.6
TRP	0.12	0.09	0.09

Table 4.25: Nutrient content of raw materials (%)

Nutrient contents	Bulk	TDN (%)	TRP (%)
Wheat Grain	1	0.65	0.12
Wheat Hay	1	0.6	0.1
Oats Grain	1	0.65	0.12
Oats Hay	1	0.6	0.1
Barley Grain	1	0.65	0.12
Barley Hay	1	0.6	0.1
Maize Grain	1	0.6	0.11
Maize Hay	1	0.58	0.06
Groundn. Hay	1	0.6	0.11
Lucern Hay	1	0.63	0.12
Lick Pmix	1	0.8	0.25
Lhay Pmix	1	0.63	0.12
Hpveld Pasture	1	0.6	0.095

The model also specifies maximum and minimum levels of each raw material that may be included in the feed ration.

4.5.6 Other important data

The model also specifies that a maximum short-term loan of 30% of the value of the capital investment can be used for operating costs if necessary. This amount must be repaid at the end of each year (beginning of the next year) before another short-term loan can be obtained. However, this amount is not really important since the model is structured in such a way that the typical farm cannot borrow more money than can be paid back. A 17% nominal interest rate on loans and a 10% nominal interest rate on a positive bank account were assumed for the purpose of this study (2002 values). It was assumed that the inflation rate is 7% and all interest rates are converted to real interest rates since the model is based on constant prices and technology.

All monetary values are automatically discounted to present value in the model by using a 9% discount rate (14% long-term interest rate minus 7% for inflation plus 2% for additional risk in agriculture).

The age distribution of long-term crops was obtained from survey data and from the annual tree/vine census from the Deciduous Fruit Producers Trust (DFPT) and from SA Wine Industry Statistics (SAWIS). The maximum lifespan of all long-term crops (excluding lucerne) is assumed to be 20 years. Although this is a bit short for pecan nuts and olives, it was necessary to simplify the model for computational purposes.

4.6 SUMMARY AND IMPLICATIONS FOR MODELLING

It is a daunting task to set up a database to run 22 typical farms in seven regions over a 20-year planning horizon. The models are structured in such a way to enable the database to be updated with relative ease. However, there should be no misunderstanding regarding the input that will be required to update all the data from time to time (preferably at least every two to three years).

The following implications for the models are important:

- The Stratified Random Sampling method used with unequal sampling fractions allows the population to be divided into subpopulations (typical farms) that are less variable than the original population (Northern Cape irrigation areas). It was also pointed out that different parts of the population can be sampled at different rates when it is advisable (e.g. due to time and money constraints).
- The irrigation regions were selected to represent typical farms in 7 irrigation regions for the Northern Cape. Relatively homogeneous areas in terms of farm structure, water allocation per ha, and physical location of the stretch of river were considered in selecting the regions.
- For the purposes of this report, the Vaalharts, Vanderkloof/Riet River, and Douglas / Prieska regions are referred to as the North Eastern regions, Boegoeberg as the middle region, and the Upington/Kakamas, Augrabies/Blouputs, and Below Blouputs (BBlou) as the Western Regions.
- Total estimated water use entitlements for irrigation in the Northern Cape (including boreholes) are estimated at approximately 142 921 ha (approximately 1606 million m³).
- The North Eastern regions contribute approximately 60%, the middle 8.4%, and the Western regions 42% to total irrigation water use entitlements. However, in general, the Eastern regions produce higher valued crops than the North Eastern regions.
- Aggregation factors are used to aggregate typical farms first to the total for the sub-region and then to the total for the Northern Cape. A lack of information on total production for individual crops necessitates estimates based on farm survey data and total irrigation water use entitlements for the Northern Cape. However, to reach the

objectives of this study, the authors believe that the assumptions for aggregating current (2002) crop production areas to total irrigation water use entitlement in the ratios calculated from the farm survey data are justified since there is no other base to work from. It was pointed out earlier that it is quite possible for the actual irrigated area to be over-estimated in this way since several crops use more water than the water allocation per ha. On the other hand, more crops use less water than the water allocation per ha.

- There is great variance between typical farms and regions in terms of farm structure, labour use per ha, and the ratio between canal abstraction and abstraction directly from the river. This is important for understanding the results of the models, since it will determine the reaction of each typical farm to changes in parameters when scenarios are analysed. Different typical farms will react differently when the same parameters are changed because of economies of scale, farm structure, water usage, etc.
- Differences in yield, direct variable costs, and alternative crop prices were discussed. It should be clear that these differences will also be reflected in modelling results, especially when the scenarios induce structural changes.
- Since water is probably the most important input in irrigation farming, crop water requirements will also have a major impact on modelling results. The demand for irrigation is a derived demand from the demand / profitability of irrigation crops. Therefore, if market risks are high and profitability is low, water demand will decrease for certain crops. In any event, there will be "winners" and "losers" since not all crops are necessarily affected by the same market impacts at the same time.
- The reader may perceive that because there is less emphasis in this report on the livestock industry, that it is not important. However, the importance of the livestock industry in the Northern Cape and the link to irrigation farming has been pointed out. Since the models are already extremely complicated, the livestock modelling part was carried out in a fairly simple way by including just three quality parameters (dry matter or bulk, total digestible nutrients and total protein). This relatively simple way of handling the livestock enterprise does not imply that the models cannot capture substitution between feed crops for use as feed on the farm and feed crops that can be sold for cash depending on crop price levels.

- The choice of interest rates and discount rates in this study is not really important since these parameters can easily be changed.
- It was also pointed out that the maximum amount of short-term loans specified is also not that important since the models are structured in such a way that typical farms will never borrow more than is absolutely necessary and can be repaid within one year.

Finally, modellers often say "Garbage in, Garbage out". This saying is, of course, the essence of any modelling exercise especially on the scale of the modelling exercise conducted in this study. However, the research team discussed the data used in this study with several stakeholders on numerous occasions and are convinced that this is the best information available at present. This does not imply that there is no scope for improvement as new information becomes available.

CHAPTER 5

MARKET PROSPECTS FOR CROPS

5.1 INTRODUCTION

It was pointed out in Chapter 2 that risk management is the systematic application of management policies, procedures, and practices to the tasks of identifying, analysing, assessing, treating, and monitoring risk. It was also pointed out that effective risk management involves anticipating possible difficulties and planning to reduce their consequences, not just reacting to unfavourable events as they occur. The intention of this chapter is to build on the risk management literature discussed in Chapter 2 and use market information for selected crops to anticipate market risks. The following general aspects are important with regard to the market situation for crops:

- Local farmers can expect not to be protected from imports when the Rand is strong since most of our crops are already close to import parity price. Therefore local prices are not expected to rise substantially because of a devaluating exchange rate.
- On the positive side, the tremendous input cost increases experienced since the 2002 season can be expected to flatten off.

It is not the purpose of this study to do a comprehensive market study for every possible crop that is physically and biologically adapted for all the irrigation sub-regions of the Northern Cape. The reader must be aware that market analysis is part and parcel of farming activity since the market conditions for most crops can change overnight. Since the base year for the models is 2002 only the risk elements affecting the most important crops are addressed in this chapter from a market study that was conducted in 2002/2003. An exception is table grapes and dry grapes since several scenarios depend on a good insight from the reader into the evolution of these industries in the years proceeding the base year (2002/2003). This chapter will therefore also include the results of the 2002 market study for these crops. During 2006 the market analysis was updated for all crops and can be

found in Appendix A. Most of the information for the market analysis was obtained from the United States Department of Agriculture (USDA), the Food and Agricultural Organisation (FAO), and Agri Mark Trends (AMT), specialists in market information for grains, oil seeds, and livestock. Information pertaining to deciduous fruit was obtained from Optimal Agricultural Business Systems (OABS) which manages an Information Bureau for the Deciduous Fruit Producers Trust. The most important aspect of this Chapter is to identify risks and trends and considering strategies to counter them.

During 2003, three workshops were held in the Orange River region (Douglas, Upington, and Augrabies) where participants were asked to assist the research team in identifying market and other risks for the crops grown in the respective regions. The outcome of these workshops is discussed in the final section of this chapter (summary and conclusion).

5.2 RISK FACTORS FOR MAIZE PRODUCTION

There are many potential risk factors in maize production under irrigation conditions. However, the following were identified as the most important:

- International stocks have a direct correlation with price.
- World consumption is strong and growing as the world population grows.
- China, the USA, and the southern hemisphere countries are the most important to monitor in terms of production.
- Great volatility of both the area planted as well as production.
- Yield is clearly in a definite growth trend.
- The exchange rate is important in calculating import parity, and the strengthening rand is an important risk factor for local prices.
- Local climatic conditions. For irrigated maize, this will not necessarily be short-term drought periods but micro-climatic conditions as well as hail storms and flood conditions.
- Bio-fuel and the demand for feedstock will most certainly start to play a major role in the maize industry.

Possible risk reducing strategies:

A timely and accurate market information system including international stocks, weather reports (in the most important producing countries), crop estimates (local and international), bio-fuel developments (medium to long-term impact), SAFEX price movements, exchange rate expectations and world politics that may impact on this, and world grain reports, etc. Farmers that do not have the capacity to set up a network to obtain all the necessary information should make use of credible market information service providers or consultants.

- Farmers should diversify their farming operations as far as possible. This strategy could include diversification into livestock to make use of crop residuals in the event of a crop failure and or to use own produced feed crops for livestock production in the event of extremely low prices. Every individual farmer should work out a risk reducing strategy for their own individual circumstances.
- Irrigation farmers are less vulnerable to drought, so more attention should be given to price risk compared to yield risk.
- Crop insurance.
- Input cost cutting strategies to reduce input costs without yield or quality losses.

5.3 RISK FACTORS FOR WHEAT PRODUCTION

The risk factors involved in wheat production are largely identical to those for maize:

1. The exchange rate is important in the calculation of import parity, and the strengthening rand is an important risk factor for local prices.
2. Northern hemisphere production impacts on international stock levels and therefore on the international price for wheat.
3. Local climatic conditions: for irrigated wheat, not necessarily short-term drought periods but micro-climatic conditions as well as hail storms and flood conditions.
4. Increasing input costs: although the recent strengthening of the rand was supposed to lead to a decrease in input costs, producers believe that input prices do not decline in relation to the strengthening of the rand.

The strategies for coping with market risk are exactly the same for wheat as maize.

5.4 RISK FACTORS FOR COTTON PRODUCTION

Apart from most of the normal climatic risks, there are a few others:

- Since China, the USA, and India dominate world production. Any climate impact on these countries has a huge impact on the international cotton market.
- The divergence between supply and demand is expected to widen to the greatest level in fifteen years. This tendency is positive for South African producers since it will positively impact on the international cotton price.
- A combination of high international prices and low local production is therefore expected to push prices to even higher levels.
- There is a strong substitution effect between wool and cotton, which are both natural fibres. It is therefore necessary to analyse international and national market conditions not only for cotton but also for wool.
- Demand for cotton seed is very much price elastic since cotton oil and oilcake are less popular than other oilseeds. A relatively small price increase will therefore induce a relatively large reduction in demand. In a similar way, relatively small increases in supply volumes will result in a surplus situation.

Implications for market risk strategies:

- Need for a good market analysis capacity.
- Need for diversification

5.5 RISK FACTORS FOR GROUNDNUTS

- World production and specifically China, India, and Nigeria determine the world price of groundnuts. Any variation in production in these countries, especially upward variation, is a risk for South African producers.

- World stocks are also a major determinant of international prices. It is clear that there is a close correlation between stocks and prices.
- In the long run, demand for groundnuts in the EU, Indonesia, Canada, and, for South African producers, Japan, will be a major driving force for growth in the industry.
- The demand for better quality nuts is increasing, and other uses, including the edible market, have increased by nearly 6% per year since the 1992/93 season as the edible market in Europe expands.
- In South Africa, there is a close correlation between the maize and wheat price and the production area of groundnuts. Japan is a major importer of South African groundnuts. In order to satisfy this market, constant supply and good quality are important factors. A substantial fluctuation in domestic production makes it difficult to establish a stable export market. This variation in production volumes is a strategic risk for the industry.
- Exports are a large part of the total domestic production and represent a substantial share of total consumption. One result of a small crop is that only a limited quantity of groundnuts is being exported.
- Exchange rate fluctuations
- Input costs (relative high input cost due to intensive labour requirements).
- Micro-climatic conditions.

Risk reducing strategies for groundnuts will be similar to those for wheat and maize.

5.6 RISK FACTORS FOR VEGETABLES

Considerable fluctuation in the vegetable markets makes medium- or long-term predictions impossible. However, there is inherently strong local demand for vegetables as part of a staple diet. Because of the difficulty in market projections as well as the relatively high management requirement, vegetables are considered to be high-risk crops. The three main vegetables grown in South Africa in terms of value of production are potatoes (R1078 mill.), tomatoes (R459 mill.), and onions (R286 mill.).

It is a fact that farmers react to current market conditions when they make their planting decisions. However, wise farmers will plant more when present conditions are bad and less

when conditions are good because they know that chances of conditions reversing next season are good.

5.7 TABLE GRAPES

The market report for table grapes does not distinguish between an international review and South Africa. The discussion focuses on a southern hemisphere (SH) perspective. All the information in this section was obtained from Optimal Agricultural Business Systems (OABS) and the Deciduous Fruit Information Bureau. OABS is responsible for supplying the table grape industry with up-to-date logistical and market information and also manages a statistical database for the industry. The information bureau is independent and the only source of official industry statistics.

5.7.1 Southern hemisphere supplies

Chile is the biggest competitor against South African grapes in the European market. Table 5.1 shows that South Africa is the largest producer of table grapes in the southern hemisphere. Australia is not included in these figures since they do not export their product to the same markets. South Africa, Chile, Argentina, and Brazil are the major suppliers to the UK and Europe.

Table 5.1: S.Hemisphere table grape exports to Europe and UK (million 5.5 kg cartons)

Country	2001	2002	*2003
Argentina	3.6	3.6	3.6
Chile	15.8	16.2	17
SA & Namibia	28.2	36.6	38.8
Brazil	1.2	1.5	2.0
Total to Europe and UK	47.8	57.9	61.4

*2003 Estimate

Figure 5.1 shows that 84% of South African table grape exports go to Europe and the UK. The UK is primarily a Seedless market: 50% of Red and White Seedless grapes go to the UK. Europe receives 63% of the exported crop.

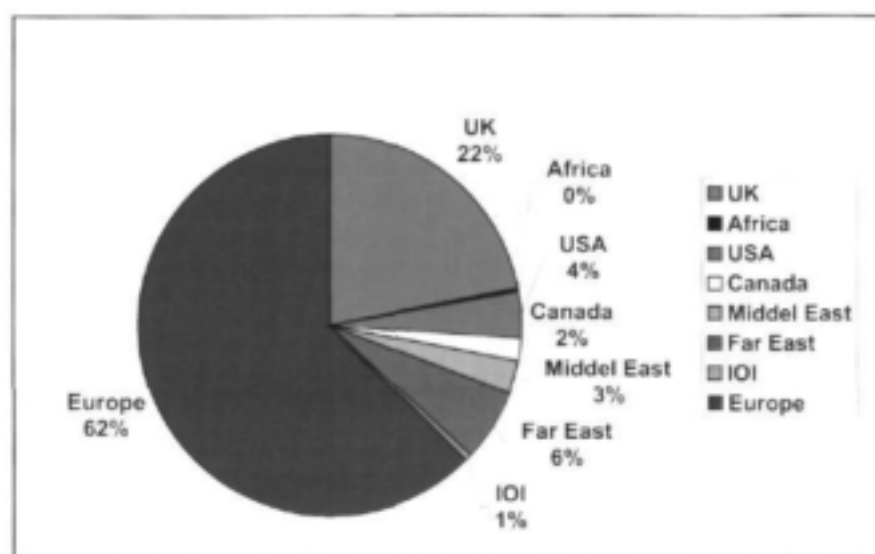


Figure 5.1: Export destinations for South African table grapes

Figure 5.2 represents the export volumes from southern hemisphere countries to the UK and Europe market during the 2002/2003 season.

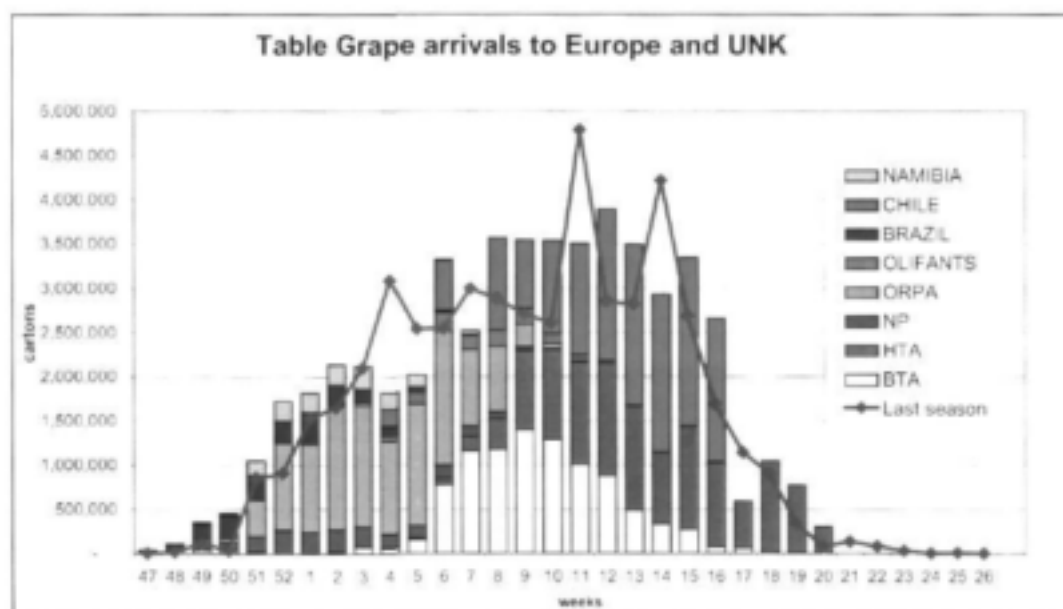


Figure 5.2: Table grape export suppliers to Europe and the UK

From Figure 5.2, it is clear that grapes from Brazil compete against grapes from the Northern Province and early grapes from the Orange River area, whereas grapes from

Chile compete against grapes from the Berg River and Hex Valley. Also, although volumes from Brazil are relatively small, they can have a major impact on price levels early in the season. It is therefore of paramount importance for the industry to promote collaboration between southern hemisphere exporters to coordinate their efforts where possible to ensure that markets are not oversupplied.

5.7.2 Demand

5.7.2.1 UK Market

The U.K. is the most mature market for SA deciduous products. Volume exports of SA grapes have grown over the past five years. The UK, like the US, has become principally a seedless market. Grapes (mainly seedless) represent one of the fastest growing fresh produce products available in the UK portfolio. UK consumers are exposed to grapes over a 52-week season, from various global sources. SA has an established reputation as a reliable supplier of quality grapes to the UK market. The main competition to SA grapes during the SH season emanates from Chile.

The UK has a population of 59.1 million, of which there are an estimated 40 m potential consumers of grapes. In reality, probably 19 million regularly consume the fruit. There are 22 million households with an average of 2.7 persons per household. The latest available GDP figures are £891 billion with private consumption representing 65.9% of the total. The unemployment rate is low, around 5%. Inflation rates are low, and interest rates have tended to be stable.

5.7.2.2 European Market

Our major competitors are Chile, Brazil, and Argentina. They could prove to be some of our greatest allies. Fortunately, SA Seedless grapes peak in weeks 4 to 7 whereas the Chilean seedless grapes only arrive from week 10. A further complication is that the EU consumer's expendable income is under pressure, as all products have become more expensive, although fresh fruit has not experienced this same inflationary trend.

5.7.3 South African production trends

Table 5.2 shows the SA Table Grape Exports per variety group from 1997 to 2002. It is clear that most South African table grapes are in the white seedless group, followed by black seeded, white seeded, and red seeded.

Table 5.2: SA exports per variety group (million 5.5 kg cartons)

VARIETY GROUP	1997	1998	1999	2000	2001	2002
BLACK SEEDED	9.3	11.5	12.9	12.1	11.59	11.09
RED SEEDED	0.9	2.2	3.9	5.5	6.33	6.7
RED SEEDLESS	0.93	2.2	2.7	3	3.2	4.0
WHITE SEEDED	5.5	8	9.2	9.8	8.5	8.3
WHITE SEEDLESS	5.4	6.4	9.6	7.8	9.2	14.0
Grand Total	22.03	30.3	38.3	37.2	38.82	45.09

Source: Paltrack (2003); PPECB (2003)

Figure 5.3 shows table grape intake per region. It is clear that the Northern Province and the Orange River dominate the early part of the season (week 44 to week 2), the Berg River is in the middle (week 3-6), and the Hex River in the middle to late season (week 7-16). Of relevance to this study is the fact that Namibian grapes are also part of the early season.

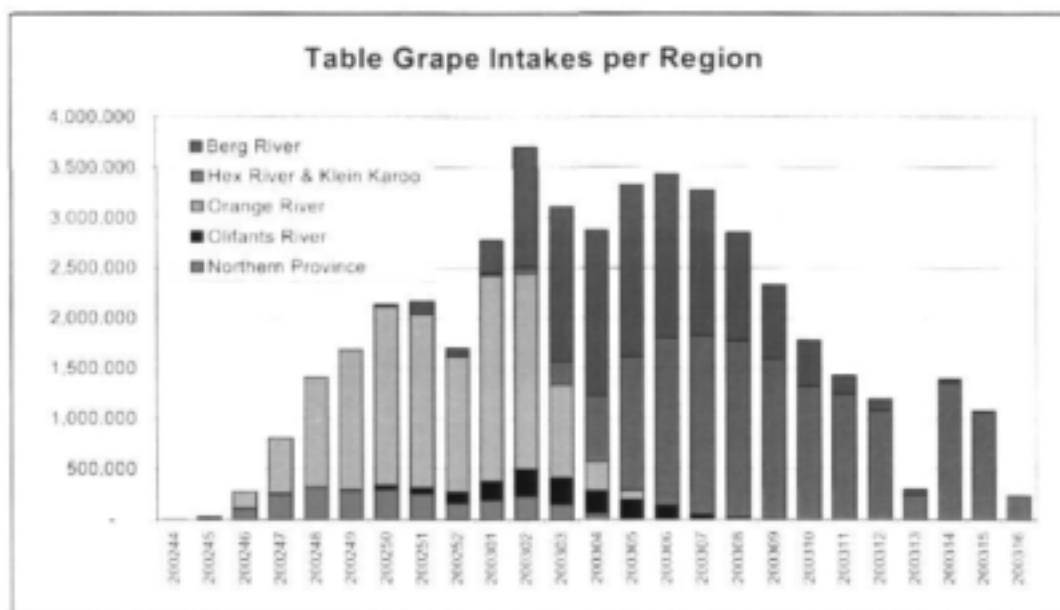


Figure 5.3: SA table grape intake per region

The Namibian grapes at Auschenkehr are approximately 10 days earlier than the earliest grapes on the South African side of the Orange River. The impact of this will be discussed later in this report.

Table 5.3 is a projection of growth per cultivar for the South African table grape industry up to 2006. It is clear that White Seedless varieties will be responsible for most of the growth, followed by Red Seedless and Red Globe. Also, it is clear that the popularity of White Seeded grapes is dwindling.

Further, total production volume will increase from around 44 million 5.5 kg cartons to approximately 58 million cartons by 2006, a growth of 14 million cartons in four years (30% growth). The Orange River region will be responsible for most of this growth. Major constraints in the other regions are land and water.

Also, the Berg and Hex Rivers, which produce later in the season, are linked to the earlier regions since prices early in the season dictate prices later in the season. It was pointed out earlier that Namibian grapes are earlier than Orange River grapes. Substantial growth is expected for the Namibian industry, which will push production on the South African side of the river more towards the "middle" section of the market.

The high prices that farmers received in the Blouputs region in the beginning of the season will come under pressure in future years. The lower price earlier in the season will also impact on the other production regions. However, on the positive side, the situation can be prevented if the South African industry joins forces with its Namibian neighbours and coordinates marketing efforts to ensure that the price in the beginning of the season is pushed as high as possible.

Only the future will tell if the two countries can manage to achieve this.

Table 5.3: Export projections in 4.5 kg cartons X 1000

VARIETY	Actual	Actual	Actual	Projection			
	2000	2001	2002	2003	2004	2005	2006
Thompson / Sultana	5,433	5,851	8,958	9,900	10,400	10,800	11,100
Sugraone	2,293	2,943	3,871	4,400	4,800	5,200	5,600
Regal Seedless	43	216	782	2,050	2,750	2,950	3,150
Prime Seedless	0	111	396	1,650	2,500	3,500	4,000
Other	46	45	51	100	90	90	90
Total White seedless	7,815	9,166	14,058	18,100	20,540	22,540	23,940
Flame Seedless	501	632	1,589	1,851	2,100	2,320	2,520
Sunred Seedless	2,503	2,561	2,178	2,512	2,372	2,272	2,172
Crimson Seedless	20	85	253	792	1,500	2,000	2,400
Ralli Seedless	0	0	0	5	20	70	150
Other	0	0	0	0	0	0	0
Total Red seedless	3,024	3,278	4,020	5,160	5,992	6,662	7,242
Midnight Beauty	0	0	0	1	10	100	200
Other	0	0	0	0	0	0	0
Total Black seedless	0	0	0	1	10	100	200
Total seedless	10,839	12,444	18,078	23,261	26,542	29,302	31,382
Queen of the Vineyard	141	97	68	60	50	40	40
Bien Donne	549	461	247	250	200	150	100
Waltham Cross	2,719	2,042	1,750	2,000	2,000	2,000	2,000
Bellevue / Peridot	54	45	3	3	3	3	3
New Cross	70	25	13	10	10	0	0
Dauphine	5,295	4,748	4,992	4,900	4,800	4,750	4,500
Majestic	483	593	556	500	400	300	250
Victoria	367	481	563	800	900	1,000	1,000
Muscat Supreme	124	38	81	81	81	81	81
Ander	51	42	67	67	67	67	67
Total White seeded	9,853	8,572	8,340	8,671	8,511	8,391	8,041
Black Gem	342	363	351	350	350	350	350
Dan Ben Hannah	1,889	1,974	1,632	1,900	1,900	1,800	1,700
Sonita	164	77	55	55	55	55	55
Alphonse	2,146	2,056	1,990	1,900	1,800	1,700	1,600
La Rochelle	2,523	2,551	2,731	2,800	2,800	2,800	2,800
Bonheur	1,609	1,393	1,299	1,200	1,100	1,000	1,000
Barlinka	3,293	3,144	3,285	3,100	3,100	3,100	3,100
Red Globe	4,474	6,339	6,723	7,200	7,500	7,800	8,000
Piobella	1	0	0	0	0	0	0
Other	58	36	90	122	122	100	100
Total Black seeded	16,499	17,933	18,156	18,627	18,727	18,705	18,705
Total black minus Red Globe	12,025	11,594	11,433	11,427	11,227	10,905	10,705
TOTAL	37,191	38,949	44,574	50,559	53,780	56,398	58,128

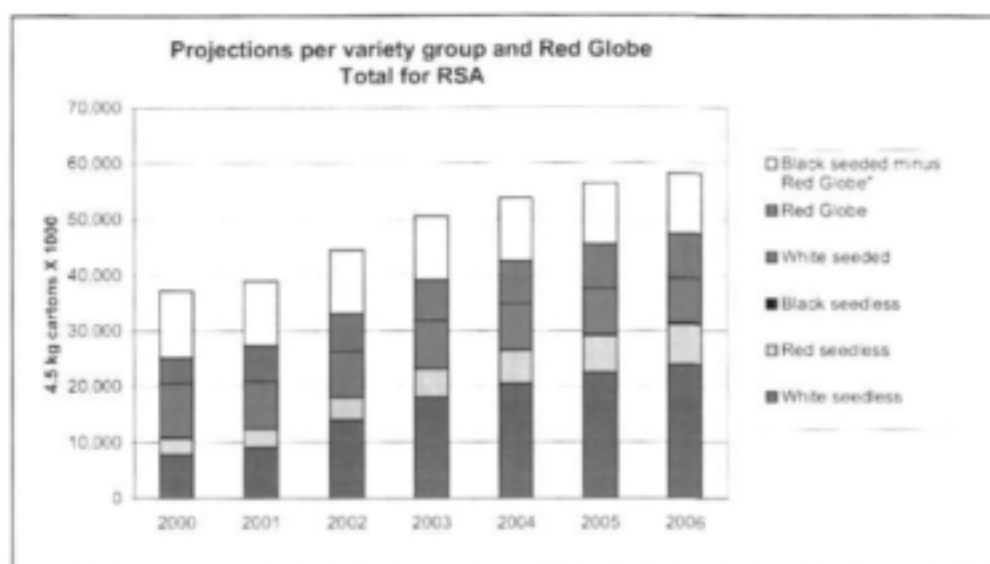


Figure 5.4: Projected growth per variety group

5.7.3.1 Impact of exchange rate on profitability

Table 5.4 shows the weighted average DIP prices for all table grape cultivars in all regions. Although there are substantial differences between regions, it is convenient to calculate a average price to analyse the profitability of table grapes at industry level. Although the 2002/2003 calculations are not available yet, it is expected that the strengthening of the rand during the season will reduce the average DIP price to approximately R20.

Table 5.4: Table grape weighted average DIP* payments per 5.5 kg carton

YEAR	DIP (Rand/carton)
1997/98	20.07
1998/99	25.06
1999/2000	23.08
2000/2001	37.80
2001/2002	43.83

Note: DIP = Delivered in port

A calculation was made to show the impact of the exchange rate fluctuations. The calculation is fairly simplistic in that it is assumed that the cost structure stays the same. However, it is common knowledge that input cost does not come down immediately if the local currency strengthens against other currencies. The assumption is therefore not too far

fetched, with the exception of transport (shipping) costs. The analysis in Table 5.5 clearly shows how a strengthening rand exchange rate impacts on farm profitability. It was mentioned earlier that the average DIP price for the industry is expected to will be approximately R20 for the 2002/2003 season. At this price, table grapes are exporting at a loss.

Table 5.5: Table grape profitability (Rand)

Rand/Euro exchange rate	10.0	9.5	9.0	8.5	8.0	7.5	7.0
	Rand	Rand	Rand	Rand	Rand	Rand	Rand
Gross price (Euro)	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Gross price (Rand)	80.00	80.00	76.00	72.00	68.00	64.00	60.00
Import tariffs	6.35	6.35	6.35	6.35	6.35	6.35	6.35
Importers commission	6.93	6.93	6.93	6.93	6.93	6.93	6.93
Overseas handling costs	7.12	7.12	7.12	7.12	7.12	7.12	7.12
CIF	59.60	59.60	55.60	51.60	47.60	43.60	39.60
Insurance	0.43	0.43	0.43	0.43	0.43	0.43	0.43
Sea transport	9.00	9.00	9.00	9.00	9.00	9.00	9.00
FOB	50.17	50.17	46.17	42.17	38.17	34.17	30.17
Loading costs and port tax	1.53	1.53	1.53	1.53	1.53	1.53	1.53
Exporters commission	4.17	4.17	3.89	3.61	3.33	3.05	2.77
D.I.P.	44.47	44.47	40.75	37.03	33.31	29.59	25.87
DFPT levy	0.23	0.23	0.23	0.23	0.23	0.23	0.23
PPECB levy	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Transport to port	0.86	0.86	0.86	0.86	0.86	0.86	0.86
Production and packing costs	28.56	28.56	28.56	28.56	28.56	28.56	28.56
Net Farm Income (NFI)	14.58	14.58	10.86	7.14	3.42	-0.30	-4.02
Standard carton weight (kg)	4.50	4.50	4.50	4.50	4.50	4.50	4.50
NFI per ton	3,240	3,240	2,413	1,587	760	-67	-893

It is important to note that average production costs in the Orange River region are substantially higher than in other regions because of its remoteness. It is therefore obvious that lower prices will impact severely on table grape farmers in this region.

5.7.3.2 DIP price trends for the most important cultivars

Figure 5.24 to 5.27 are included to give the reader a feeling for the massive price fluctuations which can occur during the same season and between seasons. The reader should be aware that the 2001/2002 season was approximately two weeks late, which is reflected in the statistics.

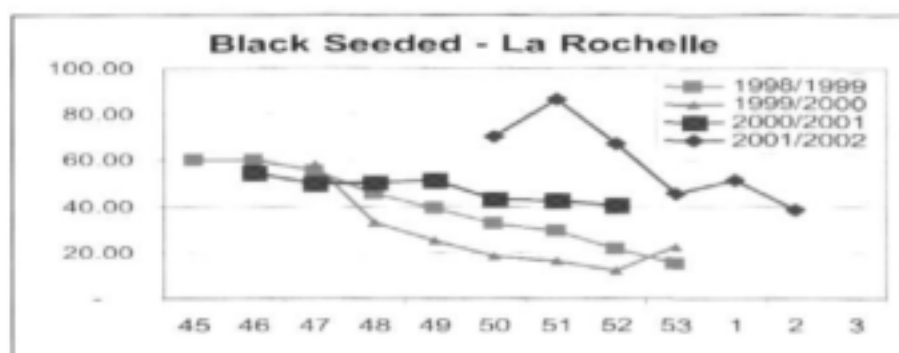


Figure 5.5: Black seeded price fluctuations

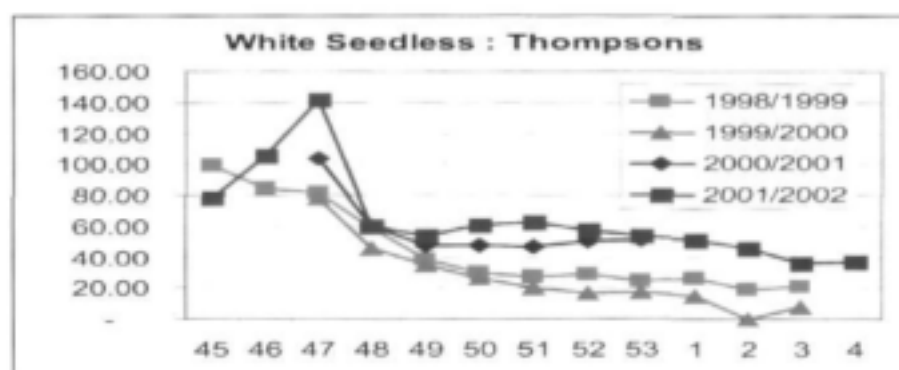


Figure 5.6: Thompsons price (white seedless) fluctuations

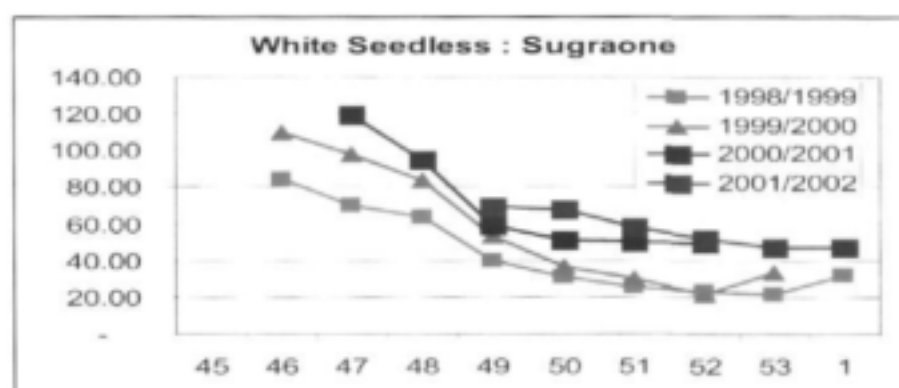


Figure 5.7: Sugraone (white seedless) price fluctuations

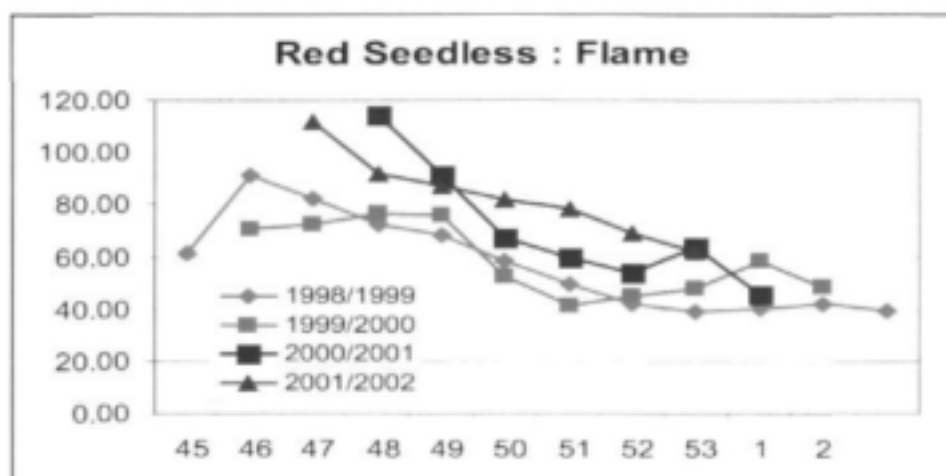


Figure 5.8: Red seedless price fluctuations

It is clear that the season starts with relatively high prices. However, prices decline every week of marketing. It is therefore obvious that the early regions will be more profitable than the later regions. Also, price decreases are not moderate but significant. A price can fall by as much as 30-40% percent within the first two weeks of marketing.

5.7.4 Risk factors for table grapes

During 1996, it was estimated that one hectare of export grapes provides an income equal to the Northern Cape per capita income for 2.96 persons. It is clear not only that a great deal of foreign exchange is earned but also that the industry creates substantial employment opportunities that could be doubled with expansion. However, expansion and developments in other regions entail substantial risks:

- Expansion in the market does not necessarily keep up with the impressive growth in production.
- Developments in Namibia can reduce profitability of table grapes in the Orange River.
- Infrastructure development could be too slow (roads, ports etc.)
- Climatic risks: the Orange River is known for its unexpected hail storms in the harvesting season as well as unexpected rain.
- New "bugs" in the region: exotic bugs appeared in the region in the 2003 season.

- New cultivar development: the lifetime of table grape cultivars tends to be much shorter than for other deciduous fruits.

Production costs in the Orange River (due to its remoteness) are relatively higher than in other production regions. If table grape prices come under pressure, profitability and return on capital investment will decline substantially. The author believes that the table grape industry will remain a high value industry in this region for the foreseeable future. However, individual farmers should be very careful not to indulge in excessive loan capital to finance expansions since relative price levels and profitability are sure to come under pressure in the years to come.

Implications for risk management strategies:

- Development of a good information system including crop estimates, regional intake information, shipments, market destinations, and retail prices.
- An effort to develop the local market to make the industry less vulnerable to international marketing conditions.
- Good market intelligence about southern hemisphere competitors, especially Chile and Brazil.
- A major effort to gain market access to new markets, to include a strong partnership with the National Department of Agriculture.
- A constant effort to reduce the logistical cost of export to remain internationally competitive.
- A constant effort to reduce local on-farm production cost.
- Diversification to enable farmers to absorb adverse marketing conditions.

5.8 DRIED GRAPES (RAISIN)

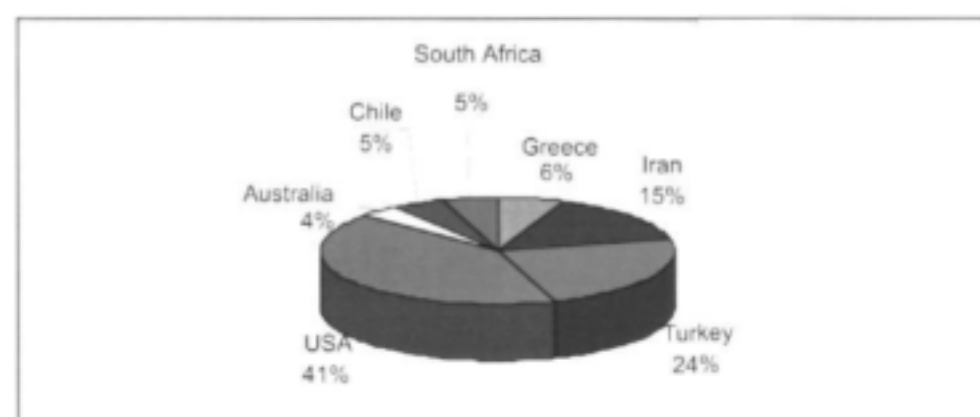
5.8.1 International overview

In 2002/03, dried grape production in selected producing countries is forecast to decline by 1%. Table 5.6 and Figure 5.9 shows the contribution to world production of selected countries.

Table 5.6 : Dried grape production – selected countries

C o u n t r y	E s t i m a t e d p a c k o u t f o r 2 0 0 2 (m e t r i c t o n n e s)
G r e e c e	4 9 . 0 0 0
I r a n	1 2 2 . 0 0 0
T u r k e y	1 9 0 . 0 0 0
U S A	3 3 6 . 0 5 0
A u s t r a l i a	3 2 . 2 0 0
C h i l e	3 8 . 0 0 0
S o u t h A f r i c a	4 0 . 4 9 6
T o t a l	8 0 7 . 7 4 6

Unfavourable weather conditions are likely to affect crop supplies in Turkey and Greece, while production in Mexico and the United States is projected to be the same as last year. In the southern hemisphere, favourable weather conditions and increased planting areas in Australia, Chile, and South Africa are expected to return dried grape crops to normal levels (FAO, 2003).

**Figure 5.9: Contribution of countries to total world production (2002):**

The USA is by far the biggest producer of dried grapes in relation to other countries, followed by Turkey and Iran. South Africa is responsible for only 5% of world production. The total production of dried grapes includes sultanas, raisins, goldens, and currants. Table 5.7 shows the domestic consumption of major producing countries.

Table 5.7 : Dried grapes - estimated domestic consumption of major producing countries

Country	Estimated domestic consumption (metric tonnes)
Greece	7,000
Iran	20,000
Turkey	25,000
USA	210,000
Australia	20,000
Chile	4,000
South Africa	10,500
Total	296,500

Figure 5.10 shows that all of the major producing countries' domestic consumption is forecast to exceed their total production, causing great deficits, especially in the USA and Australia, which will probably lead to a higher demand for dried grapes by these countries.

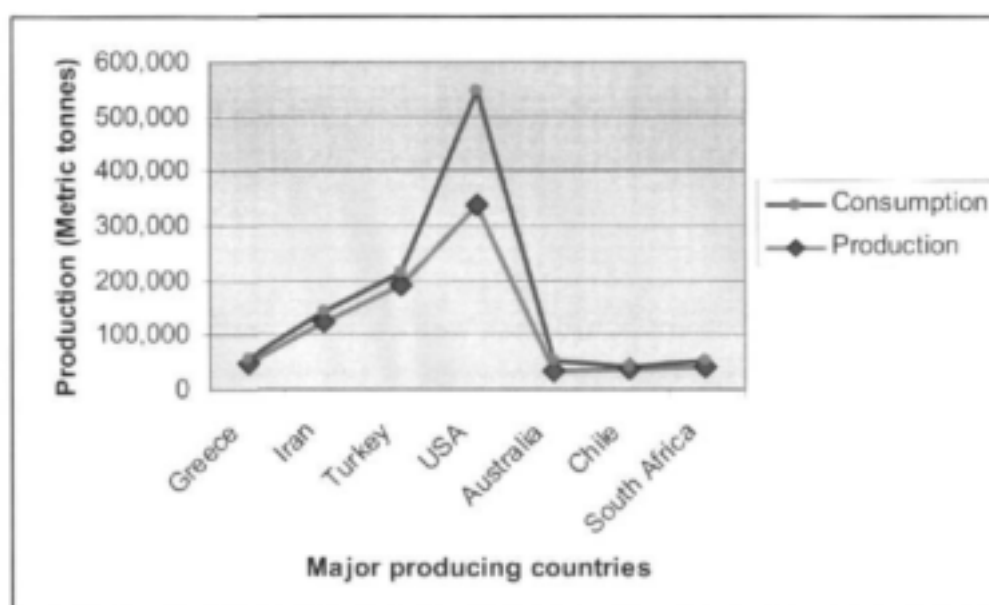


Figure 5.10: The estimated production in relation to domestic consumption

The deficits that these countries experienced will be countered by imports to satisfy their demand for dried grapes, making them some of the biggest importers of dried grapes. As can be seen in Table 5.8, the major producing countries are also the major exporting countries of dried grapes.

Table 5.8: Dried grapes estimated exports of major producing countries (ton)

Country	Total available estimated product for marketing	Estimated exports from 1/9/2002 to 31/8/2003
Greece	26,000	17,500
Iran	111,000	90,000
Turkey	231,000	176,000
USA	503,300	102,000
Australia	31,500	9,000
Chile	38,500	23,000
South Africa	36,734	22,173
Total	978,034	439,673

5.8.1.1 Turkey

Turkey is the second largest producer of dried grapes in the world after the United States. In 2002/03, dried grape production is forecast to fall between 10 and 14% from last year as a result of heavy rainfall during the harvest season.

Turkey is the top dried grape exporter in the world, with exports valued at more than R1674⁴ million in 2001/02. Between 1999 and 2001, its total exports averaged nearly R1944 million. Turkey's top export markets were the U.K., Germany, the Netherlands, Italy, and Australia. Collectively these five markets comprised 69% of the country's dried grape exports.

Prices were lower early in the growing season (approximately R6760/ ton of standard 9) but rose after the rains. Currently, the price is about R8320/ ton for a standard #9 bulk and about R8840*/ ton for a standard #10. Number 9's and 10's generally make up a sizable proportion of the crop and are the first buying choice of many traders.

Dried grape export opportunities to Turkey are minimal. In 2001/02, total imports were just over R13 million. Greece was the largest supplier of dried grapes to Turkey, accounting for nearly 50% of all imports. The U.S. shipped just over R3 million worth of dried grapes in 2001/02, making it Turkey's second largest supplier of imported dried

⁴ An average exchange rate of R10.40 for the year 2001/02 was used to convert prices from U.S. dollars to South African rand.

grapes. Dried grape imports are unlikely to increase given the high import duty on imported dried grapes, which is currently at 56.1%.

5.8.1.2 United States

The United States is a leading world exporter of dried grapes, second to Turkey. In 2001/02, U.S dried grape exports totaled over R1508 million. Between 1999 and 2001, its total exports averaged over R1684 million. The United States' largest export markets were the U.K., Canada, Japan, Germany, and Sweden. Collectively, these 5 markets comprised nearly 64% of its dried grape exports. On average, about 33% of the U.S. dried grape crop is exported.

The United States is the largest dried grape producer in the world. The forecast for 2002/03 dried grape production is at 339,411 tons, an increase of 1%. Since 1999, the industry has been beset with surplus production and stagnant domestic demand, resulting in large stock inventories.

Dried grape imports totaled more than R124 million in 2001/02. Chile, Mexico, Argentina, South Africa, and Iran were the top 5 suppliers of dried grapes.

5.8.1.3 Iran

Iran is the third largest exporter of dried grapes behind Turkey and the United States. Iran is also one of the major producing countries of dried grapes. Iran's exports for 2002/03 are forecast at R1080 million. Unfortunately, very little information is available on production trends for this country.

5.8.1.4 Greece

Greece is the sixth largest exporter of dried grapes behind Chile and South Africa. In 2001/02, Greece's dried grape exports totaled over R405 million. Between 1999 and 2001, its total exports averaged R728 million. Increased competition in European markets from Turkish dried grape exports led the decline in trade. Greece's largest export markets are the U.K., Germany, the Netherlands, Poland, and Australia. Collectively, these 5 markets

comprise nearly 85% of its dried grape exports. On average, 80% of Greece's dried grape crop is exported.

Disastrous rainstorms are likely to have a dramatic impact on dried grape production. Some estimates indicate that between 31 and 67% of the 2002/03 dried grape crop could be lost. As a result of the smaller crops, exports, which have already been affected by competition from Turkey, are expected to decline even further. Despite the production shortfall, Greece is expected to supply export markets with dried grape inventories collected from previous years. In 2001/02, dried grape imports totaled over R23.9 million.

5.8.1.5 Chile

Dried grape production for 2003/03 is forecast to be 38,000 tons, the same level as the previous year. Dried grape supplies could increase significantly in the future if discarded table grapes from new vineyards are diverted to dried grapes. More than 90% of Chile's dried grape production is exported.

Chile is the fourth largest dried grape exporter in the world. In 2001/02, Chile's dried grape exports totaled more than R364 million. Mexico, the United States, Colombia, Peru, and Brazil were its top export markets. These 5 markets comprised 62% of all exports in 2001/02 season. Between 1999 and 2001, its dried grape exports averaged over R447 million.

Chile's dried grape imports are insignificant (totaled only R197 600 in 2001/02), of which 75% originates from Mexico. A 7% import tariff on dried grapes is expected to fall to 6% in 2003. In addition, an 18% value-added tax is charged on all consumer items, both domestic and imported.

5.8.1.6 South Africa

South Africa is the world's fifth largest exporter of dried grapes. In 2001/02, dried grape exports were valued at R208 million. The devaluation of the rand during the 2001/2002 season boosted exports despite the glut of quality dried grapes on the international market. Canada, Germany, the Netherlands, France, and the U.K. are the top export markets for

South Africa. These 5 markets comprised 73% of all exports in 2001/02. Dried grape imports are minimal. Favourable weather conditions are expected to maintain dried grape production at normal levels in 2003. The 2002 crop of nearly 40,500 tons was the largest crop since 1997.

5.8.1.7 Mexico

Mexico exported a little more than R41 million worth of dried grapes in 2001/02, with nearly 92% of the export volume going to the United States. Guatemala, Honduras, Chile, and Colombia rounded out its top 5 markets.

Production for 2002/03 is expected to remain in line with forecasts made earlier at 13,200 tons. Mexico's current economic woes could affect crop production in the future as continued problems with low prices, lack of available credit, and diversion of dried grapes for wine and juice markets are decreasing planted areas and driving farmers out of business.

Opportunities for imports to Mexico do exist, albeit for lower priced dried grapes. Chile remains the dominant supplier to Mexico, accounting for approximately 80% of the country's dried grape imports. The United States was the second largest supplier, shipping over R18 million worth of dried grapes. Under the North American Free Trade Agreement (NAFTA), both Mexico and the United States allow dried grapes to enter their borders duty-free. Dried grapes from Chile also enter Mexico duty-free.

5.8.1.8 Australia

Production forecast for 2002/03 is estimated at 32,200 tons. Favourable weather conditions and reduction in wine grape prices are expected to return dried grape production to normal levels after several years of underproduction. Sultanias account for about 90% of Australia's dried grape production.

Australia exported more than R72 million of dried grapes in 2001/02. Canada, Germany, the U.K., New Zealand, and Japan accounted for 87% of its exports in 2001/02. Australia's dried grape imports were valued at over R166 million in 2001/02. Turkey dominated the

market, supplying nearly 65% of Australia's dried grape imports. Greece, the United States, Iran, and Chile were also major foreign dried grape suppliers.

5.8.1.9 Most important import countries

Figure 5.11 represents the volumes imported by the most important dried grape importing countries. World dried grape imports totaled more than R5314 million in 2001/02. The top dried grape importing countries were the U.K., the Netherlands, Canada, Japan, and France. The U.K. imported more than R1150 million; Germany more than R583 million; Canada more than R396 million; the Netherlands more than R417 million; Japan more than R347 million; and France more than R229 million. These 6 countries imported 59% of the world's dried grape trade in 2001/02.

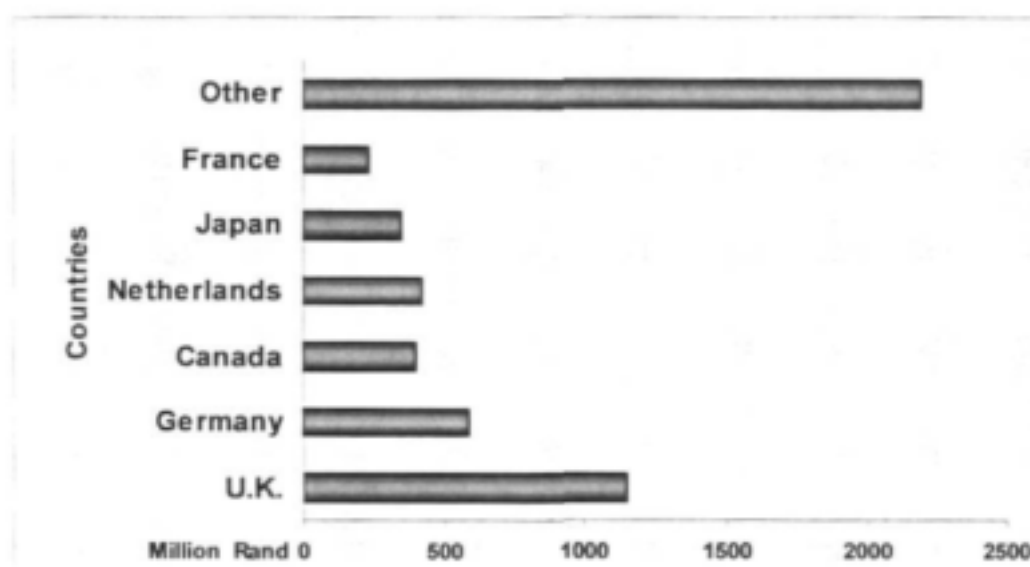


Figure 5.11: World's top importing countries of dried grapes

5.8.2 South African dried grape overview

South African dried grapes are mainly produced in the Orange River on approximately 10000 ha of irrigation land. It is very difficult to establish the exact area under dried grapes since dried grape cultivars (mainly Thompsons) are often used for fresh grape exports depending on the micro climate, price, and quality in a specific year. Table 5.9 and Figure 5.12 represent dried grape production in South Africa from 1997 to 2002. It is clear that

substantial fluctuations have occurred in local production since 1997 and that local production during the 2002 season was back at approximately the same level as in 1997. The decreases in 1998 and 2001 were due to unfavourable weather conditions in the Orange River (unexpected rain).

Table 5.9: Local production of dried grapes in S.A

Type:	1997	1998	1999	2000	2001	2002
Sultana types						
Unbleached	9300	3700	5097	4709	9158	2591
Golden	6945	6912	8539	4028	7490	5656
Thompson seedless	23950	10451	26722	27622	16562	32092
Total	40195	21063	40358	36359	33200	40339

Figure 5.12 represents the contribution of different types of dried grapes. It is clear that Thompson seedless dried grapes are the most popular, followed by Golden and Unbleached which alternated in second place. Table 5.10 shows the average grading results for the period 1992 to 2003. There is clearly substantial fluctuation in quality from year to year, for three main reasons: hail, rain, and frost, as Table 5.13 reflects. From Table 5.11, it is clear that producer payments in the Groblershoop region for Thompsons dried grapes in 2003 are, with the exception of industrial grade, in nominal terms, at the same level as in 1998. However, in real terms, the price is substantially lower (only 70% of the 1998 price). The depressed price has put farm profitability in most regions under severe pressure.

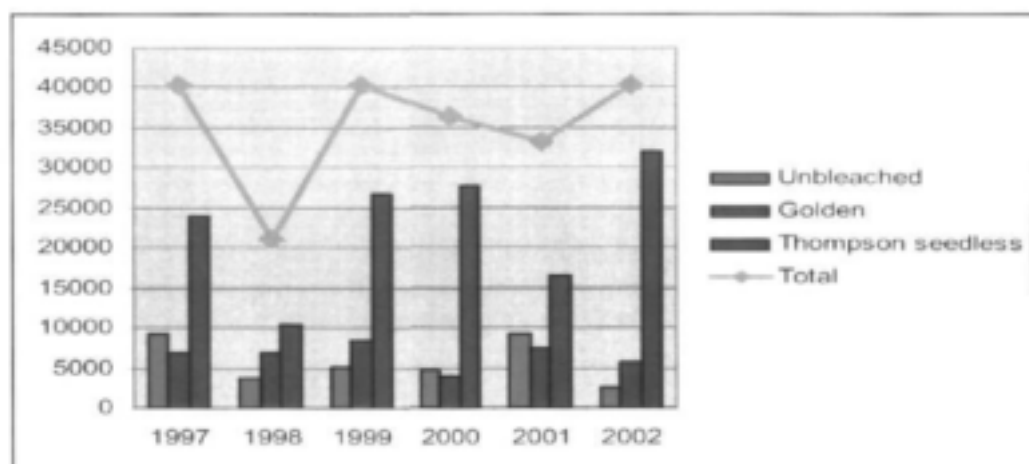


Figure 5.12: S.A. production trend over 6 years

Table 5.10: Joint average grading results for Groblershoop / Mylpaal

OR SULTANAS													
GRADE	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	AVERAGE
Choice (%)	65.4	44.8	13.2	35.1	28.2	40.8	54.2	54.1	24.2	58.7	40.1	68.5	43.9
Standard (%)	31.0	46.2	76.3	43.3	54.1	45.1	32.7	32.7	60.9	29.0	39.4	19.3	42.5
Industrial (%)	7.0	4.8	6.1	16.4	13.1	8.6	8.1	8.3	9.7	7.1	13.6	7.7	9.2
OF NO VALUE (%)	5.9	4.2	4.4	5.2	4.6	5.5	5.0	4.9	5.3	5.1	7.0	4.4	5.1
Total (Tons)	4,479	3,484	2,313	2,353	1,214	2,658	934	1,764	1,975	3,741	751	2148	2318
% of Total	72%	73%	53%	44%	37%	50%	32%	33%	32%	66%	12%	50%	46%
SUNDRIED THOMPSON RAISINS													
GRADE	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	AVERAGE
Choice (%)	56.1	53.6	35.1	57.7	64.1	50.3	77.0	69.2	53.9	66.0	44.6	78.7	58.9
Standard (%)	31.0	33.3	44.5	27.2	23.3	34.6	12.8	20.2	28.4	18.9	34.5	10.9	26.6
Industrial (%)	7.0	7.1	13.3	8.6	7.2	8.1	5.1	5.6	10.1	8.8	11.3	5.7	8.2
OF NO VALUE (%)	5.9	6.0	7.1	6.5	5.4	7.0	5.2	4.9	7.5	6.3	9.5	4.7	6.3
Total (Tons)	1,629	1,180	1,947	2,805	1,925	2,275	1,636	3,296	4,071	1,553	5,511	1,909	2,478
% of Total	26%	25%	45%	53%	58%	43%	56%	61%	66%	28%	85%	44%	49%
GOLDEN SULTANAS													
GRADE	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	AVERAGE
Choice (%)	72.7	58.3	22.8	34.0	54.5	57.1	54.4	72.2	41.1	62.2	54.6	77.0	55.1
Standard (%)	15.5	26.6	62.1	53.6	33.7	26.6	34.1	16.7	44.4	21.7	18.8	10.3	30.3
Industrial (%)	6.4	8.6	9.0	6.6	6.5	8.2	6.1	7.4	8.5	9.4	18.7	8.4	8.7
OF NO VALUE (%)	5.4	6.5	6.1	5.8	5.3	8.1	5.4	5.7	6.0	6.8	7.9	4.4	6.1
Total (Tons)	118	121	85	178	171	336	356	341	151	346	221	275	225
% of Total	2%	3%	2%	3%	5%	6%	12%	6%	2%	6%	3%	6%	5%

Table 5.11: Total payment per grade per product type – Groblershoop/Mylpaal region (Rand per dried ton)

SUNDRIED THOMPSON RAISINS												
GRADE	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Choice	2118.23	3040.00	2793.24	2876.21	3566.30	4030.00	4200.00	6300.00	5950.00	4040.00	3950.00	4200.00
Standard	1558.23	2700.00	2215.23	2053.12	2972.96	3350.00	3000.00	4600.00	4400.00	3000.00	3050.00	3100.00
Industrial	678.23	1000.00	1501.35	1432.08	2019.37	2220.00	2300.00	3100.00	3000.00	2100.00	1700.00	1400.00
GOLDEN SULTANAS												
GRADE	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Choice	3070.00	3880.00	4096.23	5245.52	5603.66	5370.00	6300.00	8500.00	7100.00	7000.00	6600.00	7000.00
Standard	1810.00	1980.00	2182.44	2780.85	3609.08	3440.00	4000.00	4500.00	4800.00	5300.00	4800.00	4800.00
Industrial	920.00	1000.00	1319.22	1123.12	1101.53	1140.00	2100.00	2500.00	2800.00	2500.00	1300.00	1400.00
OR SULTANAS												
GRADE	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Choice	2350.93	2820.00	2910.00	3633.72	4465.11	4820.00	4800.00	7000.00	6800.00	4700.00	4800.00	5750.00
Standard	1740.93	2160.00	2180.00	2644.32	3150.45	3000.00	3500.00	4500.00	4200.00	3500.00	3200.00	3250.00
Industrial	810.93	950.00	1540.00	1452.88	1850.77	1800.00	2200.00	3100.00	2500.00	2300.00	1400.00	1400.00

Table 5.12: Joint average producer realisation for the Groblershoop/Mylpaal (Rand per dried ton)

GOLDEN SULTANAS												
GRADE	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Choice	2231.89	2262.04	933.94	1783.48	3053.99	3066.27	3427.20	6137.00	2918.10	4354.00	3603.60	5390.00
Standard	280.55	526.68	1355.30	1490.54	1216.26	915.04	1364.00	751.50	2131.20	1150.10	902.40	494.40
Industrial	58.88	86.00	118.73	74.13	71.60	93.48	128.10	185.00	238.00	235.00	243.10	117.60
Total (R/dried ton)	2571.32	2874.72	2407.97	3348.14	4341.85	4074.79	4919.30	7073.50	5287.30	5739.10	4749.10	6002.00
Rand per fresh ton	642.83	718.68	601.99	837.03	1085.46	1018.70	1229.83	1768.38	1321.83	1434.78	1187.28	1500.50
SUNDRIED THOMPSON RAISINS												
GRADE	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Choice	1188.33	1629.44	980.43	1659.57	2286.00	2027.09	3234.00	4359.60	3207.05	2666.40	1761.70	3305.40
Standard	483.05	899.10	985.78	558.45	692.70	1159.10	384.00	929.20	1249.60	567.00	1052.25	337.90
Industrial	47.48	71.00	199.68	123.16	145.39	179.82	117.30	173.60	303.00	184.80	192.10	79.80
Total (R/dried ton)	1718.85	2599.54	2165.88	2341.18	3124.09	3366.01	3735.30	5462.40	4759.65	3418.20	3006.05	3723.10
Rand per fresh ton	429.71	649.89	541.47	585.30	781.02	841.50	933.83	1365.60	1189.91	854.55	751.51	930.78
OR SULTANAS												
GRADE	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Choice	1537.51	1263.36	384.12	1275.44	1259.16	1966.56	2601.60	3787.00	1645.60	2758.90	1924.80	3938.75
Standard	539.69	997.92	1663.34	1144.99	1704.39	1353.00	1144.50	1471.50	2557.80	1015.00	1260.80	627.25
Industrial	56.77	45.60	93.94	238.27	242.45	154.80	178.20	257.30	242.50	163.30	190.40	107.80
Total (R/dried ton)	2133.96	2306.88	2141.40	2658.70	3206.01	3474.36	3924.30	5515.80	4445.90	3937.20	3376.00	4673.80
Rand per fresh ton	533.49	576.72	535.35	664.67	801.50	868.59	981.08	1378.95	1111.48	984.30	844.00	1168.45

Table 5.13: Production, reasons for crop damage, and producer realisation for Groblershoop/Mylpaal*

TOTAL SULTANA INTAKES													
GRADE	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	AVERAGE
Total (Tons)	6,226	4,785	4,345	5,335	3,310	5,269	2,926	5,401	6,197	5,640	6,483	4,332	5,021
Damage	Frost/Rain		Rain	Frost/Rain	Frost/Rain	Rain	Hail	Frost/Hail	Rain		Rain	Frost/Hail	
Crop load	Good	Poor	Average	Good	Average	Very Good	Very Poor	Average	Good	Poor	Very Good	Poor	
ALL SULTANA TYPES													
PRODUCT TYPE	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	
Thompsons	450	641	971	1231	1817	1453	2088	3333	3127	941	2555	1641	
OR Sultanas	1535	1680	1140	1172	1176	1753	1253	1801	1417	2612	391	2317	
Golden Sultanas	49	73	47	112	224	260	599	447	129	352	162	381	
Average (R/dried ton)	2034	2393	2158	2515	3217	3466	3940	5582	4673	3905	3108	4339	
Average (R/fresh ton)	508	598	539	629	804	866	985	1395	1168	976	777	1085	

*Considering the average % contribution of each of the product types produced annually

Considering Figure 5.13, the local industry seems to have reached the bottom of a depressed market situation and to be in a recovering phase. This is mainly due to the international market situation which was described in the previous section.

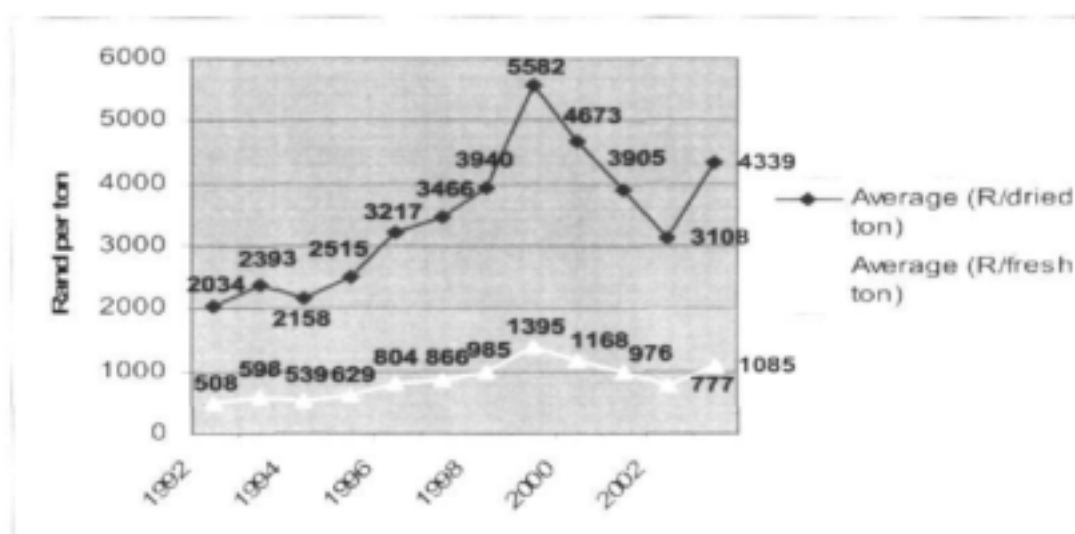


Figure 5.13: Realisation per ton raisins (all types) for Groblershoop / Mylpaal

Although 2002 is an exception, and it is probably too soon to make predictions, OR sultanas seem to be gaining ground at the expense of Thompsons in terms of average realisation (see Figure 5.14).

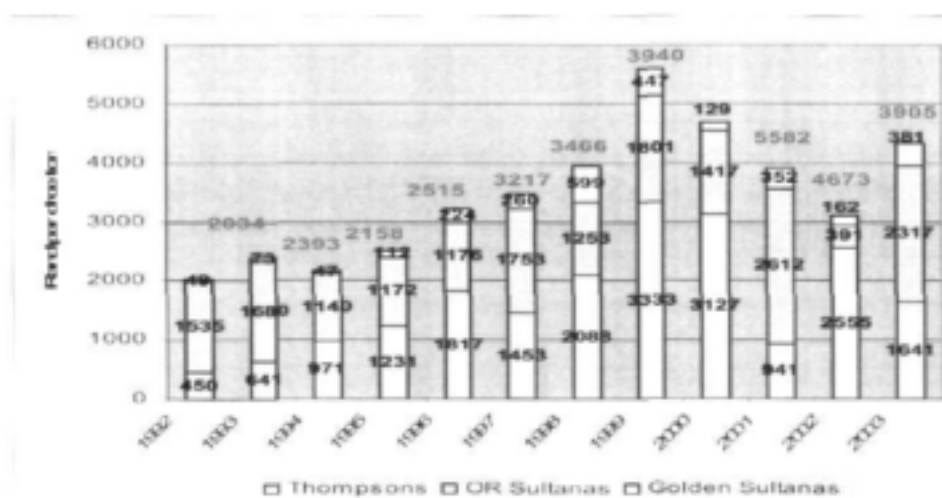


Figure 5.14: Composition of realisation Groblershoop/Mylpaal (R / dried ton)

Figure 5.15 represents the composition of the total crop and explains the observation made from this figure. In terms of the volumes produced (with the exception of 2002), OR sultanas are clearly gaining ground.

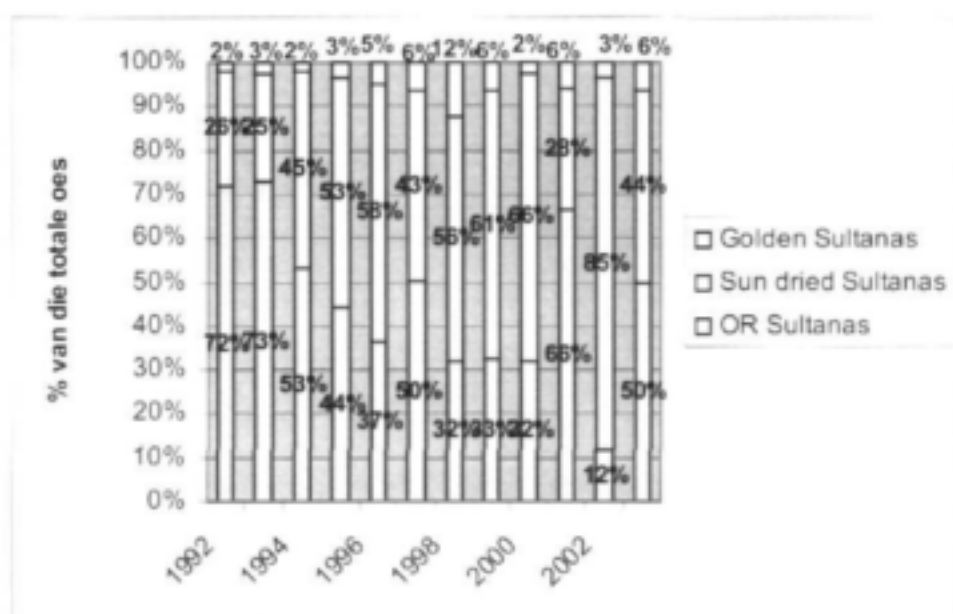


Figure 5.15: Composition (product type) of the raisin trends

5.8.3 Risk factors in raisin productions

From the background information, it is clear several risks are involved in dried grape production. They are the following:

- Climatic conditions such as frost, hail, and rain during the harvest. The statistics show that farmers only had 5 good/very good years over a period of 12 years, indicating that dried production is a risky business. However, the reader must be aware that there is a strong link between dried grape production and table grape production in the Orange River. Sultana and Thompson grapes are very versatile and can be used for both.
- International market conditions: demand for dried grapes is very elastic; a small over supply normally results in a large price decrease.
- Exchange rate fluctuations.

- Increasing production costs
- Fragmented export effort and lack of export standards.
- Threat of cheap low-quality imports.

The implication for market risk management strategies are the following:

- Investment in dry infrastructure to reduce the risk of rain during the harvest season.
- Collaboration in the local industry to set and enforce high quality export standards
- Investment in an efficient market information system and communication of this information to decision makers. This may include crop estimates, market destinations, international price information, etc.
- Most farmers on dry grape farms in the Orange River region are already diversified. However, in many cases, it is just with another grape commodity (table grapes, wine, juice) exposed to the same climatic and other production risks. These farmers should also consider diversification, even if it is with the same crop in different areas.

Innovative marketing strategies in the years to come should be able to increase profit margins again.

5.9 RISK FACTORS FOR WINE PRODUCTION

Production risks in wine production are relatively low compared to table and dried grapes. The most important risk factor is to invest a substantial amount of capital to increase the volume of quality wine from the region without knowing if the region will be able to change consumers' perceptions. The challenge of the wine industry in the Orange River is to change the perception of consumers.

Also, the Northern Cape wine industry is in a relatively advantaged position since the brandy market is growing and the Orange River contributes to a substantial volume of distilled wine. Finally, the Orange River is also in a position to attain considerably higher yields than other wine-producing regions in South Africa.

5.10 RISK FACTORS FOR PECAN NUTS (ALTERNATIVE CROP)

Accurate production data for pecan nuts in South Africa does not exist. The total area under production is estimated to be approximately 2000 to 2500 ha. The problem in South Africa is not necessarily a lack of demand but rather to introduce the product to the general public through generic marketing. The industry is not properly organised, highly fragmented with very little coordination. Also, on most farms, the crop is just a side line, and production probably far under the potential of the trees due to relatively low management input.

The Middle Eastern and European nations, with the Netherlands in first place, have a very high per capita consumption. Most nuts from South Africa are directly shipped to Rotterdam from where it is re-packed and distributed. Substantial potential therefore exists to add value in South Africa before shipment. A better organised local industry is a prerequisite for such an operation.

South Africa's main competitors are the USA, Mexico, Australia, and Argentina. In spite of the present economic problems in Argentina, it is expected to become our main competition. Recent research proved that pecan nut oil is the healthiest plant oil. The use of this oil reduces cholesterol and could play a major role in controlling this disease. Efficient marketing is the key for a profitable future for pecan nut farmers. The medium to long-term prospects are relatively good.

5.11 RISK FACTORS FOR OLIVES (ALTERNATIVE CROP)

Olives are not a well tested traditional crop in the Lower Orange River region. However, in recent years, substantial new plantings have been observed in the Vaalharts region. New untested crops in a region normally constitute a risky business since observed results to plan from are often lacking. Other risks include:

- Substantial expansions in South Africa: the local table olive market is relatively saturated (Costa, 1998); a small increase in production can lead to an oversupply in local markets.

- Also, competition in the international fresh and oil market is strong, and it is difficult to penetrate these markets especially with the relatively small South African production volumes.

5.12 PISTACHIO (ALTERNATIVE CROP)

Growth in this industry has been curbed by the relatively long time period required for a pistachio tree to reach full production, typically ranging from eight to ten years and resulting in excessive development costs. These significant costs, combined with the long time horizon for initial investment payback, serve to limit the number of new plantings that typically occur as commodity prices rise. As a result, overall average earnings have remained fairly consistent as there is a limited tendency for growers to respond rapidly to anticipated profitability through overplanting (Wikipedia, 2003).

The initial planting of choice was the Kerman variety on the *Pistacia Atlantica* rootstock, commonly known as the Atlantica rootstock. However, Atlantica rootstock has since proved susceptible to the *Verticillium Dahliae* wilt organism, a disease most commonly associated with land formerly planted with cotton. Many orchards planted on such cotton land have suffered significantly and will require eventual replanting. The pistachio industry recently responded with the development of the *Pistacia Integerrima* rootstock (commonly known as Pioneer Gold), which has proven resistant, but not immune, to the wilt organism. An additional benefit of the Pioneer Gold rootstock is increased vigour and production as compared to Atlantica rootstock (Wikipedia, 2003).

Mature pistachio orchards exhibit a pronounced alternate bearing cycle similar to avocados, with the entire industry generally rotating between a large crop one year and a smaller crop the next. This tendency seems more pronounced in orchards planted on the Atlantica rootstock than in those planted on Pioneer Gold rootstock, especially in marginal orchards or those lacking in cultural care.

An extensive industry study of this alternate bearing phenomenon has yet to discover a "cure", but certain cultural practices such as summer pruning have shown promise in reducing variability in production. In order to compensate for increasing crop sizes and the

alternate bearing characteristic of the pistachio tree, the pistachio industry was faced with the challenge of effectively marketing the nuts for attractive grower returns. While nut prices have trended down as production has increased, net resultant revenues, on a per ha basis, have continued to climb.

As noted, however, revenues per ha are much more a function of yield per ha than of price per kg. Clearly, the economics of pistachio production are based on high yields per ha. Orchards which produce at higher yield rates are relatively insulated from swings in nut prices.

Export markets continue to show promise for additional sales, especially in the Far East and Japan, Hong Kong, and Taiwan in particular. Most products are sold on the retail or consumer market, with relatively small amounts being sold for industrial or processing uses. Given the strong domestic market, per-capita consumption climbed steadily during the early eighties as prices declined from historical levels. However, consumption slowed in the latter part of the decade as prices rose in response to declining production. This appears to illustrate the industry's need for a steady, consistent supply and the ability to accurately forecast future crop sizes.

Overall, the key to continuing profitability for pistachios is contingent upon the growers' ability to maintain high levels of production and quality standards as well as the industry's ability to effectively educate the consuming public as to the superior quality of local pistachios. Obviously, the impact of the changing global economy and the lifting of the trade embargo with Iran may impact the industry in coming years. Given this background, the industry could become a viable component of agri-business in the Lower Orange River.

However, very little information is available on the production of pistachios under South African climatic conditions, and until the crop has been tested in the Lower Orange River, it should be regarded as a high-risk crop.

5.13 OTHER ALTERNATIVE CROPS

Other alternatives identified in the Orange River Development Project Replanning Study (ORDPRS) (1998) for the G5 (Boegoeberg) to G9 (Alexander Bay) regions are:

- Lemon
- Grapefruit
- Figs
- Special export vegetables
- Paprika
- Grape (juice)
- Granadilla
- Papaya
- Avocado

Unfortunately, very little is known about the successful production and marketing of some of these crops in the Orange River region since they are not proven crops there. Recently, an opportunity to produce 400 ha paprika arise because of the situation in Zimbabwe. However, this market is very closed and only accessible to a few individuals. Also, the collapse of the Goodhouse paprika project dampened enthusiasm to produce this crop.

5.14 RESULTS OF THE COMMODITY WORKSHOP OF 2003

It was mentioned earlier that many of the risks pointed out during the workshops held in 2003 are similar. For the purpose of the report, **all** the risks mentioned during the short-term crop workshop and the long-term crop workshop are listed in the following two sections. The reader should note that not all these risks are necessary directly market related. However, they all eventually impact on production costs and therefore on the competitiveness of the region in producing these crops.

5.14.1 Short-term crop workshop - Douglas

The following aspects were pointed out, not necessarily in order of importance:

- Mechanisation costs are too high and will increase if the rand weakens again.
- Labour cost too high and not at all linked the Consumer Price Index (CPI)

- No support from government.
- Lack of research support from government.
- Huge fluctuation in international markets.
- Land tax will eventually destroy agriculture.
- Too much politics in agriculture.
- Yield increases necessary to achieve the same margins--research.
- International commodity--price risk. Farmers cannot control this.
- Exchange rate fluctuations. Immediate impact on producer prices but delayed impact on input costs, especially if the rand strengthens.
- Economies of scale. Farming operations need to get bigger to counter decreasing profit margins.
- Not enough buyers--monopolistic forces at work.
- High interest rates and a bigger contribution from loans to operational capital make farmers more and more vulnerable to financial set-backs.
- Need for a higher producer emphasis on the marketing side. Access to up-to-date market intelligence has become a prerequisite for sustainable farming operations.
- Relatively high capital investment and very low return--difficult to attract young people and investors.
- Adding value is extremely important but easier said than done.
- Need for higher efficiency. More crop per input.
- Double cropping is fast becoming a problem in the wheat/maize production regions--will probably move to two crops in three years, putting pressure on farm profitability.
- Organic farming will become NB

For the purpose of this report, it was decided to adhere to exchange rate fluctuations in the modelling exercise.

5.14.2 Long-term crop workshop – Upington / Augrabies

The marketing risks and other indirect market concerns raised at the workshop are listed in the following three sections.

5.14.3 Vine – general comments

- Price pressure
- High input costs
- Lack of support from government to develop new markets
- Tariffs--uneven playing field
- Collapsing infrastructure
- Lack of cooperation between farmers
- Input providers get tariff support, there should be export incentives
- Market access
- Risk of not being able to meet transformation targets
- Loss of government capacity to negotiate trade agreements
- Need to develop futures for grapes
- Local industry not well organised
- High taxes
- Huge fluctuations in supply
- Monopolistic input providers
- Not enough cultivars
- Need for more collaboration between emerging and commercial farmers
- Not enough technical support
- Research
- Information--study groups
- Farmers do not have control over many input costs
- Land tax
- Capital gain tax
- Minimum wages
- Land reform
- Unstable prices
- Old vines, reduced profitability

5.14.4 Raisins

- Climate variation--low yield
- Low prices--exchange rate fluctuations
- Stagnation in traditional uses
- World oversupply
- Stricter demands from buyers--Eurepgap
- Pressure from government policies
- Fragmentation of the industry--more packers and competition
- Liquidation of many farmers, less farmers, problem with research funds
- Labour problems: costs
- Labour problems: HIV
- Farm safety
- Lack of reliable, accurate, and affordable market information
- Need to develop niche markets
- Increasingly skew playing field
- High input costs
- Product development is crucial--need to add value--lack of innovation
- International prices do not increase in real terms
- Increasing competition from cheap suppliers--less quality
- Input cost increases at higher rate than product prices
- Low labour productivity
- Not enough young farmers
- Profits of the middle man too high--does not share the risks
- Need to develop the local market
- Reduced land values

5.14.5 Table grapes

- Increasing competition--Chile, Brazil
- Finance risks--risk sharing (input providers and marketers)
- Lack of market information on new markets

- Need for more market research and more info on exporters
- Low prices compared to extremely high input costs
- Too many exporters that compete for the same markets
- Lack of reliable market and other financial information
- Climate change risks
- Uneven risk sharing
- Need to work on products of origin (Orange River region)
- Risk of flaws in quality control--need to increase standards
- Need for better planning--farmers do not do sensitivity analysis
- Growth in access to new markets is too small
- Share of technical experience is essential
- Exchange rate fluctuations
- Input costs too high, increases risk
- Farmers do not have enough control over cost compared to service providers
- Globalisation
- Return on capital investment is too low to attract investors
- Economies of scale constantly under threat
- Lack of effective collaboration between farmers

5.14.6 Lucerne

- Stagnant prices
- High labour costs
- High input costs
- Lack of support from government
- Less risky than table grapes
- Need for shorter cut period
- Orange River do have a comparative advantage
- Need to cut out the middle man
- Need for high quality
- Research
- Value adding

5.15 IMPLICATIONS FOR MARKET RISK MANAGEMENT

The intention of this chapter was to give the reader some kind of background on the marketing environment for selected crops that are grown in the Northern Cape. The project team realise that this information is already outdated, but since the entire modelling exercise is based on 2000-2002 prices, it was decided to update the information to 2006 in Appendix A of this report.

The following market risk management implications are important:

- It was pointed out in Chapter 2 that there are mainly two sources of risk to be managed: operational risk and strategic risk. Operational risk is mainly the risks involved with day-to-day farm management, the risk of doing the right things wrong, doing the wrong things wrong, and doing the wrong things right. The latter is probably the highest operational risk. On the other hand, strategic risk is mainly the risk of doing the wrong things.
- This chapter indicated that having good market information and market intelligence is probably the most important strategy to counter market risks. It is not possible for management to plan for possible events if these events are unknown or if information is lacking to formulate good strategic and operational plans.
- It was also pointed out earlier that the efficient allocation of irrigation water is a national concern. Therefore, there is a sound argument for government and industry bodies to invest in information systems to enable farmers to make decisions that will reduce their market risks and that will contribute to a more efficient allocation of scarce water resources.
- Finally, although there are several direct and indirect market-related risks, it is impossible to analyse the impact of all of these on the efficient allocation of water in the irrigation regions of the Northern Cape within the scope of this study. For the purpose of this study and to show the link between the micro and macro models, only two scenarios will be analysed in detail and the results included in this report. These are:

-
- A scenario that analyses the impact of a long-term trend of reduced table grape prices--"table grape scenario".
 - A scenario of significant increases in water tariffs--"input cost scenario".

CHAPTER 6

THE ORANGE RIVER MODELLING FRAMEWORK

6.1 BACKGROUND ON MODEL DEVELOPMENT

The typical farms are the primary production units within a sub-regional modelling framework. The sub-regional models are therefore an aggregation of typical farms and the Orange River regional model an aggregation of the sub-regional models. The modelling framework should therefore be constructed in such a way as to reveal the long-term economic impact of micro and macro risk factors at farm and regional level.

The advantages of DLP were pointed out earlier in Chapter 2, section 2.8. The objective function (objective of farmers specified in mathematical terms) is optimised through the simultaneous solution of all time periods (over the planning horizon). Two important aspects can be concluded from this:

- In a decision framework, the plan in the first year is the optimal direction of actions with present expectations of the future.
- For a couple of years, the plan indicates the dynamic growth of the farm over time.

The method is dynamic since the time factor is explicitly taken into consideration. The eventual plan is therefore the best plan given present expectations of prices and technology available to the farmer. It can be concluded that this method will without doubt give a fairly accurate estimate of the impact on the long-run economic feasibility of typical farms and regions within the study area.

The initial objective was to attempt to build a regional dynamic linear programming model linking all the representative farm models in one modelling framework. However, this idea was abandoned after one attempt (for the Boegoeberg sub-region). The basic theoretical

outline is simple. However, with just three representative farms in this model, solving time became a problem since the model would run for more than 30 minutes on a computer with a 2.4 gigabyte processor. The author believes that any model that cannot be solved within 5 to 10 minutes is impractical and will not be popular in practice since it becomes a time-consuming process to debug such a large model and run several scenarios in an acceptable time limit. During 2005, a new GAMS solver with an enormous capacity was released, CPLEX, which reduced solving time from 30 minutes to approximately 1 minute. After the first failed attempt, it was decided to develop the typical farm models as stand-alone models and to include all the typical farm models in one regional (Orange River) model in the second step. To study the impact at regional level, it is necessary to build a spatial model with links between representative farms to see in which direction water will be reallocated in an environment where farmers are fully informed of market conditions (optimal situation). This report only deals with phase 1 (typical farm models) and phase 2 (aggregated regional model). A description of phase 3 of the modelling process can be found in Volume 2 of the reports.

6.2 *TYPICAL FARM MODELS (DLP)*

The basic structure and supporting theory of whole-farm planning models and dynamic linear programming in particular were discussed earlier in this document. The intention of this section is to give the reader a schematic outlay of these models. The full GAMS code for one of the typical farms models is available in Appendix D. Only one of the typical farm models' GAMS code is presented in Appendix D since all the other models are similar.

A dynamic linear programming model was constructed for each of the typical farms. Figure 6.1 shows the typical farm modelling structure for sub-regions in the Orange River. The models are constructed in such a way that they are executed individually for the different scenarios to analyse the impact of risk factors on an individual farm basis. All the models were done in this way, but only one is described in this chapter.

The basic structure of the models is more or less the same; the differences between the 21 models are in the databases for each representative farm.

The following sections give a condensed summary of one of the models (Augrabies-Blouputs) and are discussed in terms of the algebraic sets, database, variables, equations, and objective function (also see section 2.5.4). The objective of this description is to give the reader a feeling for what the models can and cannot do. It is not necessary to read through all these sections. However, the authors believe that these sections will give readers with a basic knowledge of linear programming and GAMS at least some insight into the structure of the models.

Most of the models have approximately 140 000 rows and 114 000 columns over the 20-year planning horizon.

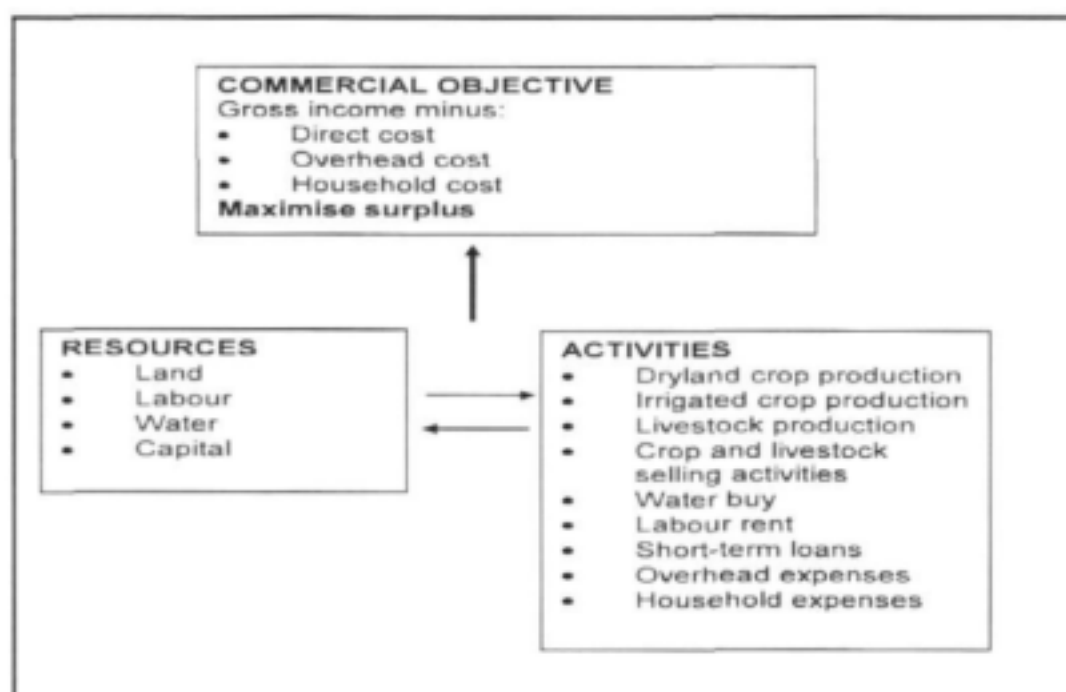


Figure 6.1: Typical farm DLP modelling structure

6.2.1 Sets

Sets are the algebraic notations used to refer to elements that will be used in the modelling framework. The following sets are standard for all the typical farm models:

Table 6.1: Typical farm model sets (Augrabies-Blouputs example)

Sets	Description	Elements (Augrabies-Blouputs example)
i	All enterprises included in the model	RWine, WWine, Drygrape, Jugrape, Tabegr, TabegrS, Citrus, Lucern, Wheat, Peas, Maize, Oats, Cotton, Sheep, Hoveld, Lox, LHay
acv	All crop and livestock enterprises	RWine, WWine, Drygrape, Jugrape, Tabegr, TabegrS, Citrus, Lucern, Wheat, Peas, Maize, Oats, Cotton, Sheep
ca	All crops	RWine, WWine, Drygrape, Jugrape, Tabegr, TabegrS, Citrus, Lucern, Wheat, Peas, Maize, Oats, Cotton
ccv	Crops that cannot be used for animal feed	RWine, WWine, Drygrape, Jugrape, Tabegr, TabegrS, Citrus, Peas, Cotton
veg	Vegetable crops	Peas
gc	Grain crops	Wheat, Maize, Oats
fc	Feed crops	Lucern, Wheat, Maize, Oats, Hoveld
cau	Single-year crops	Wheat, Peas, Maize, Oats, Cotton
mya	Multi-year crops	RWine, WWine, Drygrape, Jugrape, Tabegr, TabegrS, Citrus, Lucern
mya	Multi-year crops excluding lucern	RWine, WWine, Drygrape, Jugrape, Tabegr, TabegrS, Citrus
tbl	Converted Substances	TabegrS
p	Hyproducts	Grain, Stable, Pasture, Hay, Pmx, Grl, Taper, Tdry, TWine, TJuice
vo	Natural veed	Hoveld
y	All years	y1983-y2022
my	Mooring years	y2003-y2022
py	Plant years	y1983-y2002
gs	Growth stages	G01-G05
l	Irrigation technology	img0, img0R, img0L, img0R, img0L
m	Inputs	Labour, Tractor, Water, Capital
w	Water sources	River, Canal
wpr	Pump water sources	River
d	Farm dams	Dams
av	Livestock enterprises	Sheep
ap	Livestock hyproducts	Lyn, Wool
avap	Terminating livestock at end of planning	Lyn
n	Nutrients	Bulk, TDN, TRP
fp	Feed bank products	Grain, Hay
fu	Purchased feed	Lox, LHay
mo	Months	m1-m12
dev	Mixed deviation	Gm1-Gm100
gsu,gsd	Short term crops growth stages	G01
oh	Overheads	House, Overh, Laoc, Utax
s	Savings	Invest
l	Debt	Stoans

6.2.2 The database of typical farm models

A database was developed for each of the representative farm models. The databases are in Microsoft Excel and were developed in such a way that they can easily be updated. The main parameters are presented in Table 6.2.

The Excel spreadsheet contains the following worksheets:

- All the farm data from the farm survey in one worksheet. These are used to calculate the coefficients for the total regional farm survey.
- One worksheet for each typical farm containing all the farm survey data for the farms that are included in the group of farms used to construct the typical farms (mainly farm structure, resource availability, and overhead costs).
- Worksheets containing water, tractor, and labour use for each crop
- A worksheet with all the crop and livestock budget coefficients. These include yields, price, and direct costs.
- A worksheet with the terminal value of long-term crops and of livestock at different growth stages.

Table 6.2: Data parameters for representative farm models (66 parameters)

Data parameter	Description
Grond(b)	Defines the area of total land b available
Veldarea(v)	Area natural veld v
LUT(i, mo)	Land use of crop i in month mo
Yearsoc(mj)	Land occupation of crops mj
HO(oh, mt)	Household expenses oh in year mt
NFI(mt)	Maximum non farm income per year mt
OVC(oh, mt)	Overhead expenses oh in year mt
Labcost(oh, mt)	Labour costs oh per year mt
Landtax(oh, mt)	Land tax oh in year mt
Deprec(mt)	Depreciation costs per year mt
OS(i, p, mt)	Begin stocks of feed crop i product p in year mt in TON
ESV(i, p)	Value of end feed stocks i product p
IC(m)	Cost of additional inputs m per unit
ICW(w, mt)	Cost of water when charged per ha from water source w in year mt
ICWV(w, mt)	Cost of water per m3 of water from water source w in year mt
ENTITLE(w, mt)	Area entitlement from water source w in year mt
INTST(i)	Interest on loans i
INTINV(s)	Real interest rate on investment s
MaxC(mt, m)	Maximum own capacities of resource m in year mt
MaxR(mt, m)	Maximum rent capacities of resource m in year mt
MaxOC(mt, *)	Maximum own capital available in year mt
YST(i, b, p)	Yield of short-term crops i from irrigation technology b in tons
YLT(mj, gsl)	Yield of long-term crops mj growth stage gsl in tons
YLTsub(i, gsl, p)	Use of additional operating capital per ha to convert standard Sulfanas i in growth stage gsl to product p
LUPB(i, b)	Land use possibilities of crop i irrigation technology b
AVL(p)	Specify which products p is possible from crop i
APRA(a, mt, ap)	Specify which products ap is possible from livestock a in year mt
ResSTLTC(i, b, m)	Use of labour and tractor hours and capital resources m by ST crops i on irrigation technology b
ResSTwater(i, mo)	Use of water resources by short-term crops i per ha in month mo
ResSTlab(i, gsl, b)	Use of labour hours per ha for crop i in growth stage gsl with irrigation technology b
ResSTtrac(i, gsl, b)	Use of tractor hours per ha for crop i in growth stage gsl with irrigation technology b
ResSTwater(i, b, gsl, mo)	Use of labour hours per ha for crop i in growth stage gsl with irrigation technology b
ResSTcap(i, gsl, b)	Use of operating capital per ha for crop i in growth stage gsl with irrigation technology b
Adcap(i, gsl, b, p)	Use of operating capital per ha for converting from standard Sulfanas i produced with irrigation technology b to
Termval(i, b, gsl)	Terminal values of long-term crops i produced with irrigation technology b in growth stage gsl
Maxmw(mo, w)	Maximum monthly water delivering capacity in month mo from water source w
Maxawp(mt, w)	Maximum annual water entitlement in year mt from water source w
Maxfamd(mt, d)	Maximum annual dam capacity d to be pumped in year mt
Damtotcap(mt, d)	Dam capacity of dam d in year mt
Maxfammrel(mo, d)	Maximum water release capacity of farm dam d in month d
Imgef(b)	Irrigation efficiency of irrigation technology b
Price(i, p)	Prices of cash crops i PER TON of product p
Pfeedprf(p)	Price of purchased feed f product p
Ann(m, mt, m)	Inputs m for animal enterprises a in year mt
TermvLS(a)	Terminal value for livestock a
Aprice(a, *)	Price per kg for livestock products a *
LiveG(a)	Livestock growth for livestock enterprise a
NRG(n, a)	Animal group a nutrient requirement a per unit
INC(i, p, a)	Maximum inclusion levels of crop i product p for livestock enterprise a
NC(i, p, n)	Nutrient contents n of crop i product p in percentage
QD(mt, a)	Feed quantity demanded per livestock unit a in tons per year mt
PRB(i, p)	Production possibilities of crop i for products p
FRPOS(i, p)	Feed bank possibilities of feed crop i product p
Maxareast(i, b, p, t)	Maximum area under long-term crops i with irrigation technology p in year t
MaxSTarea(oj, mt)	Maximum area under short-term crops oj in year mt (base first year land use)
Maxlive(a, mt)	Maximum beginning livestock units a in year mt (base first year livestock numbers)
Verdisk(mt)	Calculate NPV of cash flow at specified rate in year mt
MaxL(mt)	Maximum loan per year mt
OPP	Days per month
Manl	Management level
PUMPC	Pumping costs from river
Landtrate	Land tax rate
Mlive	Maximum number of livestock
Vegarea	Maximum or fixed area of vegetables
MotadGMDev(a, mt)	Motad GM deviation dev for enterprise a in year mt
Meanai(mt)	Average values of each ai in year mt

- A worksheet with discount factors
- A worksheet which contains all the Motad data (risk data) for crops and livestock.

- Finally, there are worksheets for each typical farm linking all the data to data tables constructed in the GAMS code. After all data is updated, this worksheet is saved as a text file which can be read by the GAMS program.

6.2.3 Variables of typical farm models

The variables can basically be grouped into 10 types:

- Livestock production variables, including livestock numbers, growth in livestock numbers through reproduction, livestock sales, and livestock purchases
- Livestock product variables and sales
- A minimum cost feed balancing model embedded in the DLP to ensure at least a basic nutritional value of livestock feed
- Crop production variables and crop sales
- Water, labour use variables
- Rented input variables
- Some variables to use in the water balancing equations
- Overhead costs (including general overheads, household costs, labour etc.)
- Variables that calculate the annual cash flows and end balances
- Motad (risk) variables

The purpose of Table 6.3 is to present a short summary and description of these variables.

Table 6.3: Description of typical farm variables (46 basic variables)

Variables	Description
Livebeg(a,mt)	Present livestock numbers a in year mt
LSTpurch(a,mt)	Amount of livestock a purchased in year mt
Livesell(a,mt)	Sell livestock a in year mt
Liverepro(a,mt)	Reproduction of livestock a in year mt
LSTTOT(a,mt)	Total number of livestock a in specific year mt
LTAP(a,ap,mt)	Calculates maximum weight of livestock a product p sales in kg in year mt
WoolS(a,ap,mt)	Calculates wool production of livestock a product ap in kg in year mt
crst(i,b,mt)	Area of crop short-term crops i using irrigation technology b in year mt
crlt(i,b,t)	Area of crop long-term crops i using irrigation technology b in year mt
CrltSut(i,b,t,p)	Converted Sultana grape i activities with technology b in year t for product p
Totarea(mj,b,mt)	Total long-term crop area mj with technology b in specific year mt
TP(i,p,mt)	Sum total production of crop i product p produced in year mt
FBstock(i,p,mt)	Initial stock of feed i product p in year mt
Fbtr(i,p,mt)	Feed bank transfer of crop i product p in year mt
PF(f,p,a,mt)	Purchase feed f product p for animal a in year mt
Veld(v,p,a,mt)	Use of natural veldt v product p for livestock a in year mt
CS(i,p,mt)	Sell cash crops i product p in year mt
Irent(m,mt)	Rent input m in year mt
Ownlab(m,mt)	Own labour transfer m in year mt
MwaterU(mt,mo)	Monthly water use in year mt month mo
Mwatertr(w,mt,mo)	Monthly transfer from source w in year mt in month mo
AnuaWU(mt)	Annual water use in year mt
Wbal(w,mt)	Balance of water of all sources w after filling of farm dam in year mt
FarmDFILL(mt,d)	Total monthly water extracted to fill farm dam d in year mt
MWwatertr(w,mt,mo)	Monthly water extraction from source w in year mt in month mo
Damex(mt,mo)	Extraction from farm dam for irrigation in year mt month mo
TotWSCH(w,mt)	Total annual extraction from water source w to fill dam plus direct use in year mt
AFR(i,p,a,mt)	Transfer of feed production crop i product p for animal a in year mt
TAFR(a,mt)	Total animal feed mix for animal a in year mt
Loanst(l,mt)	Short term production loans l in year mt
OC(mt)	Overhead costs in year mt
Labourc(mt)	Labour costs per annum in year mt
Ltaxcost(mt)	Land tax per annum in year mt
HC(mt)	Household costs in year mt
NFincome(mt)	Non farm income in year mt
Investmnt(mt)	Investment of surplus funds in year mt
Endb	End balance after redemption of loans
Ancashfl(mt)	Annual cash flow in year mt
Endcash	End cash balance
Ltcost(mj,mt)	Total direct costs per lt crop mj per annum in year mt
TermLTval(mj,b)	Sums terminal values for LT crops mj produced with technology b
TermLSval(a)	Sums terminal values for Livestock enterprise a
MotadZ(Dev,mt)	Negative deviation counter Dev in year mt
SE	Motad calculations of the Standard error
Z	Objective function value

6.2.4 Typical farm equations

For the sake of brevity, the mathematical code for the equations is presented in Appendix D. However, to give the reader some insight into the working of the typical farm models, the equations are presented in Table 6.4.

Table 6.4: Typical farm equations (64 basic equations)

Cost	Defines objective function
Land(b,mt,mo)	Land utilisation of irrigation technology b in year mt month mo
Croparea(mj,b,mt)	Sums LT crop area mj produced with irrigation technology b in specific year mt
Sultconv(mj,b,mt)	Balance Sultana production mj produced with irrigation technology b in year mt with availability
Sultanbal(mj,b,t)	Total conversion may not exceed the specific area of grapes mj produced with technology b in year t
Sumprodlt(i,p,mt)	Sum production of long-term crop i product p in year mt
Sumprodst(i,p,mt)	Sum production of short-term crops i product p in year mt
sumreprod(a,mt)	Sums reproduction of livestock a in year mt
sumlivenu(a,mt)	Sum livestock numbers a for specific year mt
MaxliveS(a,mt)	Limit livestock sales a in year mt
Sumlive(a,ap,mt)	Sum livestock sales numbers of animal a product ap in year mt
Sumwool(a,ap,mt)	Sum wool production of sheep a of product ap in year mt
Labtr(mt)	Labour use in period mt
Ownlabtr(mt)	Transfer own labour in year mt
Labrent(mt)	Labour rent in year mt
Tracuse(mt)	Tractor use in year mt
Tracrent(mt)	Tractor rent in year mt
WateruseM(mt,mo)	Total water use by irrigation crops in year mt month mo
MwateruB(mt,mo)	Monthly water use balance in year mt month mo
MWschemeB(mt,mo,w)	Monthly water transfer from water sources w in year mt month mo
Awateru(mt)	Annual water use in year mt
AwaterUB(mt)	Annual water use balance in year mt
SchemeB(w,mt)	Balance farm dam fill plus direct irrigation water use from water source w in year mt
WschemeB(w,mt)	Transfer of maximum annual water from water source w in year mt
Waterbal(w,mt)	Subtract water to fill farm dams from availability from source w in year mt
FarmdamF(w,mt,d)	Balance filling of farm dam with farm dam capacity
Farmdsum(mt)	Balance monthly water extraction with transfers to fill farm dam in year mt
Damextr(mt,mo)	Maximum capacity to release farm dam water in year mt month mo
Damexmax(mt)	Farm dam extraction may not exceed dam capacity in year mt
Stock(fc,p,mt)	Maximum feed stock fc of product p in year mt
Bkcatrg(p,mt)	Bulk transfer grain g of product p to sell or for animal use in year mt
Bkcatr(cc,p,mt)	Bulk transfer of cash crops cc product p to sell activities in year mt
Bkfcfsale(fc,p,mt)	Balance yield distribution of feed crops product p with availability in year mt
Animalbulk(a,n,mt)	Nutrient transfer of nutrient n to animal a of bulk feed in year mt
AnminTDN(a,n,mt)	Balance minimum % TDN required for animal a nutrient n in year mt
AnmaxTDN(a,n,mt)	Balance maximum % TDN required for animal a nutrient n in year mt
AnminTRP(a,n,mt)	Balance minimum % TRP required for animal a nutrient n in year mt
AnmaxTRP(a,n,mt)	Balance maximum % TRP required for animal a nutrient n in year mt
Tandem(a,mt)	Sums total animal demand a in year mt
Maxbulk(a,mt)	Specifies maximum bulk requirement for animal a in year mt
Maxinclfc(p,a,mt)	Specifies maximum inclusion levels of own produced feed fc product p for animal a in year mt
Maxpurcf(f,p,a,mt)	Specifies maximum inclusion levels of purchased feed f product p for animal a in year mt
Maxveldu(v,p,a,mt)	Specifies maximum inclusion levels of veldt v product p for animal a in year mt
Ocost(oh,mt)	Overhead costs oh in year mt
Labpay(oh,mt)	Payment of annual labour costs oh in year mt
Ltaxpay(oh,mt)	Payment of annual land tax oh in year mt
Hcost(oh,mt)	Household costs oh in year mt
Nonfarmin(mt)	Maximum nonfarm income in year mt
Loans(l,mt)	All short term loans l in year mt
Opcap(mt)	Operating capital in year mt
Endbal	End balance after loans
Ancash(mt)	Annual cash flow in year mt
EndcashT	End cash
Minort(mj,b,pt)	Minimum or fix area of long-term crops mj produced with irrigation technology b in year pt
Maxort(mj,b,pt)	Maximum or fix area of long-term crops mj produced with irrigation technology b in year pt
MaxShort(oj,mt)	Maximum short-term crop area oj in year mt
MinShort(oj,mt)	Minimum short-term crop area oj in year mt
Maxveg(mt)	Maximum or fix area of vegetable crops in year mt
Maxspes(mj,b,mt)	Maximum of specific vegetables mj produced with technology g in year mt
Minliv(a)	Minimum livestock a
Maxliv(a,mt)	Maximum total livestock a in year mt
Maxtotliv(mt)	Maximum total livestock in any given year mt
Maxveld(v,p,mt)	Maximum dry matter available of natural veldt product p in year mt
SE_APP	Calculates standard deviation
RISK(Dev,mt)	Risk rows

The equations can be grouped into 10 sets:

- Land availability and crop area balances
- Those that convert Sultana grapes to alternative uses
- Crop and livestock product balances
- Livestock numbers and livestock growth
- Input (labour, water, and tractor) balances
- Those that balance water availability from different sources with water usage
- Those that balance minimum cost feed ration specifications
- Equations that force overhead costs into the solution
- Equations that balance loans, investments, and end balances
- Trimming equations to force the observed crop and livestock activities in the base solution
- Motad (risk) equations

6.2.5 The objective function

Endbal equation calculates a variable named Endb. The objective function basically consists of the following code:

```
CostL
+ Endb
*+ sum(mt,Ancashfl(mt))
- SUM((c,b,mt),MEAN(c,mt)*crst(c,b,mt)*LUPB(c,b))
- SUM((a,mt),MEAN(a,mt)*LSTTOT(a,mt))
-rap*SE
=e= Z.
```

The objective function specifies that the endbalance (Endb) minus the sum of discounted expected MEAN outcomes minus a Risk Aversion Parameter (rap) multiplied by Fischer's approximation of the standard error be maximised. Since the deviations from the mean in year mt are discounted, the SE is also discounted.

Alternatively, it is possible to maximise the annual cash flow (Ancashfl) instead of the end balance (Endb) minus the Motad specifications.

6.3 REGIONAL (AGGREGATED) FARM MODEL

The regional modelling framework for the middle and lower Orange River is presented in Figure 6.2. The model is a linear spatial equilibrium model designed to represent the main irrigation areas in the Orange River. This is done by maximising regional producer welfare surplus of irrigators minus the cost of supplying water. Each irrigation region is modelled using linear programming. The regional sub-models (with embedded typical farm models) are linked by a model of the river system. Water trading, transaction costs, and changes in water use are all taken into account. Positive mathematical programming (PMP) to calibrate the regional model to the exact observed base year resource use was excluded for the purpose of this project since it substantially increases computational time, especially if water trade is allowed. Risks are included in the model using the modified MOTAD technique described earlier in this report.

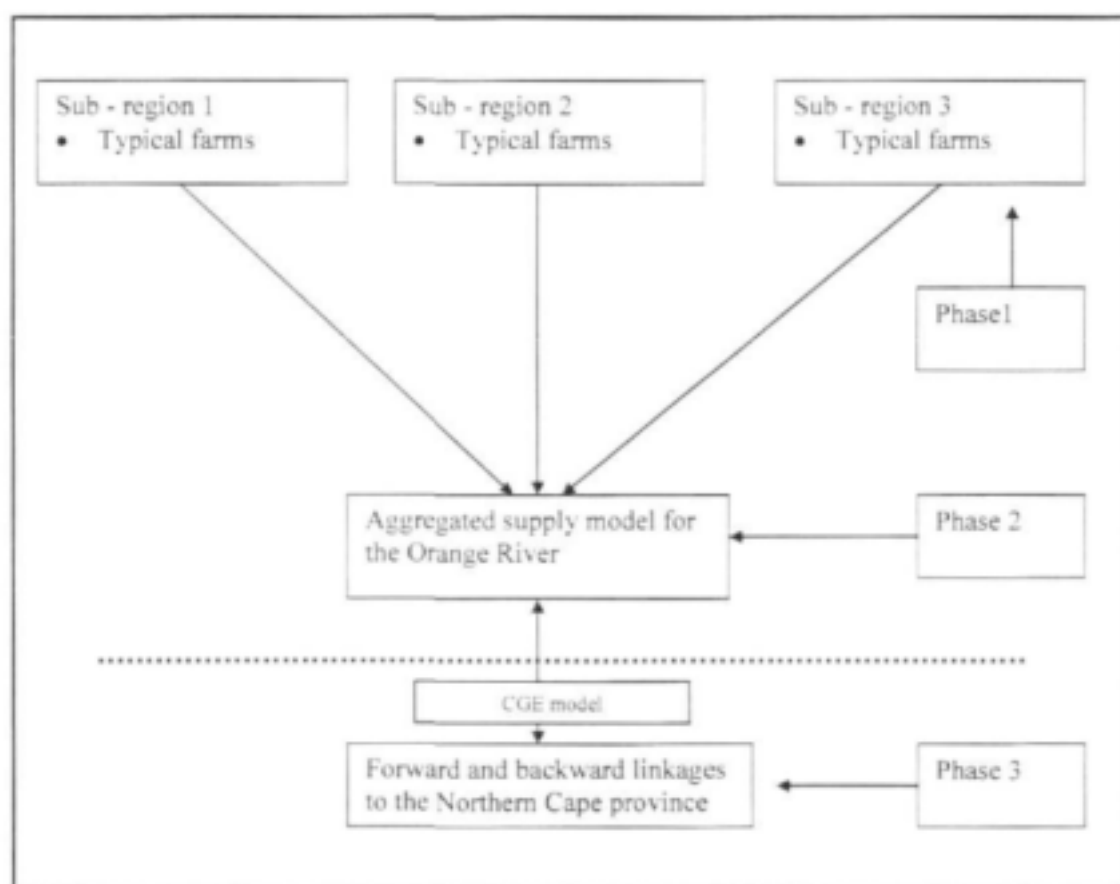


Figure 6.2: Conceptual presentation of the regional irrigation agriculture model

The detail of the GAMS code for this model is also not presented in the main report but is available in Appendix E. However, similar to the typical farm models, the sets, data parameters, variables, equations, and objective function are discussed.

6.3.1 Regional model sets

The specification of the sets is the foundation for specifying the data parameters, variables, equations, and objective function. A description of the 38 sets and their elements is presented in Table 6.5.

Table 6.5: Regional model sets (38 sets)

Set	Description	Elements
e	All enterprises	Onions, Watermelon, Lucern, RWine, WWine, Drygrape, Jugrape, Tablegr, TablegrS, Pecan, Olives, Citrus, Hplvld, Sheep, Beef, Goats, Lick, Lhay
o(c)	All crops and livestock	Onions, Watermelon, Lucern, RWine, WWine, Drygrape, Jugrape, Tablegr, TablegrS, Pecan, Olives, Citrus, Sheep, Beef, Goats
(c)	All crops	Wheat, Groundn, Maize, Oats, Barley, Cotton, Drybean, Sunflower, Soyabean, CarrotsS, Potatoes, Onions, Watermelon, Lucern, RWine, WWine, Drygrape, Jugrape, Tablegr, TablegrS, Pecan, Olives, Citrus
st(c)	All short-term crops	Onions, Watermelon
st(c)	Short-term veg	Wheat, Groundn, Maize, Oats, Barley, Cotton, Drybean, Sunflower, Soyabean
v(stc)	All vegetables	CarrotsS, Potatoes, Onions, Watermelon
sl(c)	Citrus	Citrus
o(l)	All other crops excluding Citrus	Wheat, Groundn, Maize, Oats, Barley, Cotton, Drybean, Sunflower, Soyabean, CarrotsS, Potatoes, Onions, Watermelon, Lucern, RWine, WWine, Drygrape, Jugrape, Tablegr, TablegrS, Pecan, Olives
(l)	All long-term crops	Lucern, RWine, WWine, Drygrape, Jugrape, Tablegr, TablegrS, Pecan, Olives, Citrus
oat(r)	Sulfate grapes	TablegrS
Mx(l,c)	Multi-year excluding lucern	RWine, WWine, Drygrape, Jugrape, Tablegr, TablegrS, Pecan, Olives, Citrus
kl(c)	All irrigation crops	Wheat, Groundn, Maize, Oats, Barley, Cotton, Drybean, Sunflower, Soyabean, CarrotsS, Potatoes, Onions, Watermelon, Lucern, RWine, WWine, Drygrape, Jugrape, Tablegr, TablegrS, Pecan, Olives, Citrus
fo(c)	All feed crops	Wheat, Groundn, Maize, Oats, Barley, Lucern, Hplvld
p	By products	Grain, Hay, Pasture, Pmx, Gr1, Tabel, TDry, TWine, TJuce
nv(c)	Natural veldt	Hplvld
cc(c)	No feed crops	Cotton, Drybean, Sunflower, Soyabean, CarrotsS, Potatoes, Onions, Watermelon, Lucern, RWine, WWine, Drygrape, Jugrape, Tablegr, TablegrS, Pecan, Olives, Citrus
ap	Livestock products	Live, Wool
at(ap)	Terminating livestock products	Live
n	Nutrients	Bulk, TDN, TRP
fb(p)	Feed bank	Grain, Hay
pf(c)	Purchased feed	Lick, Lhay
sl(c)	Livestock enterprise	Sheep, Beef, Goats
l	Land types	Irrg
r	All regions	Vaal, VolDR, DP, Boegoe, Uptaka, AugBlou, Bllou
b(r)	Irrigation regions	Vaal, VolDR, DP, Boegoe, Uptaka, AugBlou, Bllou
f	Typical or representative farms	f14
ss	Savings	invest
Lo	Loans	Stoan
gs	Growth stage of crop	g01*g20
Ts	Total time series	Y1994*Y2023
py(f)	Future years	Y2004*Y2023
py(f)	Past years	Y1994*Y2003
ry(f)	Remaining years after year 1	Y2004*Y2023
m	Months	Jan*Dec
Dev	Mosad deviation counters	GM1*GM100
q	Water sources	River, Canal
h	Irrigation intensity	Drop, Micro, Flood, Pivot, Sprinkle

The reader will note that the sets are not exactly the same as those for the typical farm models since the model was adapted from an existing model for the Berg River in the

Western Cape (from a previous WRC project and later updated in a follow-up research project for the IACC⁵).

6.3.2 Regional model data parameters

The database for the regional model is largely linked to the databases of the typical farm models in each of the sub-regions (described in section 2) included in the regional model (Orange River). It is extremely important for this data to match, since it will not be possible to replicate similar results with the typical farm models embedded in the regional model to those obtained with the individual typical farm models.

An additional worksheet not included in the typical farm database specifies the aggregation factors used to aggregate the typical farms and sub-regions to the total for the Northern Cape (see Table 4.1 in chapter 4).

Table 6.6 represent all the parameters used in the regional model. They can be divided into several categories. These include:

- Those that specify the number of typical farm in a region (e.g. *typd*)
- Specification of the resources that is available (e.g. *Aland*, *Veldarea*, *Maxloan*)
- Specification of costs per unit (e.g. *Cascost*, *Intst*, *Price*)
- Specification of scalars (e.g. *Manl*, *RAP*)
- Specification of resource use per unit of production (e.g. *CRBD*, *ADCAP*)
- Specification of the yield per production unit (*YA*, *YLT*)
- Specification of financial parameters (*INTST*, *INTINV*)
- Specification of MOTAD parameters (*MOTADGM*, *MOTADA*)

The main function of specifying parameters is to specify the input coefficients, output coefficients and upper and lower bounds for the problem to be solved.

⁵ Callaway, Louw & Nkomo (2005)

Table 6.6: Regional model data parameters (73 parameters)

Data parameter	Description
Typd(j,t)	Defines the amount of typologies t per region j
Aland(j,t,l)	Available land resources in region j for typology t land type l
Veldarea(b,t,nv)	Maximum dry matter yield of veldt in region b typology t for veldt type nv
OS(f,c,b,t,p,ph)	Begin stocks of feed fc in region b typology t for product p in year ph in ton
ESV(f,c,p)	Value of end stocks of feed fc product p
Yearsoc(i)	Land occupation of long-term crops i
Areau(i,m)	Monthly availability of land resources for crop i in month m
IRINT(i,h)	Irrigation intensity possibilities h for crop i
OH(b,t,*)	Overhead and household expenses for region b typology t
Maxloan(b,t,lo)	Maximum short-term loan for region b typology t and loan type lo
Labcost(b,t)	Labour costs per annum in region b for typology t
Deprec(b,t)	Depreciation costs per annum in region b for typology t
Landtax(b,t)	Land tax value to be taxed per annum in region b for typology t
INTST(lo)	Real interest rate on loan lo
INTINV(sa)	Real interest rate on investment sa
MaxC(b,t)	Maximum own labour in region b for typology t
MaxR(b,t)	Maximum rent capacities in region b for typology t
GasCost	Cost of additional inputs per unit
MaxOC(b,t,ph)	Maximum own capital available for region b typology t in year ph
TYP(c,b,t)	Typology definition for crop c in region b typology t
Maxarea(stc,b,t)	Fix aggregated level of short-term crops stc region b typology t in the base year
Maxgrnt(b,t,*)	Maximum for a combination of vegetables and citrus region b for typology t
Maxarealt(c,b,t,h,py)	Maximum area under long-term crops c region b typology t technology t in previous year py
CT(j,t,p,t')	Transaction costs between regions j typology t and region jp typology t
PTRFCAGRI	Transaction costs for perm trade in agnc
TRFCAGRI	Transaction costs for temp trade in agnc
CRBDaV(c,h,b)	Availability of budget information for crop ci irrigation technology h in region b
CRBD(c,i,h,b,gsi,*)	Detailed budget information * for crop ci irrigation technology h in region b for growth stage gsi
Adcap(i,gsi,h,p)	Use of operating capital per ha for converting from standard Sultanas i during growth stage gsi for irrigation
Yieldconv(c,p)	Converts total yield of crop c to product p
YLTsuft(i,gsi,p)	Yield of converted Sultanas i in growth stage gsi to product p
Price(c,p)	Price of cash crops c for product p per ton
Pricescal(c,b)	Price scaling of cash crops c per ton for different regions of the river b
Termval(i,gsi)	Terminal values of long-term crops i in growth stage gsi
WC(b,h,m)	Gross water use of crop i in region b for irrigation technology h in month m
YA(a,ap)	Yield of livestock a for livestock products ap in kg
Pfeedpr(pf,p)	Prices of purchased feed pf product p per ton
Anin(a,ph,*)	Inputs * for animal enterprises a in year ph
Termvt(S,a)	Terminal value for livestock a
Aprice(a,*)	Price per kg for livestock a products *
Maxlive(b,t,a,ph)	Maximum present livestock numbers a in region b for typology t in year ph
LiveG(a)	Parameter annual growth in livestock numbers a
LiveS(a)	Parameter for maximum selling percentage of livestock a
NRC(n,a)	Animal group a nutritional requirement n per unit (%)
INC(c,p,a)	Maximum inclusion levels of crop c product p in livestock feed for livestock a
NC(c,p,n)	Nutrient contents n of crop c product p in percentage
QD(ph,a)	Feed quantity demanded per stock unit a in tons per day per year ph
FBPOS(f,c,p)	Feed bank possibilities of crop fc product p
WDC(b,t,q,ph)	Allocation of water for irrigation in region b for typology t from water source q in year ph
MIRC(j,t,q)	Monthly water delivery capacity in region j for typology t from water source q
Maxalloc(b,t,q)	Maximum initial volumetric allocation per ha entitlement in region b for typology t from water source q
PUMPC(q)	Pumping costs of water from source q
ICW(b,t,q)	Cost of water per ha in region b for typology t from source q
ICWV(b,t,q)	Cost of water per volume of water in region b for typology t from water source q
BulkwaterR(m)	Monthly release capacity of Orange river source in month m
VerdiskT(ph)	Discount rate to calculate present value for year ph
TOTCAP	Total capacity of the Orange river
DPP	Days per month
ManL	Management level
Mlive	Maximum number of livestock
Landtrate	Land tax rate
TRADEP	Set Permanent trade on or off
TRADET	Set Temporary trade on or off
Scalefact	Scaling factor for water and monetary values
Timej	Second last year in time horizon
TOTANCRWR(j,b,h)	Total annual crop water requirement for crop i in region b with irrigation technology h
TOTDAC(i,h,b)	Total direct cost for crop i for irrigation technology h in region b
TOTRLAND(b)	Total land area available in region b
PREVLAND(k,b,py)	Total area of crop k in region b occupied in previous years py
MotadGM(Dev,c,b,ph)	Motad GM deviation
MotadGM(AV)(c,b,ph)	Motad GM deviation from average
Mean(c,b,ph)	Average values of each ci
RAP	Risk aversion parameter

6.3.3 Regional model variables

The regional model variables are basically the same as the typical farm models with two exceptions:

- Labour and tractor hours were excluded since the model is already massive. Although this is a short-coming of the current model, some compromises had to be made to enable the research team to embed 22 typical farm models in the regional model (and solve it in a reasonable time).
- In order to provide for temporary and permanent trade in the regional model, additional variables must be created to deal with this aspect.
- The reader will notice that similar variables to those of the typical farms have a set named “b” and “t” which refer to the sub-region and the typical farm within the sub-region respectively.

Table 6.7: Regional model variables (39 variables)

Variable	Description
Livestock(a,b,t,ph)	Present livestock numbers of livestock enterprise a in region b for typology t in year ph
LSTPurch(a,b,t,ph)	Number of livestock enterprise a in region b for typology t in year ph
Livestell(a,b,t,ph)	Sell livestock a from region b typology t in year ph
Liverepro(a,b,t,ph)	Reproduction of livestock a from region b typology t in year ph
LSTTO(a,b,t,ph)	Total number of livestock a in a specific year from region b typology t in year ph
LTAH(a,ap,b,t,ph)	Calculates maximum weight of livestock a product ap in kg from region b typology t in year ph
Wool(a,ap,b,t,ph)	Calculates wool production in kg from livestock a from region b typology t in year ph
FStock(a,b,t,ph)	Initial stock of feed for product p in region b for typology t in year ph
Feed(a,b,t,ph)	Feed bank transfer of crop c product p in region b for typology t in year ph
PFD(a,b,t,ph)	Purchase feed crop c product p for livestock a in region b typology t in year ph
Veld(a,b,t,ph)	Use of natural veld for product p for livestock a in region b for typology t in year ph
AH(a,b,t,ph)	Transfer of feed production from crop c product p to livestock a in region b for typology t in year ph
TAF(a,b,t,ph)	Total animal feed mix for livestock a in region b for typology t in year ph
Area(a,b,t,ph)	Area of crop c grown with irrigation technology h in region b on typology t in year ph
Totarea(a,b,t,ph)	Total long-term crop area i in a specific year in region b on typology t in year ph
TFC(a,b,t,ph)	Annual production volume of crop c product p in region b on typology t in year ph
GrS(a,b,t,ph)	Converted Sulfana grape activities of crop r with irrigation technology h in region b on typology t in year ph to
CS(a,b,t,ph)	Sell cash crop c product p in region b on typology t in year ph
OC(a,b,t,ph)	Overhead costs in region b on typology t in year ph
HC(a,b,t,ph)	Household costs in region b on typology t in year ph
TOTFAW(a,b,t,ph)	Total annual water demand in region b on typology t in year ph
TFMW(a,b,t,ph)	Typical farm monthly water demand in region b on typology t in month m year ph
TFAWPR(a,b,t,ph)	Permanent trade from other users to region b on typical farm t from water source q in year ph
TFAWPT(a,b,t,ph)	Permanent trade to other users from region b on typical farm t from water source q in year ph
TOTAPTR(a,b,t,ph)	Monthly transfers of permanent water for trade from region b on typical farm t from water source q in year ph
TOTAPMT(a,b,t,ph)	Total permanent water after permanent trade in region b on typical farm t from water source q in year ph
TFWTR(a,b,t,ph)	Temporary trade from other users to region b on typical farm t in month m from water source q in year ph
TFWTRT(a,b,t,ph)	Temporary trade to other users from region b on typical farm t in month m from water source q in year ph
Msumtr(a,b,t,ph)	Sum of monthly temp trade from other users to region b on typical farm t from water source q in year ph
Msumtr(a,b,t,ph)	Sum of monthly temp trade to other users from region b on typical farm t from water source q in year ph
PTW(a,b,t,ph)	Volume of water transferred from region j to region b from typical farm t to water source q in year ph
PTW(a,b,t,ph)	Volume of water transferred from region j to region b from typical farm t to water source q in year ph
QW(a,b,t,ph)	Volume of allocation water bought by region b typical farm t from source q in year ph (from DWAF)
Invest(a,b,t,ph)	Investment surplus for region b typical farm t in year ph
Loan(a,b,t,ph)	Short term loan to region b on typical farm t in region b in year ph
End(a,b,t,ph)	End balance after redemption of loans in region b for typical farm t
Z	Objective function free variable
Notes(a,b,t,ph)	Negative deviation counter Devc in region b
SE(b)	Notes calculation of the Standard error in region b

6.3.4 Regional model equations

Similar to the variables, the reader will note that many of the equations are similar to the typical farm models. The equations are presented in Table 6.8.

Table 6.8: Regional model equations (60 equations)

Equation	Description
Wellfare	Defines objective function
Mland(b,t,ph,m)	Monthly land requirement in region b on typology t in year ph month m
Croparea(r,b,t,ph)	Sums LT crop area r in region b on typology t in year ph
Sultconw(r,h,b,t,ph)	Converts Sultana production r produced with irrigation technology h in region b on typology t in year ph
Sultanbal(r,h,b,t,th)	Balance Sultana production r produced with irrigation technology h in region b on typology t in year th
TFCprod(l,p,b,t,ph)	Sums the total production of crop l product p in region b on typical farm t in year ph
Bkcatr(k,p,b,t,ph)	Bulk transfer of cash crop k product p in region b on typology t in year ph to sell
Maxliv(a,b,t,ph)	Maximum present livestock numbers a in region b on typology t in year ph
sumreprod(a,b,t,ph)	Sums reproduction of livestock a in region b on typology t in year ph
sumlivenu(a,b,t,ph)	Sum livestock numbers a in region b on typology t in year ph
MaxliveS(a,b,t,ph)	Limit livestock sales a in region b on typology t in year ph
Sumlive(a,ap,b,t,ph)	Sum livestock a production of product ap in region b on typology t in year ph
Sumwool(a,ap,b,t,ph)	Sum wool production of sheep a product ap in region b on typology t in year ph
Stock(fc,p,b,t,ph)	Maximum feed stock fc of product p in region b on typology t in year ph
Bkattr(c,p,b,t,ph)	Bulk transfer of crop c product p in region b on typology t in year ph to sell or be used as animal feed
Animalbulk(a,n,b,t,ph)	Nutrient transfer n of bulk feed to animal a in region b on typology t in year ph
AnnetTDN(a,n,b,t,ph)	Minimum % TDN for animal a in region b on typology t in year ph
AnmaxTDN(a,n,b,t,ph)	Maximum % TDN for animal a in region b on typology t in year ph
AnnetTRP(a,n,b,t,ph)	Minimum % TRP for animal a in region b on typology t in year ph
AnmaxTRP(a,n,b,t,ph)	Maximum % TRP for animal a in region b on typology t in year ph
Tandem(a,b,t,ph)	Sums total demand for feed for animal a in region b on typology t in year ph
Maxbulk(a,b,t,ph)	Specifies maximum bulk for animal a in region b on typology t in year ph
Maxincl(fc,p,a,b,t,ph)	Specifies maximum inclusion levels of own produced fc product p for animal a in region b on typology t in year ph
Maxpurch(pf,p,a,b,t,ph)	Specifies maximum inclusion levels of purchased feeds pf product p for animal a in region b on typology t in year ph
Maxvedu(nv,p,a,b,t,ph)	Specifies maximum inclusion level of veldt product p in total max for animal a in region b on typology t in year ph
Ocost(b,t,ph)	Overhead cost for region b typical farm t in year ph
Hoost(b,t,ph)	Household costs for region b typical farm t in year ph
Loans(b,t,lo,ph)	Maximum of All short term loans for region b typical farm t of loan lo in year ph
NDICAL(C,b,t,ph)	Calculates the net disposable income for region b typical farm t in year ph
Endbal(b,t)	Calculates the cumulative end balance for region b typical farm t at the end of the planning horizon
Mincrit(r,h,b,t,py)	Minimum past years long-term crops r produced with technology h in region b typical farm t in year py
Maxcrit(r,h,b,t,py)	Maximum past years long-term crops r produced with technology h in region b typical farm t in year py
MaxShort(stc,b,t,ph)	Maximum short term crops stc for region b typical farm t in year ph (base)
MinShort(stc,b,t,ph)	Minimum short term crops stc for region b typical farm t in year ph (base)
MaxliveST(a,b,t,ph)	Maximum livestock numbers a per annum for region b typical farm t in year ph
Maxliv(b,t)	Maximum for all livestock enterprises over the total planning horizon for region b typical farm t
MaxLTMin(r,h,b,t,ph)	MaxLTMin Restrict variation from the base year for crop r technology h for region b typical farm t in year ph
MaxLTMax(r,h,b,t,ph)	MaxLTMax Restrict variation from the base year for crop r technology h for region b typical farm t in year ph
Minveg(b,t,ph)	Minimum vegetables for region b typical farm t in year ph
Maxveg(b,t,ph)	Maximum vegetables for region b typical farm t in year ph
TOTTFWA(b,t,ph)	Total annual available through permanent and monthly trade for region b typical farm t in year ph
TFWPTFR(b,t,q,ph)	Sums permanent trade from region b typical farm t from water source q in year ph
TFWPTTO(b,t,q,ph)	Sums permanent trade to region b typical farm t from water source q in year ph
MxAPT(ro,b,t,q,ph)	Maximum permanent trade to other users from region b typical farm t water source q in year ph
TFMTTRFR(b,t,m,q,ph)	Sums temporary trade from region b typical farm t from water source q in year ph
TFMTTRTO(b,t,m,q,ph)	Sums temporary trade to region b typical farm t from water source q in year ph
Mbadeft(b,t,q,ph)	Total monthly temp trade from region b typical farm t from water source q in month ph
Mbadefto(b,t,q,ph)	Total monthly temp trade to region b typical farm t from water source q in month ph
MxATT(ro,b,t,q,ph)	Maximum temp trade from other users from region b typical farm t water source q in year ph
TAWatu(b,t,ph)	Water use by irrigation crops per annum from region b typical farm t in year ph
TFMWatu(b,t,m,ph)	Monthly water demand from region b typical farm t per month in year ph
IRdecap(b,t,m,ph)	Irrigation system monthly delivery capacity constraint for region b typical farm t per month in year ph
IRSC(m,ph)	Irrigation infrastructure monthly capacity m in year ph
Irmbal(b,t,ph)	Equalize monthly with total irrigation use for region b typical farm t in year ph
Minbal(b,t,m,ph)	Balance monthly agricultural needs with available for region b typical farm t per month in year ph
APTbal(b,t,q,ph)	Sums agricultural permanent water for region b typical farm t from water source q in year ph
TOTAPT(b,t,q,ph)	Transfer agricultural permanent water for use from region b typical farm t from water source q in year ph
Maxallo(b,t,q,ph)	Maximum water allocation for region b typical farm t from water source q in year ph
SE_APP(b)	Calculates Standard error in region b
RISK/Dev(b)	Risk rows

There are additional equations that are not in the typical farm models. These are mainly:

- Those that balance water availability before and after trade every year of the planning horizon.
- Equations that balance bulk water supply with sub-region water requirements.

6.3.5 The regional model objective function

The reader will note that the objective function of the regional model is almost identical to that of the typical farm models with the exception that all the typical farm end values (Endb) are maximised simultaneously minus the Motad specification variables. It is also important to note that all monetary values are divided by a scaling factor to improve on solving time.

Welfare ..

```
*=sum((b,t,ph)$Typd(b,t),Investmnt(b,t,ph))
+sum((b,t)$ Typd(b,t),Endb(b,t))
- SUM((i,h,b,t,ph),MEAN(i,h,ph)*cr(i,h,b,t,ph)$ (Typd(b,t) and TYP(i,b,t) and IRINT(i,h) gt 0))/scalefact
- SUM((a,b,t,ph),MEAN(a,b,ph)*LSTTOT(a,b,t,ph)$ (Typd(b,t) and TYP(a,b,t) gt 0))/scalefact
-sum(b,rap*(SE(b)/scalefact))
=c= z;
```

6.4 SUMMARY AND SCENARIO IMPLICATIONS

The development of any modelling structure is a dynamic process. There is always scope for improvement as computational capacity of computers increase and new information and techniques become available. However, the models that were developed will add tremendous value to decision making at both policy and farm level. The models have been tested (with the consent of the WRC) on at least four case studies (three on the affordability of irrigation water and one on the impact of minimum wages and land tax on farm profitability) in the region and have proven to be extremely valuable (Louw, 2001a; Louw, 2001b; Louw, 2002; Louw, 2003). Several tests were executed to test the models for validity including a simple spreadsheet formulation which was calculated manually to replicate the model results. The authors are therefore convinced that the models are mathematically correct and produce valid results.

The models were developed in GAMS and are solved with the CPLEX solver. The model output for different scenarios is transformed from a "text" format into an Excel spreadsheet

for additional calculations to present results in a user-friendly format. The GAMS code that generates the report ("text" files) was written in such a way that all the files for every scenario are exactly the same when they are transformed into Excel spreadsheet files. Scenario results can therefore be easily compared even when crop combinations and other activities change from one scenario to another. The model structure is efficient since all the data files are linked to one worksheet which is compatible with GAMS. The data to run the models can therefore easily be updated. However, it is not necessary to change anything in the "master" data file to run scenarios since the GAMS code in the models was written in such a way that parameters can be changed in the code (for example, relative increases in market prices or water tariffs) without changing anything in the "master" data file.

A defensible theoretical structure was developed to examine data intuitively and to permit comprehensive evaluation. In Chapter 7, these structured theoretical models will be used to illustrate the capacity of these models to analyse the impact of market risk on efficient water use and show the link between the regional model and the CGE model (volume 2).

SCENARIO DEVELOPMENT AND MODELLING RESULTS

7.1 INTRODUCTION

This chapter deals with sub-objectives 2 and 3 of the terms of reference:

- To develop a decision-making framework which farmers can use to reduce their risk.
- To compare present water use practices with optimal risk-reducing practices and find reasons for deviation.

The development of both the typical farm models and the regional models provides the analytical framework to analyse alternative risk-reducing strategies (sub-objective 2). In this chapter, the analytical framework that was developed is used to illustrate its potential value in reaching sub-objective 3. In Chapter 2, section 2.2.4.2, it was pointed out that knowledge of the market place is the key to managing market risks. The almost exponential growth in the table grape industry during the last 10 years leads the authors to the conclusion that farmers did not have adequate knowledge to foresee that supply would overtake demand and prices tumble to unprofitable levels. Since it is almost impossible to illustrate all the typical models (22 in 7 regions) and report on literally hundreds of possible scenarios, it was decided to illustrate only one typical farm model—specifically, the so-called “table grape” scenario. Typical examples of scenarios that can be analysed are the following:

- Import tariffs
- Medium- to long-term market outlooks
- Market access scenarios
- Input cost scenarios
- Agricultural policy scenarios that impact on competitiveness
- Impact of exchange rate fluctuations

- Economy of scale scenarios
- Value adding scenarios
- Efficiency scenarios
- Crop substitution
- Land-reform scenarios

The table grape scenario is an extremely useful case study since it contains all the elements to illustrate how lack of marketing information can lead to non-optimal resource allocations and to suggest risk-reducing practices of how the situation could have been managed in a more effective way.

The same is true for the regional (Orange River) model. The purpose of this report is not to demonstrate all the possible scenarios that can be analysed since it is possible to analyze most macro and micro impacts with this model. Therefore a similar route to the typical farm models was followed by only demonstrating selected scenarios. It was decided to use the table grape scenario in the regional model to show which direction water would have flowed in if farmers had better market information. It was also decided to do a water tariff scenario to show how overly increased water tariffs can reduce competitiveness because of increased production costs. This is a typical scenario where increased production costs may result in a less competitive agricultural sector.

Apart from demonstrating the typical farm models and regional model, the objective of some selected scenarios is also to demonstrate the link between the CGE model and micro economic models. The downward link is demonstrated by reducing the world fruit price in the CGE model by 20%. The CGE model then calculates the reduction in the South African fruit price. This scenario is tested on the typical farm and regional models.

7.2 GENERAL SCENARIO DESCRIPTION

The marketing situation regarding table grapes was already discussed in previous sections of this report. However, the following is a short summary of the current and future expectations:

- Table grape production in South Africa and in all the southern hemisphere producing countries has increased almost exponentially during the past 6-7 years. In South Africa alone, export volumes have more than doubled since 1999/2000.
- Most production growth in South Africa has come from the Orange River region. This region has historically been early in the market compared to other production regions in South Africa and also in the southern hemisphere.
- However, the "early" advantage of the Orange River has gradually been eroded by huge increases in export volumes to the UK and European markets, and this situation is not expected to change any time soon.
- Although progress has been made with market access to China, huge volumes are not expected to be flowing in that direction any time soon.
- Subsequently, the average table grape export price per 4.5 kg in the Orange River has decreased from R57 in 2000/2001 to about R44 per carton in 2003/2004 (more than 22%).
- An analysis of the CGE model where the international fruit price dropped by 20% resulted in almost exactly the same figure. The CGE model showed that the South African fruit export price will decrease by 22.7%.

7.3 TYPICAL FARM MODEL

To illustrate the typical farm models, the Augrabies-Blouputs model was selected to analyse the "table grape" scenario since the objective is also to show the link between the CGE model and farm models.

7.3.1 Farm model scenarios

The observed average table grape prices for four seasons are presented in Table 7.1. It is clear that since 2001/2002, the average table grape price decreased by almost 23%. It should be obvious that this reduction in price will not only impact on the profitability of the table grape farming activity but also on the whole farm level, the regional level and on the province.

Table 7.1: Average table grape price per 4.5 kg carton

Season	Price/4.5kg carton	% change from 2001/2002
2001/2002	57.28	
2002/2003	59.60	4.05%
2003/2004	47.39	-17.27%
2004/2005	44.25	-22.75%

Source: OABS (2005)

The following scenarios were analysed:

- Base: analysis of present situation R57.28 per 4.5 kg--no variation in current land use (meaning that no variation is possible from the base land use).
- Scen 1 = 10% decrease in the price of table grapes (TG) (R51.55 per 4.5 kg carton)--no variation in current land use
- Scen 2 = 20% decrease in the price of TG (R45.82 per 4.5 kg carton)--no variation in current land use
- Scen 3 = 30% decrease in the price of TG (R40.09 per 4.5 kg carton)--no variation in current land use
- Scen 4 = 35% decrease in the price of TG (R37.23 per 4.5 kg carton)--no variation in current land use
- Scen 5 = Base price of TG--50% variation on the current land use--no restriction on short-term crops in terms of variation from the current land use.
- Scen 6 = 10% decrease in the price of TG--50% variation on the current land use--no restriction on short-term crops
- Scen 7 = 20% decrease in the price of TG--50% variation on the current land use--no restriction on short-term crops
- Scen 8 = 30% decrease in the price of TG--50% variation on the current land use--no restriction on short-term crops
- Scen 9 = 40% decrease in the price of TG (R34.37 per 4.5 kg carton)--50% variation on the current land use--no restriction on short-term crops
- Scen 10 = 45% decrease in the price of TG--50% variation on the current land use--no restriction on short-term crops--unfeasible
- Scen 11 = 40% decrease in the price of TG, 100% increase in dry grapes--50% variation on the current land use--no restriction on short-term crops

- Scen 12 = 40% decrease in the price of TG, 130% increase in dry grapes--50% variation on the current land use--no restriction on short-term crops
- Scen 13 = 40% decrease in the price of TG, 150% increase in dry grapes--50% variation on the current land use--no restriction on short-term crops
- Scen 14 = 40% decrease in the price of TG, 100% increase in dry grapes--100% variation on the current land use--no restriction on short-term crops
- Scen 15 = 40% decrease in the price of TG, 130% increase in dry grapes--100% variation on the current land use--no restriction on short-term crops
- Scen 16 = 40% decrease in the price of TG, 150% increase in dry grapes--100% variation on the current land use--no restriction on short-term crops

For simplified analysis, the scenarios can be grouped into four sets:

- Set 1: Scenarios 1-4 show the result of reducing the price of table grapes by between 10-35% (40% is unfeasible⁶) with no deviation from the current farm structure allowed.
- Set 2: Scenarios 5 to 10 are exactly the same as the first set except that a 50% up and down variation on the current land use is allowed. The reader will note that the farm only became unfeasible when the table grape price was reduced by 45%.
- Set 3: Scenario 11-13 is basically a set of scenarios where the price of table grapes is reduced by 40%, the price of dry grapes increased by 100-150% (this is totally unrealistic but for a specific reason), and only a 50% up and down variation in the current land use is allowed.
- Set 4: Scenario 14-16 is exactly the same as the previous set except that a 100% variance on the current land use is allowed.

The huge unrealistic increase in the price of dry grapes was introduced since the model was tested at smaller increases and did not change structurally towards dry grapes. It was therefore decided to make huge increases to determine the price of dried grapes where structural changes would occur.

⁶ Unfeasible in this sense means that the farm cannot repay the required short-term loans to balance the annual cash flow within the planning horizon.

7.3.2 Farm model results

The following results are discussed:

- Changes in the return on capital investment
- Changes in the Net Farm Income (NFI)
- Structural changes
- Changes in the capitalised marginal value of land
- Changes in the capitalised marginal value of water

7.3.2.1 Capitalised return on capital investment

The return on capital investment was calculated as the sum of the capitalised cumulative cash flow at the end of the planning horizon divided by the capitalised capital investment to generate this cash flow. This method is an oversimplification since it assumes the same capital structure over the entire planning period. However, since the relative changes are more important in mathematical farm planning models than the actual figures, it is not important. These simple calculations give the analyst a fairly good indication of how the return on capital investment will change under different scenarios (see Table 7.2).

Table 7.2: Farm models – return on capital investment

Scenario	AugBlou
Base: analysis present situation R57.28 per 4.5kg - no variation in current land use	37.4%
Scen 1 = Same as Base but 10% decr. in the price of TG (R51.55 per 4.5kg carton)	28.0%
Scen 2 = Same as Base but 20% decr. in the price of TG (R45.82 per 4.5kg carton)	18.5%
Scen 3 = Same as Base but 30% decr. in the price of TG (R40.09 per 4.5kg carton)	9.1%
Scen 4 = Same as Base but 35% decr. in the price of TG (R37.23 per 4.5kg carton)	4.3%
Scen 5 = Same as Base but 50% variation on the current land use of long-term crops - no restriction on ST crops	45.3%
Scen 6 = Same as Scen 5 but 10% decr. in the price of TG	34.5%
Scen 7 = Same as Scen 5 but 20% decr. in the price of TG	23.6%
Scen 8 = Same as Scen 5 but 30% decr. in the price of TG	12.7%
Scen 9 = Same as Scen 5 but 40% decr. in the price of TG (R34.37 per 4.5kg carton)	1.9%
Scen 10 = Same as Scen 5 but 45% decr. in the price of TG - infeasible	NA
Scen 11 = Same as Scen 5 but 40% decr. in the price of TG - 100% increase in raisons	2.5%
Scen 12 = Same as Scen 5 but 40% decr. in the price of TG - 130% increase in raisons	3.0%
Scen 13 = Same as Scen 5 but 40% decr. in the price of TG - 150% increase in raisons	3.9%
Scen 14 = Same as Scen 11 but 40% decr. in the price of TG - 100% increase in raisons - current LT crop land use	1.2%
Scen 15 = Same as Scen 11 but 40% decr. in the price of TG - 130% increase in raisons - current LT crop land use	1.6%
Scen 16 = Same as Scen 11 but 40% decr. in the price of TG - 150% increase in raisons - current LT crop land use	2.7%

It should be obvious that in a region where almost 100% of the current land is occupied by long-term crops, 68% of which are table grapes, the impact of a reduction in the price of

table grapes will be devastating. The base analysis shows that return on capital investment was more than 37% percent during the table grape boom of the 2000/2001 season.

However, a reduction of 20% in the export price of table grapes causes the return on capital investment to decrease to 18.5% if structural changes cannot be made. The huge decrease is reduced to some extent if a 50% variation in current land use is allowed since farmers can react to the reduced price and make structural changes, especially in terms of Sultana production where it is possible to change to dry grapes, wine, or juice. The analysis also shows that the farm is still feasible (although only barely) at a price reduction of 35% when no structural changes is possible and at a 40% reduction if some changes are possible.

The analysis also shows that even with a huge increase in the price of raisins, it is not possible to make adequate structural changes within the 20-year planning horizon to counter a reduction of 40% in the price of table grapes.

Also, the reader should be aware that the 20% reduction in the price of table grapes since 2001 is an average figure. This means that a lot of farmers will have experienced price reductions of 30% and even more. The results are consistent with regional observations that many farmers experience tremendous financial problems.

7.3.2.2 Changes in the Net Farm Income (NFI)

Table 7.3 shows the substantial decrease in the NFI with decreasing table grape prices. When the price of table grapes is reduced by 20%, the NFI per ha decreases from R56 177 in the base analysis to R27 800 per ha in scenario 2. A 35% percent reduction in the price of table grapes reduces NFI per ha to only R6 520 per ha.

The advantage of a more flexible farming system should be clear when scenarios 5-9 are considered. If structural changes can be made, the impact can be reduced to some extent. In these scenarios, a 20% reduction in the price of table grapes results in a NFI per ha of R35 423 compared to R27 800 when no structural changes are possible.

Table 7.3: Average Net farm Income (Rand per ha)

Scenario	AugBlou
Base: analysis present situation R57.28 per 4.5kg - no variation in current land use	56,177
Scen 1 = Same as Base but 10% decr. in the price of TG (R51.55 per 4.5kg carton)	41,989
Scen 2 = Same as Base but 20% decr. in the price of TG (R45.82 per 4.5kg carton)	27,800
Scen 3 = Same as Base but 30% decr. in the price of TG (R40.09 per 4.5kg carton)	13,612
Scen 4 = Same as Base but 35% decr. in the price of TG (R37.23 per 4.5 kg carton)	6,520
Scen 5 = Same as Base but 50% variation on the current land use of long-term crops - no restriction on ST crops	68,074
Scen 6 = Same as Scen 5 but 10% decr. in the price of TG	51,746
Scen 7 = Same as Scen 5 but 20% decr. in the price of TG	35,423
Scen 8 = Same as Scen 5 but 30% decr. in the price of TG	19,106
Scen 9 = Same as Scen 5 but 40% decr. in the price of TG (R34.37 per 4.5kg carton)	2,817
Scen 10 = Same as Scen 5 but 45% decr. in the price of TG - infeasible	NA
Scen 11 = Same as Scen 5 but 40% decr. in the price of TG, 100% increase in raisons	3,818
Scen 12 = Same as Scen 5 but 40% decr. in the price of TG, 130% increase in raisons	4,516
Scen 13 = Same as Scen 5 but 40% decr. in the price of TG, 150% increase in raisons	5,903
Scen 14 = Same as Scen 11 but 40% decr. in the price of TG, 100% increase in raisons - current LT crop land use	1,859
Scen 15 = Same as Scen 11 but 40% decr. in the price of TG, 130% increase in raisons - current LT crop land use	2,907
Scen 16 = Same as Scen 11 but 40% decr. in the price of TG, 150% increase in raisons - current LT crop land use	4,124

Table 7.4 shows the relative changes in NFI compared to the base analysis. It is clear that when no structural changes are possible, the NFI is reduced by approximately 25% for every 10% reduction in price (scenarios 1-3). However, when structural changes is possible, the NFI increases with approximately 21% at a table grape price of R57.28 per 4.5 kg carton, and the reduction in NFI with every 10% decrease in the price of table grapes is limited to between 9% (difference in % reduction between Scen 8 and Scen 3) and 17% (difference in reduction between Scen 6 and Scen 1). It is interesting to note that the advantage of being able to make structural changes decreases with every 10% decrease in the price of table grapes. The reason is that it is only possible to make limited structural changes, so the advantage of reducing the negative impact of table grape price reductions is limited.

Table 7.4: Net farm income (NFI) --% change from the Base analysis

Scenario	AugBlou
Base: analysis present situation R57.28 per 4.5kg - no variation in current land use	NA
Scen 1 = Same as Base but 10% decr. in the price of TG (R51.55 per 4.5kg carton)	-25.3%
Scen 2 = Same as Base but 20% decr. in the price of TG (R45.82 per 4.5kg carton)	-50.5%
Scen 3 = Same as Base but 30% decr. in the price of TG (R40.09 per 4.5kg carton)	-75.8%
Scen 4 = Same as Base but 35% decr. in the price of TG (R37.23 per 4.5 kg carton)	-88.4%
Scen 5 = Same as Base but 50% variation on the current land use of long-term crops - no restriction on ST crops	21.2%
Scen 6 = Same as Scen 5 but 10% decr. in the price of TG	-7.9%
Scen 7 = Same as Scen 5 but 20% decr. in the price of TG	-36.9%
Scen 8 = Same as Scen 5 but 30% decr. in the price of TG	-66.0%
Scen 9 = Same as Scen 5 but 40% decr. in the price of TG (R34.37 per 4.5kg carton)	-95.0%
Scen 10 = Same as Scen 5 but 45% decr. in the price of TG - infeasible	NA
Scen 11 = Same as Scen 5 but 40% decr. in the price of TG, 100% increase in raisons	-93.2%
Scen 12 = Same as Scen 5 but 40% decr. in the price of TG, 130% increase in raisons	-92.0%
Scen 13 = Same as Scen 5 but 40% decr. in the price of TG, 150% increase in raisons	-89.5%
Scen 14 = Same as Scen 11 but 40% decr. in the price of TG, 100% increase in raisons - current LT crop land use	-96.7%
Scen 15 = Same as Scen 11 but 40% decr. in the price of TG, 130% increase in raisons - current LT crop land use	-94.8%
Scen 16 = Same as Scen 11 but 40% decr. in the price of TG, 150% increase in raisons - current LT crop land use	-92.7%

Finally, it is clear that even very large increases in the price of raisins have a very limited impact. In comparing scenario 9 with scenarios 11-16, it is clear that there is only a 2-6% advantage even if structural changes are possible. The explanation for this can be found in Table 7.5. It should be clear that even with a 150% increase in the price of raisins, table grapes are still more profitable when the table grape price is reduced by 40%. The reader should be aware that the interest on short-term loans has not been accounted for in these calculations.

Table 7.5: Table grape profitability compared to raisins

Crop	Price	Yield(t)	Net price per ton (Rand)	Gross income (Rand)	DAC (Rand)	Gross margin (Rand)	Overheads (Rand)*	NFI (Rand)
Raisins	Base	25	894	22 344	9 900	12 444	33 800	-21 356
Table grapes	Base	18	12 729	229 120	91 353	137 767	33 800	103 967
Raisins	150% increase	25	2 234	55 860	9 900	45 960	33 800	12 160
Table grapes	40% decrease	18	7 637	137 472	91 353	46 119	33 800	12 319

Notes: * In these analyses, overheads include labour, water, depreciation, and household costs. The table is over simplified since it is assumed that the overhead costs for raisins are exactly the same. On a raisin farm, overhead costs will be considerably lower.

7.3.2.3 Structural changes

It was pointed out earlier that it is not a simple matter to make huge structural changes on a farm designed to grow table grapes. In the medium term, however, it is possible to change between grapes for exports to grapes for other uses. However, this can only be done with table grapes and can only impact direct costs. In most cases, overhead and fixed costs will stay almost the same. It is useful to illustrate the possible structural changes by comparing the total area of crops of a 20-year planning horizon. To illustrate the possible structural changes in the Augrabies-Blouputs region when table grape price are reduced by 20%, it is useful to compare scenario 5 (without water trade) and scenario 9 (with water trade) in Table 7.6. Clearly, there are no significant changes. However, it is important to note that although the raisin area does not increase, the sultana area (grapes that can be converted) does increase slightly. It is also clear that some structural changes take place towards short-term crops and towards citrus (the citrus price was not changed). This result is important since it indicates a more diversified farming system if farmers had better information about the marketing environment.

Table 7.6: Possible structural changes (total area over 20-years)

Crop area (ha)	Scen5	Scen9	% Deviation
Red wine	0.0	0.0	NA
White wine	16.2	16.2	0.00%
Raisins	143.1	143.1	0.00%
Juice grapes	0.0	0.0	NA
Sultana table grapes	781.4	804.3	2.94%
All other table grapes	1022.1	955.6	-6.51%
Citrus	16.1	48.3	200.00%
Lucern	2.0	2.0	0.00%
Short-term	0.0	5.4	NA
Total	1980.9	1974.9	-0.30%
Average land use per annum	99.0	98.7	-0.30%

Table 7.7 shows the conversion of “standard”⁷ sultanas to either raisins or table grapes. Clearly, even if the price of table grapes is reduced to 40% and more, there is no indication of a conversion to sultanas (Table 7.5 explains this). However, if the price of raisins increases, it is clear that some of the table grapes are converted to raisins, and the volume converted increases as the price of raisins increases. This result is also important since it clearly shows the advantage of sultana grapes. However, it was pointed out earlier that even the huge increase in the price of raisins (which is totally unrealistic) does not improve the situation significantly.

Table 7.7: Sultanas converted to table grapes or raisins

Scenario	% of TG area	Table grape (ton)	Raisins (ton)
Base: analysis present situation R\$7.28 per 4.5kg - no variation in current land use	49.7%	716	0
Scen 1 = Same as Base but 10% decr. in the price of TG (R\$1.55 per 4.5kg carton)	49.7%	716	0
Scen 2 = Same as Base but 20% decr. in the price of TG (R\$1.82 per 4.5kg carton)	49.7%	716	0
Scen 3 = Same as Base but 30% decr. in the price of TG (R\$2.09 per 4.5kg carton)	49.7%	716	0
Scen 4 = Same as Base but 35% decr. in the price of TG (R\$2.23 per 4.5kg carton)	49.1%	710	0
Scen 5 = Same as Base but 50% variation on the current land use of long-term crops - no restriction on ST crops	53.3%	781	0
Scen 6 = Same as Scen 5 but 10% decr. in the price of TG	53.3%	781	0
Scen 7 = Same as Scen 5 but 20% decr. in the price of TG	52.5%	771	0
Scen 8 = Same as Scen 5 but 30% decr. in the price of TG	52.5%	771	0
Scen 9 = Same as Scen 5 but 40% decr. in the price of TG (R\$4.37 per 4.5kg carton)	50.0%	720	0
Scen 10 = Same as Scen 5 but 45% decr. in the price of TG - infeasible	NA	NA	NA
Scen 11 = Same as Scen 5 but 40% decr. in the price of TG - 100% increase in raisins	56.0%	625	312
Scen 12 = Same as Scen 5 but 40% decr. in the price of TG - 130% increase in raisins	56.0%	234	863
Scen 13 = Same as Scen 5 but 40% decr. in the price of TG - 150% increase in raisins	58.6%	122	858
Scen 14 = Same as Scen 11 but 40% decr. in the price of TG - 100% increase in raisins - current LT crop land use	53.6%	671	224
Scen 15 = Same as Scen 11 but 40% decr. in the price of TG - 130% increase in raisins - current LT crop land use	53.6%	431	652
Scen 16 = Same as Scen 11 but 40% decr. in the price of TG - 150% increase in raisins - current LT crop land use	53.6%	385	782

⁷ Standard in this sense means that a standard sultana budget is included in the model. With approximate costs, these grapes can then be converted to raisins, table grapes, wine, or juice.

7.3.2.4 Capitalised marginal value of land

Table 7.8 represents changes in marginal land value. It is sometimes difficult to interpret marginal values since so many things determine their values. For example, the land is only valuable if there are other adequate resources to utilise the land. If there is no water available, the land will have a very low value compared to when adequate water resources are available. Also, if the price of the products produced through irrigation agriculture decreases, the value of the land will also obviously decrease. However, in spite of the difficulty of explaining the exact values, they are extremely useful since they indicate the value of scarce resources and the relative changes between different scenarios. The general trend in table 7.8 is that marginal land values decrease as the price of table grapes decreases. This result is also consistent with observations in the region. It is clear that with a reduction of 20% in the price of table grapes, the value of the land is almost halved. This creates enormous problems for financiers and farmers since it reduces the credit rating of farmers and increases risk to financiers.

The relevance of this result is that it demonstrates the add-on effects of market risks. Not only does farm profitability decline severely, but there is an immediate impact on land value, solvability and subsequently on the financing of future farm operations.

Table 7.8: Changes in the marginal value of land (Rand/ha)

Scenario	AugBlou
Base: analysis present situation R57.28 per 4.5kg - no variation in current land use	204.946
Scen 1 = Same as Base but 10% decr. in the price of TG (R51.55 per 4.5kg carton)	116.378
Scen 2 = Same as Base but 20% decr. in the price of TG (R45.82 per 4.5kg carton)	107.632
Scen 3 = Same as Base but 30% decr. in the price of TG (R40.09 per 4.5kg carton)	86.568
Scen 4 = Same as Base but 35% decr. in the price of TG (R37.23 per 4.5kg carton)	63.158
Scen 5 = Same as Base but 50% variation on the current land use of long-term crops - no restriction on ST crops	164.748
Scen 6 = Same as Scen 5 but 10% decr. in the price of TG	113.069
Scen 7 = Same as Scen 5 but 20% decr. in the price of TG	89.817
Scen 8 = Same as Scen 5 but 30% decr. in the price of TG	69.159
Scen 9 = Same as Scen 5 but 40% decr. in the price of TG (R34.37 per 4.5kg carton)	30.496
Scen 10 = Same as Scen 5 but 45% decr. in the price of TG - infeasible	NA
Scen 11 = Same as Scen 5 but 40% decr. in the price of TG, 100% increase in raisons	20.443
Scen 12 = Same as Scen 5 but 40% decr. in the price of TG, 130% increase in raisons	22.195
Scen 13 = Same as Scen 5 but 40% decr. in the price of TG, 150% increase in raisons	24.349
Scen 14 = Same as Scen 11 but 40% decr. in the price of TG, 100% increase in raisons - current LT crop land use	27.153
Scen 15 = Same as Scen 11 but 40% decr. in the price of TG, 130% increase in raisons - current LT crop land use	38.872
Scen 16 = Same as Scen 11 but 40% decr. in the price of TG, 150% increase in raisons - current LT crop land use	47.932

7.3.2.5 Impact on the value of water

The value of irrigation water is derived from the value of agricultural products. The value of water can therefore be expected to decrease as the price of table grapes decreases. Table

7.9 shows the average capitalised marginal value of water converted from a value per m^3 to the value for one ha of water rights (in this case 15 000 m^3 per ha). The reader should know that if farmers paid these values for water rights, they would be bankrupt, since it is basically the average value of one additional unit (in this case one ha of water rights) of water. The base analysis shows extremely high capitalised marginal values for water rights that are not consistent with observations in the Orange River (mainly R10 000-R20 000 per ha). However, when the restrictions on the present farm structure are released, the values are more in line with observed water use right values. The general trend which is consistent with the literature is that marginal values decrease with every decrease in the price of table grapes.

Table 7.9: Average capitalised marginal value of irrigation water (Rand/ha)

Scenario	AugBlou
Base: analysis present situation R57.28 per 4.5kg - no variation in current land use	61 208
Scen 1 = Same as Base but 10% decr. in the price of TG (R51.55 per 4.5kg carton)	46 455
Scen 2 = Same as Base but 20% decr. in the price of TG (R45.82 per 4.5kg carton)	38 205
Scen 3 = Same as Base but 30% decr. in the price of TG (R40.09 per 4.5kg carton)	28 438
Scen 4 = Same as Base but 35% decr. in the price of TG (R37.23 per 4.5 kg carton)	20 678
Scen 5 = Same as Base but 50% variation on the current land use of long-term crops - no restriction on ST crops	57 540
Scen 6 = Same as Scen 5 but 10% decr. in the price of TG	52 995
Scen 7 = Same as Scen 5 but 20% decr. in the price of TG	32 693
Scen 8 = Same as Scen 5 but 30% decr. in the price of TG	26 123
Scen 9 = Same as Scen 5 but 40% decr. in the price of TG (R34.37 per 4.5kg carton)	17 768
Scen 10 = Same as Scen 5 but 45% decr. in the price of TG - infeasible	NA
Scen 11 = Same as Scen 5 but 40% decr. in the price of TG, 100% increase in raisons	14 048
Scen 12 = Same as Scen 5 but 40% decr. in the price of TG, 130% increase in raisons	20 048
Scen 13 = Same as Scen 5 but 40% decr. in the price of TG, 150% increase in raisons	16 740
Scen 14 = Same as Scen 11 but 40% decr. in the price of TG, 100% increase in raisons - current LT crop land use	18 638
Scen 15 = Same as Scen 11 but 40% decr. in the price of TG, 130% increase in raisons - current LT crop land use	17 288
Scen 16 = Same as Scen 11 but 40% decr. in the price of TG, 150% increase in raisons - current LT crop land use	14 805

7.3.3 Summary of farm model results

In the introduction to this chapter, it was pointed out that two sub-objectives will be addressed:

- To develop a decision making framework which farmers can use to reduce their risk.
- To compare the present water use practices with optimal risk-reducing practices and find reasons for deviation

It is possible to ask an almost unlimited number of "what if" questions with the modelling framework that was developed. However, it is not the purpose of this report to illustrate all the possible scenarios that can be analysed. The table grape scenario clearly illustrates the

potential use of this model. The following can be concluded from a risk management point of view:

- It is extremely risky in the volatile marketing environment of the global village to specialise in just one crop. This is what many farmers did in the Augrabies/Blouputs region. When the price of table grapes came down, farmers could not adjust in the short run.
- A sudden price reduction that is expected to continue in future creates financing problems. Farmers' solvability and ability to pay back loans are reduced.
- In many cases, fixed costs cannot be reduced in the short or even medium run.

The analysis indicates the following important aspects from a resource allocation and risk-aversion strategy point of view:

- The difference in farm profitability and farm structure between the base analysis and when the price of table grapes is reduced clearly shows that farmers did not have adequate information to adapt their farming practices to reduce market risks.
- It should be obvious that there is potential for inefficient irrigation water allocation if farmers either do not have access to accurate and up-to-date market intelligence or are inadequately trained to interpret this information. The analysis clearly showed the huge impact on farm profitability and capitalised marginal land value when the price of table grapes is reduced. The result clearly indicates that water is not allocated optimally if farmers do not provide for market risks. This point will be elaborated on in the regional model discussion.
- The results indicate that in the case of the Augrabies/Blouputs region, one risk-aversion strategy would have been a more diversified farming structure including more short-term crops and the capacity to be more flexible in terms of table grape production.
- Since the Augrabies/Blouputs region is remote and far from fresh produce markets, it should also be obvious that a risk-aversion strategy should include research with regard to alternative crops for the area to enable farmers to diversify to other crops than vineyards.
- The impact of reduced production costs was not analysed in this chapter. However, it should be obvious that a sensible market risk-aversion strategy will also include

measures to reduce production costs. One way is to increase economies of scale through farmers collaborating in terms of packaging and transport logistics. Similar collaboration between table grape farmers and their exporters to find ways of decreasing the cost of packaging, for example, could also make a significant contribution. A low-cost structure is an enormously powerful risk-aversion strategy in itself, since it reduces the break-even point of production and increases a farm's ability to absorb price shocks.

- From a national water allocation efficiency point of view, the results imply that it will be worthwhile for government to invest in market information systems and information communication to increase water allocation efficiency since efficient water allocation is in the general public interest.
- One possible solution could be in a so-called Public Private Partnership (PPP) between industry organisations such as the Deciduous Fruit Producers Trust and the Department of Agriculture.
- Also, there is probably a need to train farmers in the interpretation of market information and market intelligence.

Finally, although only one market risk scenario was illustrated in this chapter, the model can be extremely useful for testing risk-aversion strategies for specific typical farms with different farm structures. Although general risk-aversion strategies can be suggested, very specific strategies will need to be developed for different regions, farm structures, and farm sizes.

The other typical farm models can be used in similar way to that discussed in this chapter to analyse other irrigations in the Northern Cape and develop risk-aversion strategies for these regions.

7.4 REGIONAL MODEL (TABLE GRAPE SCENARIO)

The regional model is useful for looking at the regional impact of marketing risks and other economic impacts. The structure of this model was described in a previous chapter. The main advantage of the model is that the 22 typical farm models in 7 seven regions are linked by virtue of being solved simultaneously in one objective function and through water trading.

7.4.1 Regional model scenarios

To enable the farm model scenarios to be compared with the regional model scenarios, similar scenarios were developed. The major difference is that the models are solved with and without water trade to get an indication of which direction water trade would take place in if farmers had more complete knowledge of the marketing environment and used this knowledge to change their farm structures to be more adaptable to marketing risks. The reader should note that the practicality of physical water transfer was not considered, so theoretical water transfers are in question. However, for the purpose of this report and to develop risk-aversion strategies, this is not important.

The following scenarios were analysed:

- Base = Current land use with no water trade--20% down variation on long-term crop area for existing crops--100% up and 50% down variation on short-term crop area over the total planning horizon.
- Scen1 = Table grape price reduction of 10%--no water trade--same crop variation as Base.
- Scen2 = Table grape price reduction of 20%--no water trade--same crop variation as Base
- Scen3 = Table grape price reduction of 25%--no water trade--same crop variation as Base
- BaseB = Same as Base but 60% up and down variation on the Base long-term crop area
- Scen4 = Same as BaseB--table grape price reduction of 10%
- Scen5 = Same as BaseB--table grape price reduction of 20%
- Scen6 = Same as BaseB--table grape price reduction of 30%
- Scen7 = Same as BaseB--table grape price reduction of 33%
- BaseC = Same as Base but with **water trade allowed**
- Scen8 = Table grape price reduction of 10%--same crop variation as Base--**water trade**
- Scen9 = Table grape price reduction of 20%--same crop variation as Base--**water trade**

- Scen10 = Table grape price reduction of 25%--same crop variation as Base--**water trade**
- BaseD = Same as Base but 60% up and down variation on the Base long-term crop area--**water trade**
- Scen11 = Same as BaseB--table grape price reduction of 10%--**water trade**
- Scen12 = Same as BaseB--table grape price reduction of 20%--**water trade**
- Scen13 = Same as BaseB--table grape price reduction of 25%--**water trade**
- Scen14 = Same as BaseB--table grape price reduction of 30%--**water trade**
- Scen15 = Same as BaseB--table grape price reduction of 33%--**water trade**

To simplify the discussion of the results that follow, the scenarios are grouped into 4 sets:

- Set 1: This is the Base scenario (existing land use) plus scenarios 1 to 3 where table grape prices are reduced and only very limited structural change is possible. The only reason for the limited change is that the aggregation factors are based on existing water use rights which are not necessarily all being used.
- Set 2: This set includes BaseB and scenario 4-7. Scenarios 4-6 are the same as scenarios 1-3 with the exception that a larger variation from the base long-term crop area is allowed. Scenario 7 is analysed to determine the maximum reduction in table grape prices just before unfeasibility.
- Set 3: This set includes BaseC and scenarios 8-10. These scenarios are exactly the same as set 1, but water trade is allowed.
- Set 4: This set includes BaseD and scenarios 11-15. They are exactly the same as the scenarios for set 2, but water trade is allowed.

All the results are discussed in two sets of tables: those including set 1 and 2 scenario results (without water trade) and those including set 3 and 4 scenario results (with water trade). In a water market regime, unused water is normally traded. To understand the direction of water flow, the amount of unused water during 2002 must be estimated. This is done by calculating crop area as a percentage of total water allocation from the farm survey data for each of the regions (see Table 7.10 and Table 3.1).

Table 7.10: Estimated unused water use rights (2002)

Region	Total water allocation (ha)	Allocation not used (%)*	Allocation not used (ha)*
VaalH	50648	-17.0%	-8,610
VdkDR	22095	12.7%	2,806
DP	27789	1.2%	333
Boegoe	8966	1.0%	90
UpKaka	20139	34.9%	7,029
AugBlou	8933	30.5%	2,725
Bblou**	4771	30.0%	1,431
Total area (ha)	143341		14,414

*Estimated from survey data

** Rough estimate - no data available

The calculations in Table 7.10 reveal important information to understand in which way the water flows. Note that the total in the "Allocation not used" column is for all the regions excluding Vaalharts. According to the farm survey results, **it seems** as if irrigation farmers in the Vaalharts region extract more water than their allocation (8 610 ha or 17% more than the allocation). However, the authors want to make it clear that this could also be a sampling error: the weighted average water allocation was used, and the total water allocation for Vaalharts is a rough estimate since the borehole capacity was assumed to be 8 000 m³ per ha, which is not necessarily the case. In the sections that follow, this observation must be remembered since it explains many of the results.

It is also clear that during 2002, most of the unused water allocations were in the Western regions (UpKaka, Augblou, BBlou). In total, approximately 14 414 ha or 10% of water use allocations were unused.

7.4.2 Regional model results

The results of the regional model are discussed under the following headings:

- Changes in the aggregated objective function value. This is basically the net output of Northern Cape irrigated agriculture.
- Average Net Farm Income per region per annum and changes from the base analysis
- Structural changes per region compared to the base analysis
- Total average land use (area) per region
- Total and per ha water usage

- Capitalised return on capital investment
- Average marginal value of water
- Water trade between regions

7.4.2.1 Changes in the regional objective function values

Table 7.11 and 7.12 show the changes in the objective function when table grape prices are reduced under various scenarios where less and more variation from the base (current) land use is allowed, with and without water trade.

It is clear from Table 7.11 that when structural changes are limited, the impact of a reduction in the table grape price alone is severe. When the price of table grapes is reduced by 20%, the total net output of the Orange River is reduced by R6.33 billion over 20 years (in terms of Net Present Value) or R316.5 million per annum, on average (this is the cumulative effect of a 20% reduction in the price of table grapes over 20 years). This figure gives an indication of the cost of "not knowing". The fact that table grape farmers did not foresee that southern hemisphere supply and northern hemisphere demand conditions for table grapes would cause a long-term reduction in table grape prices resulted in an extremely high cost for table grape farmers and the economy of the Northern Cape province.

The results also show that the negative impact of a reduction in the price of table grapes is slightly reduced when farmers can sell their water right entitlements.

Table 7.11 shows inefficiencies in farm structures. When the land use restrictions are reduced, the objective function value of the BaseB scenario increases by 37.5%. The reader should bear in mind that new land use is not necessarily practical and needs more analysis since the model is not an exact replica of the real world (the model does not necessarily considers all the restrictions that face farmers).

The source of growth in the objective function will be discussed later in this chapter.

Table 7.11: Set 1 and 2 objective function values

Objective function (Obj)	Base	Scen1	Scen2	Scen3	BaseB	Scen4	Scen5	Scen6	Scen7
Obj (Million Rand)	25.277	22.110	18.948	17.972	34.767	30.303	26.236	22.341	21.149
Obj value change from Base (Million Rand)		-3.167	-6.331	-7.305	9.490	5.026	959	-2.936	-4.128
Total Orange River irrigation (ha)	102.125	102.089	102.020	101.917	110.757	110.137	109.811	109.331	108.945
Obj per ha over 20-years (Rand)	247.510	216.576	185.709	176.340	313.904	275.138	238.919	204.343	194.125
Obj per ha per annum (average) - (Rand)	12.375	10.829	9.285	8.817	15.695	13.757	11.946	10.217	9.706
% deviation from base		-12.5%	-25.0%	-28.9%	37.5%	19.9%	3.8%	-11.6%	-16.3%

An interesting result is that after the current land use restrictions are removed (Table 7.12), there is not much to gain from water trade (BaseB compared to BaseC). The objective function value only increases by about 4.5%. The relaxation of land use restrictions by itself seems to encourage more optimal water allocation and water trade can apparently do little to improve on this. However, water trade does reduce the impact of a reduction in table grape prices to some extent. The contribution of water trade to reducing the impact varies between 4.5% and about 3%. The combined impact of water trade and a relaxation on land use is a 42.1% increase in the objective function value (Base compared to BaseD).

Table 7.12: Set 3 and 4 objective function values

Objective function (Obj)	Base	BaseC	Scen8	Scen9	Scen10	BaseD	Scen11	Scen12	Scen13	Scen14	Scen15
Obj (Million Rand)	25.277	26.425	23.259	20.094	18.753	35.906	31.443	27.374	25.419	23.480	22.290
Obj value change from Base (Million Rand)		1.148	-2.018	-5.183	-6.524	10.629	6.166	2.097	142	-1.797	-2.987
Total Orange River irrigation (ha)	102.125	109.648	109.658	109.580	109.439	119.390	118.729	118.290	118.217	117.862	117.583
Obj per ha over 20-years (Rand)	247.510	240.998	212.105	183.357	171.356	300.745	264.830	231.414	215.020	199.216	189.588
Obj per ha per annum (average) - (Rand)	12.375	12.050	10.605	9.168	8.568	15.037	13.242	11.571	10.751	9.961	9.478
% deviation from base		4.5%	-8.0%	-20.5%	-25.8%	42.1%	24.4%	8.3%	0.6%	-7.1%	-11.8%

Finally, it is important to note that when land use is less restricted in duplicating current land use patterns, the decline in the objective function with a declining table grape price is less severe since structural changes towards more optimal land use can be made, given the assumptions used (the data).

7.4.2.2 Average Net Farm Income (NFI) per region

Table 7.13 to Table 7.16 indicate the change in NFI for scenarios with and without trade and with restrictive and less restrictive land use at reduced table grape prices.

Table 7.13: Average NFI per ha per region (Set 1 and 2)

Average per ha (Rand / ha/annum)	Base	Scen1	Scen2	Scen3	BaseB	Scen4	Scen5	Scen6	Scen7
VaalH	392	392	392	392	489	489	489	489	489
VokDR	1 448	1 448	1 448	1 448	1 475	1 475	1 475	1 475	1 475
DP	1 121	1 121	1 121	1 121	1 124	1 124	1 124	1 124	1 124
Boegoe	2 726	1 667	1 247	1 021	4 777	3 324	2 131	1 186	913
UpKaka	9 935	6 607	3 263	2 547	19 609	14 552	8 080	3 758	2 577
AugBlou	21 719	14 637	7 538	5 367	38 767	25 479	16 508	7 718	5 167
BBlou	14 483	11 194	7 861	6 884	22 039	16 100	12 035	8 144	6 999
Total (average)	7 404	5 341	3 267	2 687	12 611	8 935	5 977	3 413	2 678

Table 7.14: Change in NFI per region (Set 1 and 2)

Region	Base	Scen1	Scen2	Scen3	BaseB	Scen4	Scen5	Scen6	Scen7
VaalH	NA	0.0%	0.0%	0.0%	24.8%	24.8%	24.8%	24.8%	24.8%
VokDR	NA	0.0%	0.0%	0.0%	1.9%	1.9%	1.9%	1.9%	1.9%
DP	NA	0.0%	0.0%	0.0%	0.2%	0.2%	0.2%	0.2%	0.2%
Boegoe	NA	-27.1%	-54.3%	-62.6%	75.2%	21.6%	-21.8%	-56.5%	-66.5%
UpKaka	NA	-33.5%	-67.2%	-74.4%	97.4%	46.5%	-18.7%	-82.2%	-74.1%
AugBlou	NA	-32.6%	-65.3%	-75.1%	78.5%	17.3%	-24.0%	-64.5%	-76.2%
BBlou	NA	-22.7%	-45.7%	-62.5%	52.2%	11.2%	-16.9%	-43.8%	-51.7%
Total (average)	NA	-26.7%	-63.6%	-60.7%	71.3%	25.5%	-16.7%	-50.5%	-60.0%

Table 7.15: Average NFI per ha per region (Set 3 and 4)

Average per ha (Rand / ha/annum)	Base	BaseC	Scen8	Scen9	Scen10	BaseD	Scen11	Scen12	Scen13	Scen14	Scen15
VaalH	392	1 417	1 416	1 410	1 406	1 359	1 368	1 360	1 360	1 372	1 389
VokDR	1 448	1 459	1 458	1 459	1 461	1 488	1 490	1 491	1 493	1 495	1 493
DP	1 121	1 130	1 130	1 130	1 130	1 132	1 132	1 132	1 132	1 132	1 132
Boegoe	2 726	2 784	2 046	1 303	1 030	4 852	3 376	2 181	1 696	1 229	957
UpKaka	9 935	9 930	6 602	3 258	2 317	19 612	14 540	8 026	5 909	3 723	2 579
AugBlou	21 719	21 651	14 627	7 525	4 485	38 733	25 446	16 481	11 579	7 667	5 121
BBlou	14 483	14 484	11 194	7 874	6 494	22 039	16 235	12 165	10 173	8 265	7 125
Total (average)	7 404	7 557	5 496	3 423	2 616	12 745	9 084	6 120	4 820	3 555	2 828

Table 7.16: Change in NFI per region (Set 3 and 4)

Region	Base	BaseC	Scen8	Scen9	Scen10	BaseD	Scen11	Scen12	Scen13	Scen14	Scen15
VaalH	NA	261.5%	261.3%	259.7%	258.7%	246.7%	249.1%	246.8%	246.8%	250.0%	254.4%
VokDR	NA	0.8%	0.7%	0.8%	0.9%	2.8%	2.6%	3.0%	3.1%	3.2%	3.1%
DP	NA	0.8%	0.8%	0.8%	0.8%	0.9%	1.0%	0.9%	0.9%	0.9%	1.0%
Boegoe	NA	2.1%	-24.9%	-52.2%	-62.2%	78.0%	23.8%	-20.0%	-37.8%	-54.9%	-64.9%
UpKaka	NA	0.0%	-33.5%	-67.2%	-76.7%	97.4%	46.4%	-19.2%	-40.5%	-62.5%	-74.0%
AugBlou	NA	-0.1%	-32.7%	-65.4%	-79.4%	78.3%	17.2%	-24.1%	-44.8%	-64.7%	-76.4%
BBlou	NA	0.0%	-22.7%	-45.6%	-55.2%	52.2%	12.1%	-16.0%	-29.8%	-42.9%	-50.8%
Total (average)	NA	9.2%	-17.5%	-44.4%	-54.1%	79.2%	32.5%	-8.9%	-25.9%	-42.5%	-51.8%

It is clear that in the Base analysis, average NFI per ha per annum ranges from R392 per ha in Vaalharts (the lowest) to more than R21 700 per ha for the Augrabies-Blouputs regions. However, it is interesting to note that when trade is allowed, the Vaalharts region relatively gains the most with more than a R1 000 per ha increase in NFI per ha. The explanation for this can be found in the crop water requirements. Vaalharts is the largest single irrigation region (35% of the total), where approximately 70% of the crops are wheat and maize. The average crop water requirement for maize is between 3 600 m³ – 7 200 m³; for wheat, it is

5 550 m³ - 7 800 m³ depending on early or late cultivars. It should be clear that in a double cropping system on a farm with an average water entitlement of 9 000 m³ per ha, farmers cannot produce two crops on one ha with one ha of water entitlement since the combined requirement varies between 9 150 m³ and 15 000 m³. Therefore, when trade is allowed, water flows in the Vaalharts direction, and total land use increases substantially.

The analysis also shows (Table 7.14, Scen 2) that the NFI of Augrabies-Blouputs farmers decreased by approximately 53% with a 20% decrease in the price of table grapes. The result is (unsurprisingly) almost identical to that of the individual Augrabies-Blouputs typical farm model.

The results also indicate a substantial increase in NFI per ha when land use restrictions are reduced (Set 3 Base C). The NFI in Augrabies-Blouputs increases from approximately R27 000 to R44 000 since more table grapes are produced at the base table grape price. Similarly to the discussion of the objective function value, the results indicate that there is not much difference between trade and no-trade restrictions after land use restrictions are relaxed. This is because if land use is less restrictive (the calibration constraints), the model solution is more optimal even without water trade. Therefore, when land use restrictions are reduced, some inefficiencies are removed, and when water trade is introduced, the difference is not significant.

7.4.2.3 Structural changes per region compared to the base

Table 7.17 and Table 7.18 indicate the structural changes for the Set 1 and 2 scenarios. It is clear that when structural changes are restricted and there is no water trade, only small changes take place (set 1). In the BaseB scenario, where water trade is not permitted but land use is less restrictive, it is clear that some areas produce less (BBlou) and other areas more (Vaalharts and Boegoeberg) short-term crops. Also, there are significant changes in the long-term crop area especially in the regions below Boegoeberg and the DP and VDKDR regions, where substitution takes place away from short-term crops in favour of long-term crops. Table 7.17 and Table 7.18 also indicate that when the price of table grapes is reduced and structural changes can be made (BaseB and Scen4-Scen7), less substitution takes place towards long-term crops.

Table 7.17: Change in short-term crop area (Set 1 and 2 scenarios)

Region	Base	Scen1	Scen2	Scen3	BaseB	Scen4	Scen5	Scen6	Scen7
VaalH	28 554	28 554	28 554	28 554	29 786	29 786	29 786	29 786	29 786
VdkDR	14 381	14 381	14 381	14 381	13 984	13 984	13 984	13 984	13 984
DP	19 560	19 560	19 560	19 560	19 416	19 416	19 416	19 416	19 416
Boegoe	1 514	1 514	1 501	1 501	1 649	1 649	1 614	1 522	1 533
UpKaka	130	130	130	130	120	120	120	121	119
AugBlou	6	6	6	6	6	6	6	6	6
BBlou	304	301	304	301	194	199	206	213	207
Total (average / annum)	64 448	64 448	64 437	64 433	65 155	65 160	65 131	65 048	65 050
Region	Base	Scen1	Scen2	Scen3	BaseB	Scen4	Scen5	Scen6	Scen7
VaalH	NA	0.0%	0.0%	0.0%	4.3%	4.3%	4.3%	4.3%	4.3%
VdkDR	NA	0.0%	0.0%	0.0%	-2.6%	-2.6%	-2.6%	-2.6%	-2.6%
DP	NA	0.0%	0.0%	0.0%	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%
Boegoe	NA	0.0%	-0.8%	-0.8%	8.9%	8.9%	6.6%	0.6%	1.3%
UpKaka	NA	0.0%	0.0%	0.0%	-7.9%	-7.8%	-7.9%	-7.5%	-8.9%
AugBlou	NA	0.1%	0.1%	0.2%	0.1%	0.1%	0.2%	0.3%	0.3%
BBlou	NA	-0.9%	0.3%	-1.0%	-36.0%	-34.6%	-32.2%	-29.9%	-31.7%
Total (average)	NA	0.0%	0.0%	0.0%	1.1%	1.1%	1.1%	0.9%	0.9%

Table 7.18: Change in long-term crop area (Set 1 and 2 scenarios)

Region	Base	Scen1	Scen2	Scen3	BaseB	Scen4	Scen5	Scen6	Scen7
VaalH	7 736	7 736	7 736	7 736	6 271	6 271	6 271	6 271	6 271
VdkDR	1 504	1 504	1 504	1 504	2 343	2 343	2 343	2 343	2 343
DP	977	977	977	977	1 230	1 230	1 230	1 230	1 230
Boegoe	5 663	5 661	5 681	5 678	5 524	5 517	5 582	5 767	5 752
UpKaka	12 118	12 120	12 095	12 043	17 442	17 388	17 159	16 860	16 503
AugBlou	6 073	6 045	6 007	5 968	8 536	8 050	7 947	7 679	7 651
BBlou	3 605	3 599	3 582	3 577	4 265	4 180	4 147	4 134	4 144
Total (average / annum)	37 677	37 643	37 583	37 483	45 602	44 978	44 680	44 283	43 895
Region	Base	Scen1	Scen2	Scen3	BaseB	Scen4	Scen5	Scen6	Scen7
VaalH	NA	0.0%	0.0%	0.0%	-18.9%	-18.9%	-18.9%	-18.9%	-18.9%
VdkDR	NA	0.0%	0.0%	0.0%	55.8%	55.8%	55.8%	55.8%	55.8%
DP	NA	0.0%	0.0%	0.0%	25.9%	25.9%	25.9%	25.9%	25.9%
Boegoe	NA	0.0%	0.3%	0.3%	-2.5%	-2.6%	-1.4%	1.8%	1.6%
UpKaka	NA	0.0%	-0.2%	-0.6%	43.9%	43.5%	41.6%	39.1%	36.2%
AugBlou	NA	-0.5%	-1.1%	-1.7%	40.6%	32.6%	30.9%	26.4%	26.0%
BBlou	NA	-0.2%	-0.6%	-0.8%	18.0%	16.0%	15.0%	14.7%	14.9%
Total (average)	NA	-0.1%	-0.2%	-0.5%	21.0%	19.4%	18.6%	17.5%	16.5%

The situation changes substantially when water trade is permitted, especially in the Vaalharts region. The total area used for short-term crops increases by approximately 6 980 ha (difference between Base and BasB) or 13.8% of the total water use entitlement in the Vaalharts region. The reader should know that this is not more land being irrigated but land being double cropped (see Table 7.19 and Table 7.20). This result confirms the analysis of Table 7.10, which implied that a significant water shortage in the Vaalharts region prevents double cropping.

However, when the calibration restrictions on the long-term crop area are relaxed (BaseD compared to Base), substitution towards short-term crops is reduced to some extent. Approximately 660 ha less land is cultivated with short-term crops. It is also clear that

there is a significant increase in long-term crops in the area downstream, including Boegoeberg. The total average long-term crop area increases by approximately 30% (difference between Base and BaseD). It is also clear that water trade does make a difference when calibration constraints are relaxed. Approximately 9% more long- and short-term crops are produced.

The impact of a 20% reduction in the price of table grapes indicates, as expected, that the average long-term crop area will decrease. When structural changes are allowed (BaseD and scenarios 11-15), the analysis indicates that the long-term crop area in the Northern Cape will decrease by approximately 1%--1.5% for each 10% reduction in the price of table grapes. However, although it is not shown in the table here, various substitutions take place:

- More table grapes converted to raisins
- More citrus in some areas
- More lucerne
- It is generally accepted that the supply function for long-term crops is very inelastic. This is consistent with the observed situation in these regions.

Table 7.19: Change in short-term crop area (Set 3 and 4 scenarios)

Region	Base	BaseC	Scen8	Scen9	Scen10	BaseD	Scen11	Scen12	Scen13	Scen14	Scen15
VaalH	28 554	35 534	35 531	35 533	35 543	34 868	34 856	34 868	34 877	34 893	34 932
VokDR	14 381	14 370	14 371	14 369	14 368	13 970	13 973	13 975	13 973	13 967	13 970
DP	19 560	19 548	19 548	19 547	19 547	19 380	19 378	19 380	19 378	19 380	19 380
Boegoe	1 514	1 526	1 521	1 509	1 508	1 613	1 589	1 587	1 535	1 497	1 448
UpKaka	130	130	129	129	130	120	119	118	118	117	117
AugBlou	6	6	6	6	6	6	6	6	6	6	6
BBlou	304	297	298	298	297	204	221	220	227	226	227
Total (average / annum)	9,207	10,202	10,201	10,199	10,200	10,023	10,020	10,022	10,016	10,012	10,011
Region	Base	BaseC	Scen8	Scen9	Scen10	BaseD	Scen11	Scen12	Scen13	Scen14	Scen15
VaalH	NA	24.4%	24.4%	24.4%	24.6%	22.1%	22.1%	22.1%	22.1%	22.2%	22.3%
VokDR	NA	-0.1%	-0.1%	-0.1%	-0.1%	-2.9%	-2.8%	-2.8%	-2.8%	-2.9%	-2.9%
DP	NA	-0.1%	-0.1%	-0.1%	-0.1%	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%
Boegoe	NA	0.8%	0.5%	-0.3%	-0.4%	6.6%	5.0%	4.8%	1.4%	-1.1%	-4.3%
UpKaka	NA	-0.4%	-0.8%	-0.8%	-0.2%	-8.4%	-8.7%	-9.8%	-9.7%	-10.3%	-10.4%
AugBlou	NA	0.1%	0.1%	0.0%	0.1%	0.1%	0.2%	0.2%	0.2%	0.2%	0.2%
BBlou	NA	-2.3%	-2.0%	-1.8%	-2.2%	-32.7%	-27.2%	-27.5%	-25.4%	-25.6%	-25.4%
Total (average)	NA	10.8%	10.8%	10.8%	10.8%	8.9%	8.8%	8.9%	8.8%	8.7%	8.7%

Table 7.20: Change in long-term crop area (Set 3 and 4 scenarios)

Region	Base	BaseC	Scen8	Scen9	Scen10	BaseO	Scen11	Scen12	Scen13	Scen14	Scen15
VaalH	7.736	8.086	8.088	8.086	8.084	9.302	9.302	9.312	9.308	9.290	9.251
VokDR	1.504	1.527	1.526	1.529	1.531	2.370	2.365	2.362	2.365	2.376	2.370
DP	977	999	999	1.000	1.000	1.288	1.290	1.288	1.290	1.288	1.288
Boegoe	5.663	5.699	5.715	5.741	5.738	5.683	5.738	5.737	5.836	5.910	6.011
UpKaka	12.118	12.201	12.206	12.176	12.096	17.658	17.506	17.148	17.119	16.911	16.588
AugBlou	6.073	6.098	6.095	6.055	5.992	8.540	8.039	7.943	7.853	7.660	7.665
BBlou	3.805	3.629	3.626	3.613	3.598	4.388	4.347	4.349	4.332	4.341	4.328
Total (average / annum)	37.677	38.238	38.254	38.198	38.040	49.229	48.587	48.136	48.103	47.775	47.503
Region	Base	BaseC	Scen8	Scen9	Scen10	BaseO	Scen11	Scen12	Scen13	Scen14	Scen15
VaalH	NA	4.5%	4.6%	4.5%	4.5%	20.2%	20.2%	20.4%	20.3%	20.1%	19.6%
VokDR	NA	1.5%	1.4%	1.7%	1.8%	57.6%	57.3%	57.0%	57.3%	58.0%	57.6%
DP	NA	2.2%	2.2%	2.4%	2.4%	31.8%	32.0%	31.8%	32.0%	31.8%	31.8%
Boegoe	NA	0.6%	0.9%	1.4%	1.3%	0.4%	1.3%	1.3%	3.0%	4.4%	6.1%
UpKaka	NA	0.7%	0.7%	0.5%	-0.2%	45.7%	44.5%	41.5%	41.3%	39.5%	36.9%
AugBlou	NA	0.4%	0.4%	-0.3%	-1.3%	40.6%	32.4%	30.8%	29.3%	26.1%	26.2%
BBlou	NA	0.7%	0.6%	0.2%	-0.2%	21.7%	20.6%	20.6%	20.1%	20.4%	20.1%
Total (average)	NA	1.5%	1.5%	1.4%	1.0%	30.7%	29.0%	27.8%	27.7%	26.8%	26.1%

If the market price of crops is reduced and with it profitability, there is a chain reaction:

- There is an immediate impact on solvability since financiers consider their risks and reduce the value of fixed assets to cover loans, knowing that payback ability is under threat.
- If it is a long-term impact, farmers know that they probably have to change to alternative crops or cultivars, but they normally experience cash flow problems and lack the financial resources to change.

When some farms go bankrupt, it is similar to a snowball effect: financiers reduce the value of assets, and the situation in the specific region just deteriorates.

7.4.2.4 Total average land use

Tables 7.21 and 7.22 shows the change in total irrigation land used per region based on monthly land use and on total crop production in the Northern Cape for different table grape price, water trade, and restrictive land use scenarios. The reader will note that the area in Table 7.22 is significantly higher than Table 7.2. This is because Table 7.2 considers double cropping and therefore total land use per annum.

Table 7.21: Northern Cape irrigation land use (Set 1 and 2)--based on monthly average land use (ha)

Region	Base	Scen1	Scen2	Scen3	BaseB	Scen4	Scen5	Scen6	Scen7
VaalH	36,290	36,290	36,290	36,290	36,057	36,057	36,057	36,057	36,057
VdkDR	15,885	15,885	15,885	15,885	16,327	16,327	16,327	16,327	16,327
DP	20,537	20,537	20,537	20,537	20,647	20,647	20,647	20,647	20,647
Boegoe	7,177	7,175	7,183	7,179	7,173	7,166	7,195	7,289	7,285
UpKaka	12,249	12,251	12,225	12,174	17,562	17,506	17,279	16,980	16,622
AugBlou	6,079	6,051	6,013	5,974	8,542	8,056	7,953	7,665	7,657
BBlou	3,909	3,900	3,887	3,878	4,449	4,379	4,353	4,347	4,351
Total average land use (ha)	102,125	102,089	102,020	101,917	110,757	110,137	109,811	109,331	108,945
Region	Base	Scen1	Scen2	Scen3	BaseB	Scen4	Scen5	Scen6	Scen7
VaalH		0.00%	0.00%	0.00%	-0.64%	-0.64%	-0.64%	-0.64%	-0.64%
VdkDR		0.00%	0.00%	0.00%	2.78%	2.78%	2.78%	2.78%	2.78%
DP		0.00%	0.00%	0.00%	0.53%	0.53%	0.53%	0.53%	0.53%
Boegoe		-0.02%	0.08%	0.03%	-0.06%	-0.15%	0.26%	1.56%	1.51%
UpKaka		0.02%	-0.18%	-0.61%	43.38%	42.92%	41.07%	38.63%	35.71%
AugBlou		-0.46%	-1.08%	-1.72%	40.51%	32.52%	30.83%	26.42%	25.96%
BBlou		-0.22%	-0.56%	-0.80%	13.82%	12.03%	11.35%	11.19%	11.30%
Total average land use change		-0.04%	-0.10%	-0.20%	8.45%	7.85%	7.53%	7.06%	6.68%

Note: These areas are based on total monthly land use divided by 240 months.

Similarly to the previous section, most changes are in the Vaalharts region and in the region in and below Boegoeberg. Land use in the Base analysis is approximately 119% compared to 127% when the calibration constraints are released.

Table 7.22: Northern Cape irrigation land use (Set 1 and 2)--based on total crop production (ha)

Region	Base	Scen1	Scen2	Scen3	BaseB	Scen4	Scen5	Scen6	Scen7
VaalH	66,992	66,992	66,992	66,992	68,362	68,362	68,362	68,362	68,362
VdkDR	30,543	30,543	30,543	30,543	30,760	30,760	30,760	30,760	30,760
DP	40,301	40,301	40,301	40,301	40,331	40,331	40,331	40,331	40,331
Boegoe	9,127	9,126	9,121	9,117	9,352	9,345	9,339	9,341	9,348
UpKaka	13,211	13,213	13,187	13,136	18,920	18,865	18,642	18,344	17,983
AugBlou	6,415	6,387	6,349	6,310	9,012	8,532	8,429	8,161	8,133
BBlou	4,560	4,548	4,539	4,526	5,088	5,034	5,017	5,019	5,017
Total land use (ha)	171,149	171,110	171,032	170,925	181,826	181,229	180,881	180,318	179,934
Total OR water entitlements (ha)	143,341	143,341	143,341	143,341	143,341	143,341	143,341	143,341	143,341
Land use as % of entitlement	119%	119%	119%	119%	127%	126%	126%	126%	126%
Region	Base	Scen1	Scen2	Scen3	BaseB	Scen4	Scen5	Scen6	Scen7
VaalH		0.00%	0.00%	0.00%	2.05%	2.05%	2.05%	2.05%	2.05%
VdkDR		0.00%	0.00%	0.00%	0.71%	0.71%	0.71%	0.71%	0.71%
DP		0.00%	0.00%	0.00%	0.08%	0.08%	0.08%	0.08%	0.08%
Boegoe		-0.01%	-0.07%	-0.11%	2.46%	2.38%	2.32%	2.34%	2.41%
UpKaka		0.02%	-0.18%	-0.57%	43.22%	42.80%	41.11%	38.85%	36.12%
AugBlou		-0.44%	-1.03%	-1.63%	40.48%	33.00%	31.40%	27.21%	26.78%
BBlou		-0.25%	-0.46%	-0.75%	11.59%	10.40%	10.03%	10.06%	10.03%
Total land use		-0.02%	-0.07%	-0.13%	6.24%	5.89%	5.69%	5.36%	5.13%

The impact on total crop production area is significant when trade is allowed, especially when calibration constraints on the long-term crop area are released (see Table 7.23 and Table 7.24).

Table 7.23: Northern Cape irrigation land use (Set 3 and 4)--based on average monthly land use (ha)

Region	Base	BaseC	Scen8	Scen9	Scen10	BaseD	Scen11	Scen12	Scen13	Scen14	Scen15
VaalH	36 290	43 620	43 619	43 618	43 627	44 170	44 158	44 179	44 185	44 183	44 183
VdkDR	15 885	15 897	15 898	15 898	15 899	16 340	16 338	16 337	16 338	16 343	16 340
DP	20 537	20 546	20 546	20 547	20 547	20 668	20 669	20 668	20 669	20 668	20 668
Boegoe	7 177	7 228	7 236	7 250	7 246	7 296	7 326	7 324	7 370	7 407	7 460
UpKaka	12 249	12 331	12 336	12 305	12 226	17 778	17 625	17 264	17 237	17 028	16 705
AugBlou	6 079	6 104	6 101	6 060	5 998	8 545	8 045	7 949	7 859	7 665	7 671
BBlou	3 909	3 925	3 923	3 911	3 895	4 592	4 568	4 569	4 558	4 567	4 555
Total average land use (ha)	102 125	109 648	109 658	109 650	109 439	119 360	118 728	118 260	118 217	117 862	117 583
Region	Base	BaseC	Scen8	Scen9	Scen10	BaseD	Scen11	Scen12	Scen13	Scen14	Scen15
VaalH		20.20%	20.20%	20.19%	20.22%	21.72%	21.68%	21.74%	21.76%	21.75%	21.75%
VdkDR		0.07%	0.07%	0.08%	0.08%	2.88%	2.85%	2.84%	2.85%	2.88%	2.86%
DP		0.05%	0.05%	0.05%	0.05%	0.64%	0.64%	0.64%	0.64%	0.64%	0.64%
Boegoe		0.67%	0.62%	1.02%	0.97%	1.67%	2.08%	2.05%	2.70%	3.21%	3.94%
UpKaka		0.67%	0.71%	0.46%	-0.18%	45.14%	43.89%	40.94%	40.73%	39.02%	36.38%
AugBlou		0.41%	0.37%	-0.30%	-1.33%	40.58%	32.34%	30.76%	29.28%	28.10%	26.20%
BBlou		0.42%	0.36%	0.06%	-0.34%	17.48%	16.86%	16.89%	16.61%	16.82%	16.53%
Total average land use change		7.37%	7.38%	7.31%	7.16%	16.91%	16.26%	15.83%	15.76%	15.41%	15.14%

Note: These areas are based on total monthly land use divided by 240 months.

This impact can mainly be explained by the impact of double cropping. It is clear that land use is approximately 119% in the Base analysis compared to 132% with water trade but more restrictive land use constraints and 138% with less restrictive calibration constraints.

Table 7.24: Northern Cape irrigation land use (Set 3 and 4)--based on total crop production (ha)

Region	Base	BaseC	Scen8	Scen9	Scen10	BaseD	Scen11	Scen12	Scen13	Scen14	Scen15
VaalH	86 992	84 169	84 165	84 167	84 192	84 607	84 575	84 617	84 630	84 650	84 695
Vd*DR	30 543	30 559	30 559	30 558	30 558	30 771	30 774	30 773	30 773	30 770	30 769
DP	40 301	40 301	40 301	40 300	40 300	40 329	40 327	40 329	40 327	40 329	40 329
Boegoe	5 127	5 190	5 195	5 198	5 193	5 449	5 480	5 459	5 448	5 448	5 451
UpKaka	13 211	13 397	13 401	13 371	13 280	19 146	18 995	18 645	18 640	18 431	18 107
AugBlou	6 415	6 704	6 700	6 662	6 600	9 100	8 576	8 503	8 448	8 244	8 185
BBlou	4 560	4 569	4 568	4 557	4 540	5 264	5 270	5 270	5 266	5 273	5 263
Total land use (ha)	171 149	188 889	188 889	188 813	188 663	198 686	197 979	197 595	197 533	197 145	196 799
Total OR water entitlements (ha)	143 341	143 341	143 341	143 341	143 341	143 341	143 341	143 341	143 341	143 341	143 341
Land use as % of entitlement	119%	132%	132%	132%	132%	138%	138%	138%	138%	138%	137%
Region	Base	BaseC	Scen8	Scen9	Scen10	BaseD	Scen11	Scen12	Scen13	Scen14	Scen15
VaalH	25.64%	25.64%	25.64%	25.68%	25.68%	26.29%	26.25%	26.31%	26.33%	26.36%	26.43%
Vd*DR	0.06%	0.06%	0.06%	0.06%	0.06%	0.76%	0.76%	0.76%	0.76%	0.74%	0.74%
DP	0.00%	0.00%	0.00%	0.00%	0.00%	0.07%	0.07%	0.07%	0.07%	0.07%	0.07%
Boegoe	0.69%	0.75%	0.77%	0.72%	3.53%	3.65%	3.63%	3.52%	3.51%	3.55%	
UpKaka	1.41%	1.44%	1.21%	0.52%	44.93%	43.79%	41.13%	41.10%	39.51%	37.06%	
AugBlou	4.50%	4.44%	3.84%	2.87%	41.65%	33.69%	32.55%	31.68%	28.51%	27.59%	
BBlou	0.21%	0.18%	-0.07%	-0.43%	15.44%	15.58%	15.58%	15.49%	15.65%	15.41%	
Total land use	10.37%	10.37%	10.32%	10.23%	16.08%	15.68%	15.45%	15.42%	15.19%	14.99%	

The main conclusion from this result is that there are inefficiencies in water allocations (given the limitations of the model). Although most changes (even without trade) are in the Vaalharts region, there are also substantial changes in the Western regions (Upington-Kakamas and Augrabies-Blouputs). Consistent with the other results, the model shows

again that there are only marginal changes in land use after land use restrictions are relaxed.

7.4.2.5 Total and regional water usage

Table 7.25 and Table 7.26 indicate that water usage increases by approximately 120 million m³ per annum when water trade is introduced. Although this is a lot of water, it only represents about 7.5% of the total annual water entitlement or about 9 000 ha (almost equal to the shortage of 8 600 ha in Vaalharts pointed out earlier). However, this is mainly through water trade of existing allocations (unused water) or inefficient water use. Most changes are in the Vaalharts region. It is important to note that when current land use restricts structural changes, water usage does not change when the price of table grapes is reduced. The same is true for reductions in the price of table grapes after water trade is allowed.

Table 7.25: Total regional average water use (mill m³) per annum (Set 1 and 2)

Region	Base	Scen1	Scen2	Scen3	BaseB	Scen4	Scen5	Scen6	Scen7
VaalH	452	448	448	448	447	447	447	447	447
VdkDR	215	207	207	207	215	215	215	215	215
DP	249	244	244	244	246	246	246	246	246
Boegoe	134	128	128	128	124	124	125	126	125
UpKaka	220	207	207	206	270	269	264	261	262
AugBlou	97	91	91	90	114	107	106	104	107
BBlou	72	66	66	66	70	70	70	70	70
Total (average / annum)	1438	1391	1391	1390	1486	1479	1473	1469	1473

Table 7.26 shows that when current land use restrictions are relaxed, water usage in all regions increases substantially since unused water is used. A very interesting result is that when water trade is introduced, total water usage increases, but the average crop water usage per ha is lower than when no trade is possible (Base analysis). This result indicates that there are gains in water use efficiency with water trade. Even more interesting is a comparison between Base and BaseC (where water trade is the only difference) and BaseB and BaseD (where water trade is the only difference). When the price of table grapes is reduced, water trade analysis indicates that water usage is consistently higher for all the scenarios when water trade is allowed than when it is not. This analysis is important since it emphasises the fact that the system is more flexible when trade is allowed and that water will flow to higher value uses.

Also, it is obvious that total water usage in the table grape production regions will change slightly because of structural changes that take place as the price of table grapes is reduced. However, these are only moderate since water is used for other crops.

Table 7.26: Total regional average water use (mill m³) per annum (Set 3 and 4)

Region	Base	BaseC	Scen8	Scen9	Scen10	BaseD	Scen11	Scen12	Scen13	Scen14	Scen15
VaalH	452	593	593	593	593	599	599	600	600	600	600
VokDR	215	210	210	211	211	219	220	219	218	218	219
DP	249	244	244	244	244	247	247	246	247	247	247
Boegoe	134	135	134	135	135	133	133	134	136	137	138
UpKaka	220	212	212	212	211	278	278	270	265	266	272
AugBlou	97	102	102	102	103	121	114	114	116	116	118
BBlou	72	68	68	68	67	76	77	77	78	78	78
Total (average / annum)	1438	1563	1563	1564	1564	1673	1667	1660	1663	1661	1670

Table 7.27 and Table 7.28 show average water use per ha. It is clear that changes in the price of table grapes do not have a significant impact on average water use per ha if structural changes are restricted.

Table 7.27: Average water use (m³) per ha (Set 1 and 2)

Region	Base	Scen1	Scen2	Scen3	BaseB	Scen4	Scen5	Scen6	Scen7
VaalH	12.459	12.346	12.346	12.346	12.407	12.407	12.407	12.407	12.407
VokDR	13.529	13.042	13.042	13.042	13.175	13.175	13.175	13.175	13.175
DP	12.118	11.866	11.866	11.866	11.906	11.906	11.906	11.906	11.906
Boegoe	18.667	17.844	17.870	17.866	17.280	17.287	17.350	17.264	17.208
UpKaka	17.950	16.900	16.903	16.916	15.375	15.393	15.253	15.355	15.745
AugBlou	15.937	15.056	15.092	15.133	13.309	13.313	13.365	13.528	14.026
BBlou	18.312	17.016	17.026	17.054	15.842	15.950	16.060	16.079	16.065
Total (average / annum)	15.567	14.867	14.878	14.889	14.185	14.185	14.205	14.217	14.245
Region	Base	Scen1	Scen2	Scen3	BaseB	Scen4	Scen5	Scen6	Scen7
VaalH		-0.9%	-0.9%	-0.9%	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%
VokDR		-3.6%	-3.6%	-3.6%	-2.6%	-2.6%	-2.6%	-2.6%	-2.6%
DP		-2.1%	-2.1%	-2.1%	-1.8%	-1.8%	-1.8%	-1.8%	-1.8%
Boegoe		-4.4%	-4.3%	-4.3%	-7.4%	-7.4%	-7.1%	-7.5%	-7.8%
UpKaka		-5.8%	-5.8%	-5.8%	-14.3%	-14.2%	-15.0%	-14.5%	-12.3%
AugBlou		-5.5%	-5.3%	-5.0%	-16.5%	-16.5%	-16.1%	-15.1%	-12.0%
BBlou		-7.1%	-7.0%	-6.9%	-13.5%	-12.9%	-12.3%	-12.2%	-12.3%
Total (average / annum)		-4.5%	-4.4%	-4.4%	-8.9%	-8.9%	-8.8%	-8.7%	-8.5%

However, when structural changes take place, crop combinations change and water usage per ha increases. It is also clear that a decrease in table grape prices induces a slight increase in water use per ha since crops with a higher crop water requirement are produced (for example, citrus).

Table 7.28: Average water use (m3) per ha (Set 3 and 4 scenarios)

Region	Base	BaseC	Scen8	Scen9	Scen10	BaseD	Scen11	Scen12	Scen13	Scen14	Scen15
VaalH	12 459	13 586	13 586	13 589	13 593	13 570	13 568	13 573	13 570	13 569	13 571
VdkDR	13 529	13 239	13 241	13 242	13 245	13 398	13 443	13 399	13 369	13 364	13 374
DP	12 118	11 873	11 873	11 874	11 874	11 926	11 927	11 926	11 928	11 927	11 926
Boegoe	18 667	18 625	18 584	18 593	18 589	18 193	18 201	18 321	18 420	18 440	18 505
UpKaka	17 950	17 182	17 178	17 217	17 264	15 648	15 764	15 617	15 619	15 633	16 275
AugBlou	15 937	16 703	16 709	16 846	17 112	14 179	14 173	14 324	14 814	15 065	15 330
BBlou	18 312	17 229	17 235	17 279	17 312	16 587	16 761	16 874	17 004	17 187	17 180
Total (average / annum)	15,567	15,491	15,487	15,520	15,573	14,786	14,834	14,852	14,961	15,032	15,166
Region	Base	BaseC	Scen8	Scen9	Scen10	BaseD	Scen11	Scen12	Scen13	Scen14	Scen15
VaalH		9.0%	9.0%	9.1%	9.1%	8.9%	8.9%	8.9%	8.9%	8.9%	8.9%
VdkDR		-2.1%	-2.1%	-2.1%	-2.1%	-1.0%	-0.6%	-1.0%	-1.2%	-1.2%	-1.1%
DP		-2.0%	-2.0%	-2.0%	-2.0%	-1.6%	-1.6%	-1.6%	-1.6%	-1.6%	-1.6%
Boegoe		-0.2%	-0.4%	-0.4%	-0.4%	-2.5%	-2.5%	-1.9%	-1.3%	-1.2%	-0.9%
UpKaka		-4.3%	-4.3%	-4.1%	-3.7%	-12.8%	-12.2%	-13.0%	-13.0%	-12.9%	-9.3%
AugBlou		4.8%	4.8%	5.7%	7.4%	-11.0%	-11.1%	-10.1%	-7.0%	-5.3%	-3.8%
BBlou		-5.9%	-5.9%	-5.6%	-5.5%	-9.4%	-8.5%	-7.9%	-7.1%	-6.1%	-6.2%
Total (average / annum)		-0.5%	-0.5%	-0.3%	0.0%	-6.6%	-4.7%	-4.5%	-3.9%	-3.4%	-2.6%

7.4.2.6 Marginal value of water

It was pointed out earlier in this report that marginal values are often very difficult to interpret and even more so in huge regional models since so many variables have an impact on them. Apart from the same factors that impact these values at farm level, there are also regional impacts when typical farms and regions are linked by water supply equations where water can be traded. The dual value of the water-use right constraint represents the capitalised marginal value of water. In water markets, the water-use right constraint will always be optimally binding since no producer will purchase water unless he uses it productively, and any producer with an unused portion of his or her water use right will be better off selling it. The capitalised marginal values for water are presented in Table 7.29 and Table 7.30. The trends are consistent with micro economic theory. It is clear that the marginal water values are reduced substantially when water trading is introduced. Theoretically, they should move towards the same value in all uses and towards zero. However, in a model with differences in transaction costs between different regions and other restrictions that restrict the flow of water, they can differ.

Table 7.29: Marginal value (Rand/ha) of water (Set 1 and 2)

Region	Base	Scen1	Scen2	Scen3	BaseB	Scen4	Scen5	Scen6	Scen7
VaalH	10 449	10 449	10 449	10 449	10 485	10 485	10 485	10 485	10 485
VdkDR	12 243	12 243	12 243	12 243	12 199	12 199	12 199	12 199	12 199
DP	11 215	11 215	11 215	11 215	11 795	11 795	11 795	11 795	11 795
Boegoe	14 310	14 305	13 955	13 850	15 740	12 250	12 200	12 125	11 955
UpKaka	105	105	105	180	5 040	6 120	4 155	5 220	5 400
AugBlou	285	285	285	285	300	285	285	285	300
BBlou	2 220	1 785	2 160	2 175	7 905	7 125	6 690	6 480	6 135

It is also clear that within the water market regime, water flows from lower marginal value regions to higher marginal value regions (from UpKaka, Augblou, BBlou to VaalH, VdkDR and DP). It was pointed out earlier that this consists mainly of unused water entitlements traded to supply more water for farmers to produce more wheat and maize in a double cropping system. The result does not imply that the wheat/maize double cropping combination is more profitable than table grapes but that water is scarcer in the North Eastern regions than the Western regions.

Table 7.30: Marginal value of water (Set 3 and 4 scenarios)

Region	Base	BaseC	Scen8	Scen9	Scen10	BaseD	Scen11	Scen12	Scen13	Scen14	Scen15
VaalH	10.449	1.026	1.026	1.026	1.026	1.809	2.187	1.953	1.944	1.971	2.043
VdkDR	12.243	0	0	0	0	0	0	0	0	0	0
DP	11.215	1.101	1.101	1.101	1.101	1.111	1.111	1.111	1.111	1.111	1.121
Boegoe	14.310	3.645	3.645	3.645	3.645	3.480	2.610	2.955	3.210	3.480	3.810
UpKaka	105	870	870	870	8.055	885	885	870	885	915	1.545
AugBlou	285	2.400	2.400	2.400	2.400	2.415	2.400	2.400	2.400	2.400	2.415
BBlou	2.220	0	0	0	0	0	0	0	0	0	0

It is also clear from the results that the value of water in general is reduced when the price of table grapes decreases.

7.4.2.7 Water Trade

It is important to refer back to Table 7.10 to explain the direction in which water flows. It was pointed out earlier in this chapter that the farm survey data gave rise to the observation that a major shortage of irrigation water exists in Vaalharts. Table 7.31 illustrates the direction of water flow when water trade is activated in the model. For the purpose of this report, only temporary trade was activated, since the time to solve the model increases substantially when both temporary and permanent trade is activated. It is also important to note that it was assumed that water can be transferred between regions. However, it is not important for this report since the main objective is to show the direction of water flow. The relatively high marginal values recorded for the North Eastern regions explain the relatively large volume of water traded from the Western regions to the Vaalharts region since water typically flows from surplus to shortage (from lower valued to higher valued use). However, it is also clear that the water market is also active in other regions where trade takes place within the same region and between regions in the same area.

Table 7.31: Trade flow (BaseC scenario)

Area from	Area to	Total volume (mill m ³)	Total from (mill m ³)	% Contribution to total trade (from)
AugBlou	UpKaka	0.13		
AugBlou	VdkDR	0.16		
AugBlou	AugBlou	0.52		
AugBlou	DP	0.64		
AugBlou	Boegoe	0.89		
AugBlou	Vaal	53.83	56.17	38.10%
BBlou	Vaal	6.16	6.16	4.18%
Boegoe	UpKaka	0.11		
Boegoe	DP	0.4		
Boegoe	VdkDR	1.39		
Boegoe	BBlou	1.51		
Boegoe	Vaal	10.96	14.37	9.75%
DP	AugBlou	0.08		
DP	DP	0.15		
DP	UpKaka	0.16		
DP	BBlou	0.4		
DP	Boegoe	0.4		
DP	Vaal	1.41	2.6	1.76%
UpKaka	UpKaka	0.14		
UpKaka	AugBlou	0.79		
UpKaka	DP	0.95		
UpKaka	BBlou	2.02		
UpKaka	VdkDR	2.34		
UpKaka	Boegoe	8.03		
UpKaka	Vaal	41.87	56.14	38.08%
Vaal	Vaal	1.57	1.57	1.06%
VdkDR	VdkDR	0.21		
VdkDR	DP	0.94		
VdkDR	AugBlou	1.11		
VdkDR	BBlou	1.83		
VdkDR	UpKaka	2.71		
VdkDR	Boegoe	3.61	10.41	7.06%
Total trade over 20-years		147.42	147.42	100.00%
Average trade per annum (mill m ³)			7.37	

The analysis in Table 7.32 shows that when the price of table grapes is reduced by 25%, the volume of water that flows from Augrabies-Blouputs to other regions increases from 56.17 million m³ to 61.18 million m³. The result is therefore consistent with expectations. It is also clear that water mostly flows away from the traditional table grape producing regions. The reader should be aware that the results do not show trade between individual typical farms. The explanation for water flowing from Vaal to Vaal, for example, is the major differences in typical farm structure and economies of scale within a region. Total average water trade is approximately 7.37 million m³ for the BaseC scenario and increases slightly to 7.47 million m³ per annum for scenario 10. This is not even 0.5% of the total annual water entitlement of approximately 1600 million m³.

Table 7.32: Trade flow (Scen 10 scenario)

Area from	Area to	Total volume (mill m ³)	Total from (mill m ³)	% Contribution to total trade (from)
AugBlou	DP	0.11		
AugBlou	VdkDR	0.57		
AugBlou	Boegoe	3.32		
AugBlou	Vaal	57.13	61.13	41.47%
BBlou	Vaal	4.8	4.8	3.26%
Boegoe	UpKaka	0.11		
Boegoe	AugBlou	0.12		
Boegoe	Boegoe	0.28		
Boegoe	DP	0.7		
Boegoe	BBlou	1.22		
Boegoe	VdkDR	1.65		
Boegoe	Vaal	8.38	12.46	8.45%
DP	AugBlou	0.02		
DP	VdkDR	0.07		
DP	DP	0.15		
DP	UpKaka	0.28		
DP	Boegoe	0.49		
DP	BBlou	0.53		
DP	Vaal	1.58	3.12	2.12%
UpKaka	UpKaka	1.05		
UpKaka	DP	1.15		
UpKaka	VdkDR	1.6		
UpKaka	AugBlou	1.96		
UpKaka	BBlou	3.56		
UpKaka	Boegoe	12.35		
UpKaka	Vaal	32.38	54.05	36.66%
Vaal	Vaal	1.66	1.66	1.13%
VdkDR	DP	0.4		
VdkDR	AugBlou	0.92		
VdkDR	UpKaka	3.07		
VdkDR	Boegoe	3.79		
VdkDR	BBlou	3.97	12.15	8.24%
Total trade over 20-years		149.37	149.37	101.32%
Average trade per annum (mill m³)			7.47	

An analysis of the BaseD and Scen18 scenarios (Table 7.33) where current land use restrictions are relaxed reveals interesting results.

It is clear that land use restrictions (calibration constraints) prevent water from being used optimally since, compared to the previous two scenarios, water trade decreases in general. Some water still flows to the Vaalharts region, but the volume is substantially reduced. Also, less water flows from the traditional table grape producing regions to the other parts of the Northern Cape since these farms can make structural changes (assuming that they had better knowledge of the market risks and marketing environment when they started

planning their farms). It is also clear that there is more water trade within and between the traditional short-term and long-term crop regions.

Table 7.33: Trade flow (BaseD scenario)

Area from	Area to	Total volume (mill m ³)	Total from (mill m ³)	% Contribution to total trade (from)
AugBlou	UpKaka	0.2		
AugBlou	VdkDR	0.97		
AugBlou	DP	2.12		
AugBlou	Boegoe	6.1		
AugBlou	Vaal	32.14	41.53	19.2%
BBlou	Vaal	5.02	5.02	2.3%
Boegoe	DP	0.47		
Boegoe	VdkDR	0.48		
Boegoe	Boegoe	0.54		
Boegoe	BBlou	1.32		
Boegoe	UpKaka	2.62		
Boegoe	AugBlou	3.18		
Boegoe	Vaal	22.76	31.37	14.5%
DP	UpKaka	0.18		
DP	AugBlou	0.25		
DP	BBlou	1.55		
DP	Boegoe	4.26		
DP	Vaal	7.05	13.29	6.1%
UpKaka	UpKaka	0		
UpKaka	AugBlou	0.04		
UpKaka	VdkDR	0.21		
UpKaka	Vaal	42.93		
UpKaka	Boegoe	49.82	93	43.0%
Vaal	Vaal	6.2	6.2	2.9%
VdkDR	DP	1.28		
VdkDR	UpKaka	1.4		
VdkDR	BBlou	1.62		
VdkDR	AugBlou	2.43		
VdkDR	Boegoe	18.98	25.71	11.9%
Total trade over 20-year		216.12	216.12	100.0%
Average trade per annum (mill m ³)			10.81	

Table 7.34 also shows that even when the price of table grapes is reduced by 33% (just before unfeasibility), trade away from the traditional table grape regions does not necessarily increase.

The explanation is that if farmers had the knowledge to plan for such situations, farming structures would be more diversified and the impact of declining prices reduced. It is clear that the volume of water traded away from Upington/Kakamas almost halved. Water trade flow analysis is of paramount importance to gaining more knowledge on existing water allocation efficiency and predicting the direction of water flow during different marketing environment regimes.

Table 7.34: Trade flow (Scen 15)

Area from	Area to	Total volume (mill m ³)	Total from (mill m ³)	% Contribution to total trade (from)
AugBlou	VdkDR	1.28		
AugBlou	Boegoe	5.51		
AugBlou	Vaal	47.92	54.69	34.8%
BBlou	Vaal	17.19	17.19	10.9%
Boegoe	Boegoe	0.09		
Boegoe	DP	0.27		
Boegoe	VdkDR	0.42		
Boegoe	UpKaka	0.5		
Boegoe	AugBlou	0.83		
Boegoe	BBlou	1.29		
Boegoe	Vaal	12.83	16.23	10.3%
DP	DP	0.02		
DP	VdkDR	0.31		
DP	UpKaka	1.34		
DP	AugBlou	1.43		
DP	Boegoe	2.71		
DP	BBlou	3.06		
DP	Vaal	3.58	12.45	7.9%
UpKaka	AugBlou	0.69		
UpKaka	VdkDR	1.9		
UpKaka	DP	2.35		
UpKaka	BBlou	2.81		
UpKaka	Boegoe	7.95		
UpKaka	Vaal	30.05	45.75	29.1%
Vaal	Vaal	2.05	2.05	1.3%
VdkDR	UpKaka	0.74		
VdkDR	BBlou	1.04		
VdkDR	DP	1.27		
VdkDR	Boegoe	1.36		
VdkDR	VdkDR	2.02		
VdkDR	AugBlou	2.54	8.97	5.7%
Total trade over 20-years		157.33	157.33	100.0%
Average trade per annum (mill m ³)			7.87	

The results clearly indicate that water will not necessarily be traded away from the table grapes regions at the lower table grape price since farmers will make structural changes in the long-run and use the water on other crops.

7.5 REGIONAL MODEL (WATER TARIFF SCENARIO)

Water being the most important input in irrigation agriculture, it was decided to run some scenarios to determine the sensitivity of farm profitability to water tariffs. For this purpose, it was also decided to use the regional model and not the typical farm model since it would also be interesting to look at the impact of water trade. The following scenarios were analysed:

- Base = Current land use with no water trade 20% down variation on LT crop and 5% down variation on ST crops--20% LT crop and 100% ST crop variation over the total planning horizon
- Scen1 = Same as Base but 50% increase in water tariffs--no water trade
- Scen2 = Same as Base but 100% increase in water tariffs--no water trade
- Scen3 = Same as Base but 150% increase in water tariffs--no water trade
- Scen4 = Same as Base but 200% increase in water tariffs--no water trade
- Scen5 = Same as Base but 250% increase in water tariffs--no water trade
- BaseB = Same as Base but water trade
- Scen6 = Same as BaseB but 50% increase in water tariffs--**water trade**
- Scen7 = Same as BaseB but 100% increase in water tariffs--**water trade**
- Scen8 = Same as BaseB but 150% increase in water tariffs--**water trade**
- Scen9 = Same as BaseB but 200% increase in water tariffs--**water trade**
- Scen10 = Same as BaseB but 250% increase in water tariffs--**water trade**
- BaseC = Same as BaseC but 20% decrease in price of table grapes and 10% for maize and wheat--**water trade**
- Scen11 = Same as BaseC but 50% increase in water tariffs--**water trade**
- Scen12 = Same as BaseC but 100% increase in water tariffs--**water trade**
- Scen13 = Same as BaseC but 110% increase in water tariffs--**water trade**

Table 7.35 compares 2002 water tariffs with 2006 water tariffs. It is important to note that these water tariffs are average values within the model regions.

Table 7.35: Average Northern Cape water tariffs (Rand per ha)

	2002		2006		% Change	
	River	Canal	River	Canal	River	Canal
Vaal	82	716	374	946	358%	32%
VokDR	85	562	168	752	98%	34%
DP	58	280	168	407	190%	45%
Boegoe	85	750	262	1149	208%	53%
UpKaka	85	594	262	720	208%	21%
AugBlou	85	500	262	720	208%	44%
Bblou	85	500	262	720	208%	44%
Average	81	557	251	773	211%	39%

It is clear that the highest increases were on river water use entitlements (between 98-358%). The canal water use entitlement tariff increased by 30-50%.

Table 7.36 shows the water tariffs for increases in increments of 50%. The reader may think that these tariff increases are totally unrealistic. However, water tariff increases of between 100% and 358% have already occurred in most irrigation regions since the tariff increases started from a very low base tariff.

Table 7.36: Northern Cape water tariffs (Rand per ha for 2002)

	Base		50%		100%		150%		200%		250%	
	River	Canal	River	Canal	River	Canal	River	Canal	River	Canal	River	Canal
Vaal	150	442	225	663	300	884	375	1105	450	1326	525	1547
VdkDR	85	562	127.5	843	170	1124	212.5	1405	255	1686	297.5	1967
DP	58	280	87	420	116	560	145	700	174	840	203	980
Boegoe	85	750	127.5	1125	170	1500	212.5	1875	255	2250	297.5	2625
UpKaka	85	594	127.5	891	170	1188	212.5	1485	255	1782	297.5	2079
AugBlou	85	500	127.5	750	170	1000	212.5	1250	255	1500	297.5	1750
Bblou	85	500	127.5	750	170	1000	212.5	1250	255	1500	297.5	1750

To simplify the discussion of the results, the scenarios are divided into three sets:

- Set 1: Base analysis and scenarios 1-5. Water costs are increased in steps of a 50% increase from the 2002 costs to 250% of the base tariff.
- Set 2: BaseB plus scenarios 6-10. The only difference between Set 1 and 2 is that water trade is allowed.
- Set 3: BaseC plus scenarios 11-13. In these scenarios, water costs are increased in a scenario of reduced table grapes and grain prices.

7.5.1 Water tariff scenario results

Similar to the table grape scenarios, the results of the regional model water tariff scenarios are discussed under the following headings:

- Changes in the aggregated objective function value--basically the net output of Northern Cape irrigated agriculture.
- Average Net Farm Income per region per annum and the changes from base analysis
- Total average land use (area) per region
- Total and per ha water usage

- Capitalised return on capital investment
- Average marginal value of water
- Water trade between regions

7.5.1.1 Changes in the aggregated objective function value

Table 7.37 to Table 7.39 represent the objective function value for different scenarios. It is clear that when water trade is not possible (set 1), the objective function value decreases by about 1.1% in scenario 1 and 6% in scenario 5. Analysis also shows that the tempo of decrease in the objective function accelerates with every incremental increase. In the beginning, it is a 1.1% decrease for a 50% increase in tariffs, while the decrease is 1.3% for the last incremental increase.

Table 7.37: Objective function value (Set 1)

Objective function	Base	Scen1	Scen2	Scen3	Scen4	Scen5
Objective (Million Rand)	28,509	28,183	27,856	27,526	27,182	26,799
Total Orange River irrigation (ha)	106,273	106,210	106,139	106,000	105,777	105,622
Obj per ha over 20-years (Rand)	268,263	265,352	262,450	259,679	256,974	253,726
Obj per ha per annum (average) - (Rand)	13,413	13,268	13,122	12,984	12,849	12,686
% deviation from base		-1.1%	-2.3%	-3.4%	-4.7%	-6.0%

The analysis in Table 7.38 shows that when trade is possible, the objective function value increases by approximately 4.2% from the base analysis. However, when the tariffs are increased, the reduction from BaseB occurs approximately at the same rate as the scenarios without trade.

Table 7.38: Objective function value (Set 2)

Objective function	Base	BaseB	Scen6	Scen7	Scen8	Scen9	Scen10
Objective (Million Rand)	28,509	29,693	29,386	29,124	28,877	28,634	28,391
Total Orange River irrigation (ha)	106,273	114,191	114,132	114,083	114,035	113,983	113,911
Obj per ha over 20-years (Rand)	268,263	260,029	257,474	255,288	253,229	251,212	249,238
Obj per ha per annum (average) - (Rand)	13,413	13,001	12,874	12,764	12,661	12,561	12,462
% deviation from base		4.2%	3.1%	2.2%	1.3%	0.4%	-0.4%

Table 7.39 shows that a substantial impact when the price of table grapes is reduced by 20% and the price of grain by 10%.

Table 7.39: Objective function value (Set 3)

Objective function	BaseC	Scen11	Scen12	Scen13
Objective (Million Rand)	21.421	21.064	20.751	20.690
Total Orange River irrigation (ha)	113.497	113.422	113.323	113.331
Obj per ha over 20-years (Rand)	188.736	185.714	183.114	182.553
Obj per ha per annum (average) - (Rand)	9.437	9.286	9.156	9.128
% deviation from base	NA	-1.7%	-3.1%	-3.4%

The maximum water tariff increase under this scenario is 110% (Scen13). The reader should be aware that not all farms are unfeasible at this tariff. However, the model is structured in such a way that all the farms must be feasible, otherwise the results are unfeasible. Although water tariffs are a relatively small portion of total production costs with long-term crops (less than 1%), it is otherwise with short-term crops (between 5-12%). Obviously, in the North Eastern regions where land use is dominated by maize and wheat, the impact will be more severe than in the Western regions where long-term crops dominate.

7.5.1.2 Average cumulative Net Farm Income (NFI) per region

Table 7.40 represents the average NFI per region. The analysis clearly shows that the NFI decreases more in the regions where wheat and maize dominate than where long-term crops are grown.

Table 7.40: Total cumulative Net Farm Income (Mill Rand) – Set 1

Region	Base	Scen1	Scen2	Scen3	Scen4	Scen5
VaalH	397	328	271	225	190	159
VdkDR	644	630	614	596	577	562
DP	624	589	554	520	485	451
Boegoe	604	584	565	545	526	507
UpKaka	5325	5255	5187	5113	5038	4967
AugBlou	4970	4955	4939	4925	4908	4893
BBlou	1637	1635	1632	1629	1626	1623
Total (average / annum)	2029	1997	1966	1936	1907	1880
Region - Deviation from base	Base	Scen1	Scen2	Scen3	Scen4	Scen5
VaalH	NA	-17.3%	-31.6%	-43.4%	-52.1%	-59.9%
VdkDR	NA	-2.1%	-4.7%	-7.4%	-10.4%	-12.7%
DP	NA	-5.6%	-11.1%	-16.7%	-22.2%	-27.7%
Boegoe	NA	-3.2%	-6.5%	-9.7%	-13.0%	-16.1%
UpKaka	NA	-1.3%	-2.6%	-4.0%	-5.4%	-6.7%
AugBlou	NA	-0.3%	-0.6%	-0.9%	-1.3%	-1.5%
BBlou	NA	-0.2%	-0.3%	-0.5%	-0.7%	-0.9%
Total (average)	NA	-1.6%	-3.1%	-4.6%	-6.0%	-7.3%

When trade is possible, the impact of increasing water tariffs is reduced to some extent (see Table 7.41).

Table 7.41: Total cumulative Net Farm Income (Mill Rand) – Set 2

Region	Base	BaseB	Scen6	Scen7	Scen8	Scen9	Scen10
VaalH	397	1417	1259	1123	986	850	719
VdkDR	644	650	639	615	604	591	577
DP	624	629	600	572	544	515	487
Boegoe	604	613	605	600	597	598	593
UpKaka	5326	5320	5255	5217	5177	5143	5120
AugBlou	4970	4966	4957	4953	4947	4944	4938
BBlou	1637	1644	1641	1638	1635	1632	1629
Total (average / annum)	2029	2177	2137	2103	2070	2039	2009
Region	Base	BaseB	Scen6	Scen7	Scen8	Scen9	Scen10
VaalH	NA	256.8%	217.0%	182.9%	148.3%	114.2%	81.0%
VdkDR	NA	0.9%	-0.8%	-4.6%	-6.2%	-8.1%	-10.5%
DP	NA	0.8%	-3.7%	-8.2%	-12.7%	-17.3%	-21.8%
Boegoe	NA	1.6%	0.1%	-0.6%	-1.1%	-1.0%	-1.9%
UpKaka	NA	-0.1%	-1.3%	-2.1%	-2.8%	-3.4%	-3.9%
AugBlou	NA	-0.1%	-0.3%	-0.3%	-0.5%	-0.5%	-0.6%
BBlou	NA	0.4%	0.2%	0.0%	-0.2%	-0.3%	-0.5%
Total (average)	NA	7.3%	5.3%	3.6%	2.0%	0.5%	-1.0%

The set 3 scenarios in

Table 7.42 show that when the prices of table grapes and grain are reduced, some typical farms in the Douglas/Prieska region become unfeasible at water tariff increases of more than 110%. The total regional Net Farm Income is reduced by 9.9% at a 110% tariff increase.

Table 7.42: Total cumulative Net Farm Income (Mill Rand) – Set 3

Region	BaseC	Scen11	Scen12	Scen13
VaalH	733	592	442	419
VdkDR	294	287	279	277
DP	162	134	106	100
Boegoe	283	264	249	248
UpKaka	1965	1900	1822	1808
AugBlou	1884	1878	1869	1867
BBlou	905	901	896	896
Total (average / annum)	890	851	809	802
Region	BaseC	Scen11	Scen12	Scen13
VaalH	NA	-19.2%	-39.8%	-42.9%
VdkDR	NA	-2.6%	-5.4%	-6.1%
DP	NA	-17.4%	-34.7%	-38.2%
Boegoe	NA	-6.7%	-12.1%	-12.6%
UpKaka	NA	-3.3%	-7.3%	-8.0%
AugBlou	NA	-0.4%	-0.8%	-0.9%
BBlou	NA	-0.4%	-0.9%	-1.0%
Total (average)	NA	-4.4%	-9.1%	-9.9%

7.5.1.3 Total average land use per region

Table 7.43 represents the average monthly land use per region. It is clear that there is only a slight decrease in the total production area.

Table 7.43: Total Northern Cape crop area based on crop production (ha) – Set 1

Region	Base	Scen1	Scen2	Scen3	Scen4	Scen5
VaalH	66.897	66.899	66.899	66.865	66.855	66.864
VdkDR	30.615	30.615	30.615	30.613	30.601	30.581
DP	40.311	40.311	40.311	40.311	40.310	40.310
Boegoe	9.306	9.305	9.294	9.289	9.272	9.225
UpKaka	15.584	15.546	15.508	15.416	15.338	15.275
AugBlou	7.598	7.583	7.558	7.550	7.460	7.448
BBlou	5.035	5.035	5.033	5.025	5.025	5.025
Total land use (ha)	175.347	175.295	175.219	175.069	174.860	174.728
Total OR water entitlements (ha)	143.341	143.341	143.341	143.341	143.341	143.341
Land use as % of entitlement	122%	122%	122%	122%	122%	122%
Region	Base	Scen1	Scen2	Scen3	Scen4	Scen5
VaalH		0.00%	0.00%	-0.05%	-0.06%	-0.05%
VdkDR		0.00%	0.00%	-0.01%	-0.05%	-0.11%
DP		0.00%	0.00%	0.00%	0.00%	0.00%
Boegoe		-0.01%	-0.13%	-0.18%	-0.37%	-0.87%
UpKaka		-0.25%	-0.49%	-1.08%	-1.58%	-1.98%
AugBlou		-0.19%	-0.52%	-0.62%	-1.81%	-1.97%
BBlou		0.00%	-0.04%	-0.21%	-0.21%	-0.21%
Total land use		-0.03%	-0.07%	-0.16%	-0.28%	-0.35%

Although not shown here, the results for the Set 2 scenarios are similar. However, when the prices of table grapes and grain are reduced, the situation changes, and it is clear that more short-term crops are produced since land use increases from 122% to 134%.

Table 7.44: Total Northern Cape crop area based on crop production (ha) – Set 3

Region	BaseC	Scen11	Scen12	Scen13
VaalH	84.397	84.338	84.292	84.320
VdkDR	30.632	30.630	30.627	30.627
DP	40.295	40.301	40.308	40.312
Boegoe	9.376	9.377	9.363	9.365
UpKaka	15.360	15.307	15.229	15.219
AugBlou	7.454	7.457	7.470	7.473
BBlou	5.113	5.116	5.105	5.106
Total land use (ha)	192.626	192.527	192.394	192.422
Total OR water entitlements (ha)	143.341	143.341	143.341	143.341
Land use as % of entitlement	134%	134%	134%	134%
Region	BaseC	Scen11	Scen12	Scen13
VaalH	NA	-0.07%	-0.12%	-0.09%
VdkDR	NA	-0.01%	-0.01%	-0.02%
DP	NA	0.01%	0.03%	0.04%
Boegoe	NA	0.01%	-0.14%	-0.12%
UpKaka	NA	-0.34%	-0.86%	-0.92%
AugBlou	NA	0.04%	0.21%	0.26%
BBlou	NA	0.07%	-0.14%	-0.13%
Total land use	NA	-0.05%	-0.12%	-0.11%

The same trend (compared to set 1 and set 2) follows in Set 3 where increasing tariffs do not bring about significant changes in land use, which changes by less than 0.5% in total.

7.5.1.4 Total and per ha water usage

Table 7.45 represents crop water usage for the Northern Cape. It is clear that total water usage declines with increasing water tariffs if no water trade is possible.

Table 7.45: Northern Cape total crop water usage (Mill m³) – Set 1

Region	Base	Scen1	Scen2	Scen3	Scen4	Scen5
VaalH	452	448	448	448	448	448
VdkDR	218	210	210	209	208	207
DP	250	244	244	244	244	244
Boegoe	135	125	125	123	123	122
UpKaka	252	229	221	218	213	211
AugBlou	108	102	98	97	96	96
BBlou	72	69	69	69	69	69
Total (average / annum)	1487	1427	1415	1409	1401	1397

If all water tariffs increase by 250%, total annual crop water usage declines by 90 million m³ or about 6.8%. The result is consistent with the theory that demand for irrigation water is relatively inelastic especially for long-term crops and corresponds with previous work in the Berg River (Louw, 2002).

When water can be traded, water usage increases initially since water flows to the North Eastern regions. However, as water tariffs increase, demand decreases but less than in scenarios where water trade is not allowed (see Table 7.46).

Table 7.46: Northern Cape total crop water usage (Mill m³) – Set 2

Region	Base	BaseB	Scen6	Scen7	Scen8	Scen9	Scen10
VaalH	452	597	596	596	596	595	595
VdkDR	218	213	212	211	211	211	210
DP	250	245	245	245	245	245	244
Boegoe	135	137	137	137	137	137	136
UpKaka	252	238	237	236	237	237	237
AugBlou	108	110	110	110	110	110	110
BBlou	72	76	76	76	76	76	75
Total (average / annum)	1487	1614	1613	1610	1610	1609	1607

Table 7.47 represents the Northern Cape's total water usage for Set 3 scenarios. The results indicate that total water usage increases with increasing water tariffs since structural changes are probably towards crops with higher water use.

The conclusion reached is that increasing water tariffs will not necessarily lead to a decline in total water usage. If farmers can make structural changes to other crops when the price of table grapes and grain are reduced, the new combination of crops may use more water even if it is more expensive.

Table 7.47: Northern Cape total crop water usage (Mill m³) – Set 3

Region	BaseC	Scen11	Scen12	Scen13
VaalH	600	599	599	600
VdkDR	212	212	213	213
DP	245	245	245	245
Boegoe	137	137	136	136
UpKaka	231	232	233	234
AugBlou	106	106	108	107
BBlou	75	75	76	76
Total (average / annum)	1607	1607	1610	1611

7.5.1.5 Capitalised return on capital investment

Table 7.48 and Table 7.49 represents capitalised return on capital investment for the Set 1 and Set 2 scenarios respectively. Similar to the NFI results, the impact of increased in water tariffs is more severe in areas where wheat and maize dominate. The most significant change is in the Vaalharts region if water trade is not activated. The return on capital investment is reduced from 4% to 1.6% when water tariffs increase by 250%.

Table 7.48: Capitalised return on capital investment (%) – Set 1

Region	Base	Scen1	Scen2	Scen3	Scen4	Scen5
VaalH	4.0%	3.3%	2.7%	2.3%	1.9%	1.6%
VdkDR	7.4%	7.2%	7.1%	6.9%	6.6%	6.5%
DP	5.6%	5.2%	4.9%	4.6%	4.3%	4.0%
Boegoe	11.8%	11.5%	11.1%	10.7%	10.3%	9.9%
UpKaka	24.7%	24.3%	24.0%	23.7%	23.3%	23.0%
AugBlou	33.6%	33.5%	33.4%	33.3%	33.2%	33.1%
BBlou	35.5%	35.5%	35.4%	35.3%	35.3%	35.2%

Table 7.49: Capitalised return on capital investment (%) – Set 2

Region	Base	BaseB	Scen6	Scen7	Scen8	Scen9	Scen10
VaalH	4.0%	14.2%	12.7%	11.3%	9.9%	8.5%	7.2%
VdkDR	7.4%	7.5%	7.3%	7.1%	6.9%	6.8%	6.6%
DP	5.6%	5.6%	5.3%	5.1%	4.8%	4.6%	4.3%
Boegoe	11.8%	12.0%	11.9%	11.8%	11.7%	11.7%	11.6%
UpKaka	24.7%	24.6%	24.3%	24.2%	24.0%	23.8%	23.7%
AugBlou	33.6%	33.6%	33.5%	33.5%	33.4%	33.4%	33.4%
BBlou	35.5%	35.7%	35.6%	35.5%	35.5%	35.4%	35.3%

However, when trade is possible, return on capital investment increases significantly, especially in the North Eastern regions, where the impact of the increased water tariffs can be absorbed to some extent through increased production of wheat and maize.

The Set 3 scenarios are interesting (Table 7.50). In Scenario 13, water tariffs are increased to a point just before unfeasibility of the model. However, it is only at the point of unfeasibility in the Douglas/Prieska region. The other regions are still feasible even with a huge increase in water tariffs. The results clearly show that there is less impact in long-term crop regions than in wheat/maize production regions.

Table 7.50: Capitalised return on capital investment (%) – Set 3

Region	BaseC	Scen11	Scen12	Scen13
VaalH	7.4%	6.0%	4.4%	4.2%
VdkDR	3.4%	3.3%	3.2%	3.2%
DP	1.4%	1.2%	0.9%	0.9%
Boegoe	5.6%	5.2%	4.9%	4.9%
UpKaka	9.1%	8.8%	8.4%	8.4%
AugBlou	12.7%	12.7%	12.6%	12.6%
BBlou	19.6%	19.5%	19.4%	19.4%

7.5.1.6 Average marginal value of water

When water tariffs increase, the effect is similar to water scarcity. The results in Table 7.51 and When the price of crops is reduced, capitalised marginal water value will obviously decrease. Tables 7.52 to 7.53 indicate that the increase in marginal values is generally smaller than in the Set 2 scenarios (Base crop prices).

Table 7.52 are important. In general, capitalised marginal value of water increases in all regions as water tariffs are increased.

This result is even clearer when water trade is activated. Table 7.51 shows huge increases in the marginal value of the water, especially when water tariffs are increased by more than 150%.

Table 7.51: Average capitalised marginal value of water (Rand per ha) – Set 1

Region	Base	Scen1	Scen2	Scen3	Scen4	Scen5
VaalH	10,467	10,926	10,845	10,926	11,835	11,736
VdkDR	12,298	12,133	12,067	11,979	11,704	11,627
DP	11,235	11,727	11,640	11,727	12,703	12,597
Boegoe	17,950	17,570	17,355	16,620	15,985	15,650
UpKaka	105	675	1,245	1,830	2,400	2,970
AugBlou	285	945	1,620	2,280	2,940	3,615
BBlou	7,395	7,245	7,365	7,215	7,170	7,215

When the price of crops is reduced, capitalised marginal water value will obviously decrease. Tables 7.52 to 7.53 indicate that the increase in marginal values is generally smaller than in the Set 2 scenarios (Base crop prices).

Table 7.52: Average capitalised marginal value of water (Rand per ha) – Set 2

Region	Base	BaseB	Scen6	Scen7	Scen8	Scen9	Scen10
VaalH	10,467	1,026	1,494	1,494	6,489	9,369	12,240
VdkDR	12,298	0	2,409	2,409	8,503	12,023	15,532
DP	11,235	1,101	2,116	2,116	7,467	10,558	13,640
Boegoe	17,950	1,160	2,390	2,390	5,165	6,770	8,440
UpKaka	105	870	5,670	5,670	15,255	20,040	24,840
AugBlou	285	2,400	6,915	6,915	15,255	20,040	24,840
BBlou	7,395	0	0	0	6,450	11,250	16,110

Table 7.53: Average capitalised marginal value of water (Rand per ha) – Set 3

Region	BaseC	Scen11	Scen12	Scen13
VaalH	1,035	1,044	3,141	3,807
VdkDR	0	726	1,034	1,397
DP	1,111	1,121	3,371	4,086
Boegoe	1,500	7,655	17,125	18,630
UpKaka	870	5,670	10,455	11,415
AugBlou	2,400	4,635	5,055	5,550
BBlou	0	1,080	5,055	5,550

7.5.1.7 Water trade between regions

Table 7.54 and Table 7.55 show the theoretical direction in which water will be traded and the total volume of water trade.

Almost 74% of the total water traded in the BaseB analysis is from a number of regions towards Vaalharts. The average total water trade per annum is about 7.8 million m³ (less than 0.5% of the total annual water supply to agriculture. It was pointed out earlier in this chapter that according to the farm survey data there is a relatively large shortage of

irrigation water in the Vaalharts region (8 610 ha or 77 million m³). It is therefore not surprising that 73.6% of the water trade is towards Vaalharts and mainly from the AupKaka, AugBlou, and Bblou regions.

Table 7.54: Water trade – Scenario BaseB

From	To	Total volume (mill m ³)	Total volume to (mill m ³)	% of total trade
VdkDR	AugBlou	1.61		
DP	AugBlou	0.97		
Boegoe	AugBlou	0.21		
AugBlou	AugBlou	0.61	3.4	2.2%
VdkDR	BBlou	1.25		
DP	BBlou	0.48		
Boegoe	BBlou	3.29		
UpKaka	BBlou	2.5	7.52	4.8%
UpKaka	Boegoe	12.41		
AugBlou	Boegoe	0.54		
VdkDR	Boegoe	3.74		
DP	Boegoe	1.19	17.88	11.4%
VdkDR	DP	0.47		
DP	DP	0		
Boegoe	DP	0.13		
UpKaka	DP	1.05		
AugBlou	DP	0.52	2.17	1.4%
VdkDR	UpKaka	2.1		
DP	UpKaka	0.3		
Boegoe	UpKaka	0.76	3.16	2.0%
Vaal	Vaal	3		
DP	Vaal	2.58		
Boegoe	Vaal	14.35		
UpKaka	Vaal	35.41		
AugBlou	Vaal	53.55		
BBlou	Vaal	6.6	115.49	73.6%
VdkDR	VdkDR	0.41		
DP	VdkDR	0.3		
UpKaka	VdkDR	6.1		
AugBlou	VdkDR	0.54	7.35	4.7%
Total trade over 20-years (mill m³)			156.97	100.0%
Average annual water trade (mill m³)			7.8	
Total annual water entitlement (mill m³)			1606	
Water trade as percentage of total entitlement			0.5%	

With a 150% increase in water tariffs, water trade increases. The main reason for this is structural changes towards more profitable crops. Total water trade increases to approximately 0.77% of total annual water allocation.

Table 7.55: Water trade – scenario 8

From	To	Total volume (mill m ³)	Total volume to (mill m ³)	% of total trade
VdkDR	AugBlou	2.1		
DP	AugBlou	1.42		
Boegoe	AugBlou	0.34		
UpKaka	AugBlou	1.54		
AugBlou	AugBlou	0.15	5.55	2.24%
VdkDR	BBlou	1.42		
DP	BBlou	0.57		
Boegoe	BBlou	5.32		
UpKaka	BBlou	3.48	10.79	4.36%
UpKaka	Boegoe	11.24		
AugBlou	Boegoe	0.24		
VdkDR	Boegoe	2.13		
DP	Boegoe	1.1	14.71	5.94%
VdkDR	DP	0.47		
DP	DP	0.01		
Boegoe	DP	2.77		
UpKaka	DP	7.72		
AugBlou	DP	13.82	24.79	10.02%
UpKaka	UpKaka	3.37		
VdkDR	UpKaka	0.67		
DP	UpKaka	0.49	4.53	1.83%
Vaal	Vaal	2.96		
DP	Vaal	1.36		
Boegoe	Vaal	16.25		
UpKaka	Vaal	49.28		
AugBlou	Vaal	54.77		
BBlou	Vaal	4.83	129.45	52.30%
VdkDR	VdkDR	0.12		
DP	VdkDR	0.3		
Boegoe	VdkDR	20.9		
UpKaka	VdkDR	22.91		
AugBlou	VdkDR	13.46	57.69	23.31%
Total trade over 20-years (mill m ³)			247.51	100.00%
Average annual water trade (mill m ³)			12.4	
Total annual water entitlement (mill m ³)			1606	
Water trade as percentage of total entitlement			0.77%	

Table 7.56 represents water trade volumes for the BaseC scenario (decrease in crop prices). Most of the water trade is towards Vaalharts and Boegoeberg and Vanderkloof. An average of 6.8 million m³ of water trades annually – less than the BaseB scenario. The results indicate that less water will be traded when crop prices are reduced.

Table 7.56: Water trade – scenario BaseC

From	To	Total volume (mill m ³)	Total volume to (mill m ³)	% of total trade
Boegoe	AugBlou	0.12		
UpKaka	AugBlou	0.18		
VdkDR	AugBlou	1.77		
DP	AugBlou	0.72	2.79	2.1%
VdkDR	BBlou	0.45		
DP	BBlou	0.23		
Boegoe	BBlou	1.35	2.03	1.5%
UpKaka	Boegoe	9.26		
VdkDR	Boegoe	1		
DP	Boegoe	0.48		
Boegoe	Boegoe	0.01		
AugBlou	Boegoe	0.52	11.27	8.4%
VdkDR	DP	1.13		
DP	DP	0.1		
Boegoe	DP	0.02		
UpKaka	DP	0.52		
AugBlou	DP	1.75	3.52	2.6%
VdkDR	UpKaka	0.4		
DP	UpKaka	0.4		
Boegoe	UpKaka	0.41	1.21	0.9%
Vaal	Vaal	2.09		
DP	Vaal	1.88		
Boegoe	Vaal	11.13		
UpKaka	Vaal	33.55		
AugBlou	Vaal	49.45		
BBlou	Vaal	6.81	104.91	78.5%
DP	VdkDR	0.04		
Boegoe	VdkDR	0.66		
UpKaka	VdkDR	4.53		
AugBlou	VdkDR	2.66	7.89	5.9%
Total trade over 20-years (mill m ³)			133.62	100%
Average annual water trade (mill m ³)			6.68	
Total annual water entitlement (mill m ³)			1606	
Water trade as percentage of total entitlement			0.42%	

The results in Table 7.57 are of great significance. When the tariff of water increases by 110% in scenario 12, water trade increases threefold. Approximately 444 million m³ trades over the 20-year planning horizon (22 million m³ per annum or 1.38% of the total annual allocation). About 139 million m³ are traded in the direction of Vaalharts.

Table 7.57: Water trade – scenario 12

From	To	Total volume (mill m ³)	Total volume to (mill m ³)	% of total trade
VdkDR	AugBlou	1.23		
DP	AugBlou	0.3		
Boegoe	AugBlou	37.45		
UpKaka	AugBlou	0.84	39.82	8.96%
VdkDR	BBlou	2.45		
DP	BBlou	0.1		
Boegoe	BBlou	62.5		
UpKaka	BBlou	0.8	65.85	14.82%
AugBlou	Boegoe	0.58		
VdkDR	Boegoe	6.08		
DP	Boegoe	2.05		
Boegoe	Boegoe	8.8		
UpKaka	Boegoe	79.15	96.66	21.76%
VdkDR	DP	1.5		
DP	DP	0.01		
Boegoe	DP	11.14		
UpKaka	DP	10.06		
AugBlou	DP	16.06	38.77	8.73%
VdkDR	UpKaka	0.32		
Boegoe	UpKaka	3.75	4.07	0.92%
Vaal	Vaal	2.11		
DP	Vaal	1.63		
Boegoe	Vaal	22.65		
UpKaka	Vaal	56.72		
AugBlou	Vaal	52.27		
BBlou	Vaal	3.92	139.3	31.36%
DP	VdkDR	0.22		
Boegoe	VdkDR	16.64		
UpKaka	VdkDR	13.72		
AugBlou	VdkDR	29.2	59.78	13.46%
Total trade over 20-years (mill m ³)			444	100.00%
Average annual water trade (mill m ³)			22	
Total annual water entitlement (mill m ³)			1606	
Water trade as percentage of total entitlement			1.38%	

It is also significant to note that in terms of contribution to total trade, much less is traded towards Vaalharts and more to Boegoeberg, BBlou, DP and Augrabies/Blouputs. However, in terms of total value, more water flows to Vaalharts (139 million m³ compared to 104.9 million m³ in BaseC). The reason for this (although not shown in the table) is a significant increase in crops such as citrus, pecan nuts and olives.

7.6 SUMMARY

It was pointed out in the introduction that this chapter deals with sub-objectives 2 and 3 of the terms of reference:

- To develop a decision-making framework which farmers can use to reduce their risk.
- To compare present water use practices with optimal risk-reducing practices and to find reasons for deviation.

It was also pointed out that the development of both the typical farm models and the regional models provides the analytical framework to analyse alternative risk-reducing strategies (sub-objective 2). The table grape scenario is an extremely useful case study since it contains all the elements to illustrate how a lack of marketing information can lead to non-optimal resource allocations and to suggest risk-reducing practices for managing the situation more effectively.

The following conclusions can be drawn from the typical farm model results:

- The result of the CGE model corresponds with the observed reduction in table grape prices in the Orange River. The CGE model calculated that the local farm level price (Delivered in Port) will decrease by 22% if the international price of fruit is reduced by 20%. It was pointed out in Table 7.1 that the observed reduction is 22.75%. This result is important to illustrate the link between CGE (macro economic) and micro economic models.
- The typical farm model scenarios showed that a 20% decrease in the price of table grapes reduced the return on capital investment from 37.4% in the base to around 18.5% (reduction of more than 50% in Net Farm Income). This represents a huge decrease in profitability. It is also important to note that a 20% reduction in the price of table grapes is an average in reduction. There are substantial variations between the price that farmers actually receive since it will depend on markets where the farmers sell their fruit and the cost structure of the exporter. In this regard, farmers can reduce their risks. For example, it was pointed out that a reduction of around 40% is unfeasible (farmers go bankrupt), but, on the other hand, there will also be farmers with a less than 20% reduction since they are actively involved in marketing their

product. From a risk management point of view, it is therefore important for farmers to get involved on the marketing side of the supply chain. This is not only true for table grape farmers but for all crop farmers as it is a powerful marketing risk-management tool.

- It was also pointed out that marketing information is the key to managing marketing risks. In this regard, industry organisations such as the Deciduous Fruit Producers Trust and the so-called Joint Marketing Forums (JMF's) should play an important role. In the JMF's, producers and exporters collaborate to share supply (crop estimates, fruit intake, and shipments) and demand (Southern hemisphere shipments and price information for alternative markets) information.
- Timely and accurate fruit intake and shipment information, the availability of accurate market compliance information, and price information are obviously keys to efficient marketing decisions. In this regard, government can play an extremely important role by forming partnerships with industry organisations to develop information systems to improve the accuracy and timeliness of information, thereby creating an environment where the private sector can take advantage of marketing opportunities and reduce marketing risks.
- The results also clearly indicated that a more diverse farming structure is a key strategy to reduce marketing risks. The results indicated that optimum farm structures, after a reduction in the price of table grapes, are different to observed farm structures. If farmers had had better marketing information and the skills to interpret it, they would have taken other production decisions. The results clearly show that farm structures would have been more diversified. More diversified farm structures enable farmers to absorb market failures more efficiently than specialised farm structures.
- A huge increase in the price of raisins does not necessarily combat the reduction in table grapes. Since Sultana grapes are more flexible than other table grapes, the results indicate that farmers do alternate between grapes for exports and grapes for raisins when the price of table grapes is reduced. Of course, it is not an optimum market risk reduction strategy since farmers need to produce what the market wants. What the market wants changes over time, so it will not be feasible to produce Sultanas alone. However, since Sultanas represent approximately 45% of the total table grape crop mix, it is part of the risk reduction strategy to some extent. The result also corresponds with the observed reaction of table grape farmers in the

Orange River. It is not uncommon to hear industry leaders and exporters talk about the "Sultana factor" which creates enormous challenges for crop estimates since it is unknown before the season how many farmers will convert from export to raisin grapes.

- One outcome of marketing risks that is extremely difficult to manage is its impact on the value of land. Since 2002, the observed market value of land has been reduced by more than 50%. Farms sold in excess of R150 000 per ha were auctioned for less than R70 000 per ha. The impact on financing should be obvious since financiers react to the observed value of land because their security is reduced. Farms that were solvent became insolvent over a short period just because of a property re-valuation. Analysis shows that the model results are consistent with what has been observed. The average capitalised marginal value of the land decreased from R204 000 per ha (Base) to R107 000 ha with a 20% reduction in the price of table grapes. One way of managing this risk is to ensure that financing decisions are very conservative and that more emphasis is placed on ability to pay than property value. Proper price and yield sensitivity analysis should accompany any application for production loans. In the opinion of the authors, banks have also been guilty in this regard. They should play an important role in reducing marketing risks by being more conservative and insisting on proper sensitivity analysis.
- Capitalised marginal water value decreases with a reduction in the price of table grapes. The results are consistent with the micro economic theory that demand for irrigation water is derived from the demand for irrigation crops. From a policy point of view, this result is important. The spirit of the new water act is to use water to its highest value. The indirect effect of inability to manage market risks is the creation of potential for inefficient water usage. It has been pointed out that it is extremely difficult to change the farm structure on a farm designed to produce table grapes. However, if the farms were designed to be more flexible in coping with marketing risks, they would have a greater ability to absorb them.
- It was also pointed out that a reduction in the cost structure of farms should be part of marketing risk management. On the one side, farmers and marketers should continuously strive to reduce production and supply chain costs. On the other hand, government should also play an important role in reducing the cost of doing business. For example, agricultural labour, land, and water policies should consider the risks involved in agriculture (variation in crop yield and price and natural disasters).

- The importance of training farmers in market analysis and market intelligence has been mentioned. A casual observation in the region is that many farmers still do not have adequate training to cope with the post-deregulation marketing environment, especially new, emerging and older farmers. The Department of Agriculture, in partnership with industry bodies, can play an extremely useful role in educating these farmers to cope with marketing risks.
- Finally, it was pointed out that although only one market risk scenario was illustrated in this chapter, the typical farm models can be extremely useful to test risk-aversion strategies for specific typical farms with different farm structures. Although it is possible to suggest general risk-aversion strategies, very specific strategies will have to be developed for different regions, farm structures and farm sizes.

The results of the regional model came to more or less the same conclusions as the table grape scenario plus the following additional conclusions:

- The overall conclusion regarding the regional model is that it is extremely useful for indicating the direction water will trade in, to remove inefficiencies from overall water allocations.
- By analysing scenarios with and without water trade, it is possible to theoretically identify regions with surplus water and inefficiencies in water allocations, on the one hand, and on the other hand to identify regions with water shortages.
- The analysis showed that approximately 10% of total water use right allocation in the Northern Cape was unused during 2002. Most of the unused water was in the Western regions below Boegoeberg. On the other hand, the analysis showed that there was a shortage of approximately 8 600 ha (77 million m³) in the Vaalharts region. It can therefore be concluded that farmers either extract more water than their allocation or do not irrigate optimally (sub-optimal irrigation). The authors believe that the latter is most probably the case since DWAF uses aerial photographs to identify these farmers, and the penalty for over abstraction is heavy.
- When the price of table grapes is reduced by 20% and structural change is impossible, the total net output of the Northern Cape is reduced by R6.33 billion over 20 years or R316.5 million per annum (this is the cumulative effect of a 20% reduction in the price of table grapes over 20 years). This figure gives an indication of the cost of "not knowing".

- The analysis also indicates that farmers who can make structural adjustments will adjust their farm structure to the reduction in the price of table grapes.
- When water trade is possible, it can contribute to reducing the impact slightly. However, the results indicate that there is no significant difference between scenarios where structural change is possible and the same scenarios but with water trade. The result is that inefficiencies will be removed from the system through a combination of structural changes and water re-allocation.
- When water trade is activated in the model, most trade is towards Vaalharts. This result can be explained by the calculations made to determine where water shortages exist. In general, water flows from regions of unused water to those where there is a shortage.
- It was also pointed out that the wheat/maize double cropping system needs between 9 150 and 15 000 m³ depending on cultivar (early/late). It is therefore obvious that it is not possible to do double cropping in a region where the average water use allocation is 9 000 m³ unless crops are irrigated sub-optimally.
- The reduction in the Net Farm Income per region is almost identical to that of the typical farm model for Augrabies/Blouputs. This is no surprise since the same data are used in each of the models.
- Significant structural changes are induced by a reduction in the price of table grapes. Although this is not shown in the results, most of the changes in long-term crops are towards olives, pecan nuts, citrus, and lucerne. This result is important since, similarly to the typical farm model, it emphasises the importance of a diverse farming structure to cope with market risks.
- It was also pointed out that the impacts of a long-term market trend (such as a reduction in the price of table grapes) pose serious long-term financial problems to farmers. Even if they want to make structural changes, their financial situation and reduced property value prevents them from obtaining finance to make these changes.
- The analysis also shows a substantial increase in land and water use in the Vaalharts region when trade is possible. Land use increases from 119% to 138% when calibration restrictions are released and water trade is possible. Overall water use efficiency increases since water can relocate from water surplus regions to water shortage regions.

- Crop water usage per ha is also an indication of water use efficiency. Although water markets induce an increase in total water usage, water requirements per ha decrease when water trade is activated.
- The results also show that crop water usage per ha increases when the price of table grapes is reduced, indicating that structural changes induced by reduction in the price of table grapes will not necessarily be more water efficient.
- An analysis of capitalised marginal water value reveals important information. The analysis clearly shows that water is generally traded towards the regions with the highest marginal water value, from the Western regions to the North Eastern regions.
- Although relatively large volumes of water trade over the 20-year planning horizon, less than 1% of the total annual water allocation is traded.

Water tariffs are a major issue for irrigation farmers and government. To gain some insight into the impact of water tariffs, several scenarios were analysed--with trade, without trade, and with reduced crop prices. These scenarios fall into the category of increasing input cost impact on farm profitability and the ability to absorb market risks. The following can be concluded from the analysis:

- Water tariff increases to the order of 100-200% have not been uncommon in the Northern Cape since 2002. The tariff for direct abstraction from the river, in particular, increased significantly.
- Water costs as percentage of total production cost vary from less than 1% for most long-term crops to between 5-12% for short-term crops. It is therefore obvious that increased production costs will impact more negatively on farm profitability in regions where most crops are short-term.
- The result indicates that without water trade, the impact of a 150% increase in water tariffs is the reduction of total irrigation farming value (objective function value) by about 3.4%. This amounts to a cumulative effect of R290 million in present value terms over the 20-year planning horizon.
- The analysis also indicates that water trade reduces the impact of an increasing water tariff to some extent since water is allocated more efficiently.
- When the price of table grapes is reduced by 20% and grain by 10% the results are significant since it is a fairly realistic scenario that has unfolded during the last few years. The results indicate that grain farmers can now not absorb more than a 110%

increase in water tariffs. However, at the same time it is pointed out that not all farms are in the same position. The impact on regions where long-term crops are produced is insignificant.

- The total Net Farm Income is reduced by 9.9% when crop prices are reduced and water tariffs increase by 110%.
- The results also indicate that structural changes are insignificant at base analysis crop prices when water tariffs are increased. However, when crop prices are reduced, significant structural changes take place. However, they are not induced by higher water tariffs, but by reduced crop prices.
- At a water tariff increase of 250%, the total water usage only declines by approximately 6.8%. This result is consistent with results from other studies that indicate a very inelastic water demand function for agriculture and specifically for long-term crops.
- Also, the result indicates that when crop prices are reduced and water tariffs are increasing, the net result will not necessarily be a reduction in total water usage since farmers will make structural changes and the new structures may use more water.
- Both the results in the previous two bullets are important from a water demand management point of view. They indicate that water tariffs in agriculture are not necessarily an efficient tool to induce more efficient water use. There are other, market-related factors that carry more weight when farmers make crops production decisions.
- In general, capitalised marginal water value increases in all regions as water tariffs are increased. This result is even clearer when water trade is activated. Table 7.51 shows huge increases in marginal water value, especially when water tariffs are increased by more than 150%. The explanation for this result is that increased water tariffs raise water scarcity value.
- The water trade results are similar to the table grape scenarios. Water flows mainly to the Vaalharts region. The result also indicates that more water will trade at higher water tariffs. Also, the results indicate that when crop prices are reduced, there will be a reduction in water trade compared to a scenario with the same water tariff but base crop prices.
- The results also indicate that when both crop prices are reduced and water tariffs are increased, trade increases substantially, from about 6.8 million m³ to approximately 22 million m³. This result is important since it shows that reduced crop prices

increase the sensitivity of farms to increasing water tariffs. The result of these scenarios also shows that the water market becomes more active. Although the total volume of trade towards Vaalharts increases (139 million m³ compared to 104.9 million m³ in BaseC), the relative contribution to total trade decreases. The reason for this (although it is not shown in the analysis) is a significant increase in crops such as citrus, pecan nuts and olives.

The scenario results illustrated the extremely useful role that models can play in farm planning and the formulation of agricultural policies. The chapter also attempted to point out the interaction between the CGE model, farm models, and the regional model. Although it could have added value to analyse several more scenarios, the authors believe that these should be dealt with in a technology transfer project where specific scenarios can be analysed in detail in collaboration with the various stakeholders and the results transferred to all relevant stakeholders.

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

8.1 INTRODUCTION

This study focused on quantifying market risk impact on efficient irrigation water use and determining the multiplier effects of irrigation accompanied by a shift in production patterns with reference to the middle and lower Orange River on the total economy of the Northern Cape. It was pointed out in this report that the study was extended to include parts of the Vaalharts irrigation scheme and borehole irrigation to enable the modelling framework to simulate the total contribution of irrigation agriculture in the Northern Cape.

Project sub-objectives (not necessarily in the sequence in which they were addressed) were:

- To identify and quantify risk factors in irrigation agriculture.
- To develop a decision-making framework which farmers can use to reduce their risk.
- To compare present water use practices with optimal risk-reducing practices and to find reasons for deviations from the optimal.

This volume of the report only addressed sub-objective 1-3. The other sub-objectives were covered in Volume 2. They are:

- To identify and quantify the relevant products and economic sectors in the Northern Cape economy.
- To make distinguish between irrigation and non-irrigation agricultural sectors.
- To derive the relevant coefficients for the Northern Cape from the national input-output model by using the product balance approach.
- To develop a policy framework on effective water management for regions where irrigation agriculture makes a major contribution to the economy.

This chapter involves a summary and conclusion of the most important findings of this study and recommendations for further actions and research.

8.2 SUMMARY OF FINDINGS AND CONCLUSIONS

All the objectives of this project were reached and more. Instead of just simulating the middle and lower Orange River, the Vaalharts region and irrigation from boreholes were also included. The most important findings are summarised in three sections: literature review, the development of a decision-making framework and finally a comparison of present water use practices with optimal risk reducing practices.

8.2.1 Literature review

- a) The various types of market risk are price, gross margin, cash flow, and financial risk. By not hedging, a producer is exposed to all these risks.
- b) The size of the actual investment in inputs and capital all increase the risk to the producer.
- c) Changes in both support programs and the nature of agricultural markets have forced producers to become more self-reliant in the area of risk management. Risk management is relevant for most operations as a way of limiting risk in terms of price, gross margin, cash flow, and financial stability. It is a means of maintaining farm viability and protecting existing levels of equity.
- d) The literature review in this chapter is important to understand the context in which the modelling framework was developed. It was pointed out that during recent years, the marketing environment has become more risky and more volatile, both in terms of operational and strategic risks.
- e) The literature review highlighted the importance of external help / tools that producers and other decision makers should use in developing risk management strategies. It is therefore important to know what tools are available, the advantages and disadvantages of each tool, and how they can be used individually or together to manage risk. This will help producers to become more effective managers and allow them to continue to be competitive in the global marketplace.
- f) The principal purpose of risk-return analysis lies in ranking alternative farm plans on the basis of risk and examining trade-offs between risk and mean income.

However, analysing trade-offs between risk (defined as deviations from mean income) and mean income is subject to question, since risk is not expressed in a pure sense; i.e. such a risk expression is not independent of but rather dependent on mean income. Furthermore, in most cases, the only possible way to reduce (or eliminate) risk in MOTAD (and quadratic programming) is to reduce (or eliminate) income. Yet, from a practical standpoint, it is not higher income per se that poses a threat. On the contrary, it is low income, yielding negative deviations from a fixed level of acceptable target income. While it seems perfectly normal to penalize negative deviations as a source of risk, it is very difficult to view positive deviations as a genuine source of risk. That is, do rational producers really attach as much dis-utility to high-income years as they do to low-income years? If not, the Target MOTAD model appears to be a more plausible approach for examining risk-return trade offs and is also more consistent with risk literature (Watts et al., 1984). Finally, Grove (2005) pointed out that special additions to the methodology are necessary to use Motad methodology in multi-period models.

- g) The DLP technique has been extensively used in other countries, especially the USA and Europe, and, as already mentioned, SA. Any attempt to simulate the farm system should at least include the objectives of the farm unit, the resources available to reach these objectives, and alternative activities to reach them. It is an extremely useful tool to analyse "what if" questions.
- h) Risk management in agriculture has become an important part of the management function for primary producers, industry bodies, and government alike.
- i) Analytical tools as part of a framework to aid decision makers in formulating risk management strategies can be extremely useful.
- j) However, decision makers will only use these analytical tools if the value of these tools can be proven to make better decisions.
- k) Water allocation and water use efficiency are important components of the New Water Act (1998). It is therefore of paramount importance to consider the impact of market risk on efficient water allocation and water use efficiency.

8.2.2 Development of a decision-making framework

The first step in the development of a decision-making framework is to describe the system. In this study, the system is irrigation agriculture in the Northern Cape. The second

step is to develop a modelling framework to enable decision makers to get a better understanding of how the system reacts to impulses (negative or positive) from the outside (the environment). In this study, the impulses are those with a direct or indirect link to the market risks discussed in the previous section and specifically those that will be discussed in the following section. The following is a brief summary of the conclusions:

- a) The almost 143 000 ha of irrigation land (water use entitlement) makes a substantial contribution to the Northern Cape economy in terms of forward and backward economic multipliers. Volume 2 of this report gives a detailed description of the contribution of agriculture.
- b) Irrigation agriculture is also regarded as an important vehicle for the redistribution of wealth through several development projects which are either already in operation or in the planning phase.
- c) Therefore it is of paramount importance that decision makers make objective decisions to ensure that water is allocated efficiently to ensure a maximum contribution to economic growth. Water should be used in its highest value.
- d) It was already pointed out that models can be extremely useful tools in a decision-making framework to assist in making more objective decisions.
- e) It was also pointed out that market risk can result in inefficient water use if not managed properly.
- f) The objective of developing the decision-making framework in this study was to model all the irrigation regions in the Northern Cape to capture total current and potential future agricultural production. This is necessary to capture total irrigation water usage and total output from irrigation agriculture with the view of linking the output from the micro models to that of the macro model and vice-versa.
- g) It is necessary to divide the region into regions that make sense and are practical from a modelling viewpoint. The first logical division of the irrigation regions would have been the areas of the Water User Associations (WUA's). However, there is still a lot of uncertainty regarding the geographical areas of the WUA's, so it was decided to consider other practical considerations such as crop combinations and stretches of the river.
- h) Since there is a lot of uncertainty regarding the 4 000 ha allocated for development projects, it was decided to treat this area as part of the total water allocation for the Northern Cape. Theoretical land use for this area is therefore considered to be the

average current land use. However, this area can very easily be deducted for specific development projects which can be analysed as specific projects within the modelling framework as more information becomes available.

- i) The area below Blouputs is a long stretch of the Orange River and only contributes approximately 3.33 percent (4 471 ha) of total current water use entitlement. It was therefore considered that doing a survey in this region will not add value to the outcome of the modelling exercise.
- j) The description of the region in chapter 3 enabled the researchers to demarcate the total irrigation into 7 modelling regions. A farm survey of the regions revealed major differences in farm structure and economies of scale for the North East, Middle, and Western parts of the Vaal, Riet, and Orange River. From the farm survey data, 22 typical farms were developed to be included in the decision-making framework. There is a large variance between the typical farms and the regions in terms of farm structure, labour use per ha, and the ratio between canal abstraction and abstraction directly from the river. This is important to understand the results of the models since it will determine the reaction of each typical farm to changes in parameters when scenarios are analysed. Different typical farms will react differently when the same parameters are changed because of economies of scale, farm structure, water usage, etc.
- k) It is therefore possible to develop risk-reducing strategies for different farms in different regions.
- l) The North Eastern regions contribute approximately 60%, the middle 8.4%, and the Western regions 42% to total irrigation water use entitlements. In general, the Eastern regions produce higher valued crops than the North Eastern regions.
- m) Aggregation factors are used to aggregate the typical farms, first to the total for the sub-region and then to the total for the Northern Cape. A lack of information on total production for individual crops necessitates estimates based on farm survey data and total irrigation water use entitlements for the Northern Cape. It was pointed out that it is quite possible for the actual irrigated area to be over-estimated in this way since several crops use more water than the water allocation per ha. On the other hand, more crops use less water than the water allocation per ha.
- n) Since water is probably the most important input in irrigation farming, crop water requirements do have a major impact on modelling results. The demand for irrigation is derived from the demand / profitability of irrigation crops. Therefore,

if market risks are high and profitability is low, the demand for water will decrease for certain crops. In any event, there will be "winners" and "losers" since not all crops are necessarily affected at the same time by the same market impacts.

- o) The importance of the livestock industry in the Northern Cape and the link to irrigation farming were pointed out.
- p) The choice of interest rates and discount rates in this study is not really important since they are parameters that can easily be changed.
- q) It was also pointed out that the maximum amount of short-term loans specified is also not that important since the models are structured in such a way that the typical farms will never borrow more than what is absolutely necessary and can be repaid within one year.
- r) Finally, modellers often say "Garbage in, Garbage out". This saying is of course the essence of any decision-making framework, especially on the scale of the modelling exercise that was conducted in this study. However, the research team discussed the data used in this study on numerous occasions with several stakeholders and are convinced that it is the best information available at present. This does not imply that there is no scope for improvement as new information becomes available.

In the second step of the development of a decision-making framework to analyse market risk, a market study was done to identify market risk factors for the most important crops grown in the Northern Cape. This effort is of paramount importance and should not be regarded as a once-off exercise. The market analysis in chapter 5 is for 2002/2003 and the update in Appendix A for 2006. However, they should be regarded as examples of analysis to be included in a decision-making framework. The following is a summary of the conclusions from this exercise:

- a) It was pointed out that there are two main categories of risk: operational risks and strategic risks.
- b) Operational risks refer to the risks of doing things wrong and strategic risks to the risk of doing the wrong things.
- c) Market risks can fall in both categories. For example, an operational market risk may be the risk of exporting fruit through unreliable exporters whereas a strategic marketing risk may be the risk of exporting fruit to the wrong market or, from an

industry point of view, uncoordinated uncontrolled expansion of production. In the latter case, the risk is that supply will outgrow demand in the long run.

- d) It is clear from the analysis that there are direct and indirect operational and strategic market risks for all the crops that were analysed.
- e) Some of the market risks can be regarded as generic for all crops (e.g. exchange rate fluctuations and tariffs) and others are crop specific (e.g. competition for South African table grapes from other Southern Hemisphere countries).
- f) Some of the generic marketing risks that were highlighted are:

- Price pressure
- Lack of support from government to develop new markets
- Tariffs - uneven playing field
- Lack of cooperation between farmers
- Input providers get tariff support, there should be export incentives
- Loss in governments capacity to negotiate trade agreements
- Lack of market Information
- Unstable prices
- Stagnation in traditional uses
- World oversupply
- Stricter demands from buyers - Eurepgap
- Lack of reliable, accurate and affordable market information
- Need to develop niche markets
- Profits of the middle man too high - does not share the risks
- Need to develop the local market
- Exchange rate fluctuations

- g) Some of the indirect risks identified are:

- High input costs
- Collapsing infrastructure
- Input providers get tariff support; there should be export incentives
- Risk of not being able to meet transformation targets
- Local industry not well organised

- High taxes
 - Monopolistic input providers
 - Not enough cultivars
 - Need for more collaboration between emerging and commercial farmers
 - Not enough technical support
 - Research
 - Land tax
 - Capital gain tax
 - Minimum wages
 - Land reform
 - Old vines, reduced profitability
 - Climate variation - low yield
 - Fragmentation of the industry - more packers and competition
 - Labour problems: HIV
 - Farm safety
 - Increasing skew playing field
 - Low labour productivity
 - Reduced land values
 - Risk of flaws in quality control - need to increase standards
 - Need for better planning - farmers do not do sensitivity analysis
 - Share of technical experience is essential
 - Economies of scale constantly under threat
 - Lack of effective collaboration between farmers
- h) Finally there are crop-specific risks. Table grapes, for example, face increasing competition from Brazil and Chile in the UK and European markets, and there is a risk that they will not be able to move more fruit to China to normalise the UK and Europe market in the medium term. For another example, grain prices in South Africa largely depend on the production of the USA.

In the third step of the decision-making framework, the typical farm model and the regional model were developed. The following can be concluded from the modelling exercise:

- i) The development of any modelling structure is a dynamic process. There is always scope for improvement as the computational capacity of computers increases and new information and techniques become available.
- j) The models that were developed will add tremendous value to improve decision-making at policy and farm level.
- k) The models have been tested (with the consent of the WRC) on at least four case studies (three on the affordability of irrigation water and one on the impact of minimum wages and land tax on farm profitability) in the region and have proven to be extremely valuable (Louw, 2001a; Louw, 2001b; Louw, 2002; Louw, 2003).
- l) Several tests were executed to test the models for validity including a simple spreadsheet formulation, which was calculated manually to replicate the model results. The authors are therefore convinced that the models are both mathematically correct and produce valid results.
- m) The models were developed in GAMS and are solved with the CPLEX solver. The model output for different scenarios is transformed from a "text" format into an Excel spreadsheet for additional calculations to present results in a user-friendly format. The GAMS code that generates the report ("text" files) was written in such a way that all the files for every scenario are exactly the same when they are transformed into Excel spreadsheet files. Scenario results can therefore be compared without difficulty even when crop combinations and other activities change from one scenario to another.
- n) The model structure is efficient since all the data files are linked to one worksheet which is compatible with GAMS. The data to run the models can therefore easily be updated. However, it is not necessary to change anything in the "master" data file to run scenarios since the GAMS code in the models was written in such a way that parameters can be changed in the code (for example, relative increases in market prices or water tariffs) without changing anything in the "master" data file.
- o) A defensible theoretical structure was developed to examine data intuitively and to permit comprehensive evaluation. In Chapter 7, the theoretical structured models were used to illustrate the capacity of these models to analyse the impact of market risk on efficient water use and show the link between the regional model and the CGE model (volume 2).

8.2.3 Comparison of present water use practices with optimal risk-reducing practices

The most important findings for this sub-objective are discussed in three sections: typical farm model table grape scenarios, regional model table grapes scenarios, and regional model water tariff scenarios.

8.2.3.1 Typical farm table grape scenario

The following is a summary of the main findings and conclusions from the typical farm model table grape scenario results:

- The result of the CGE model corresponds with the observed reduction in table grape prices in the Orange River. The CGE model calculated that the local farm level price (Delivered in Port) would decrease by 22% if the international price of fruit is reduced by 20%. It was pointed out in table 7.1 that the observed reduction is 22.75%.
- The typical farm model scenarios showed that a decrease of 20% in the price of table grapes reduced the return on capital investment from 37.4% in the base to around 18.5% (reduction of more than 50% in Net Farm Income). This represents a huge decrease in profitability. It is also important to note that a 20% reduction in the price of table grapes is an average in reduction. There is substantial variation between the prices farmers actually receive since they depend on the markets where farmers sell their fruit and on the cost structure of the exporter.
- The results also clearly indicated that a more diverse farming structure is a key strategy to reduce marketing risks. The result shows that optimum farm structure after a reduction in the price of table grapes is different to observed farm structure. If farmers had better marketing information and the skills to interpret this information, they would have taken other production decisions. A more diversified farm structure enables farmers to absorb market failures more efficiently than a specialised farm structure.
- A huge increase in the price of raisins does not necessarily combat the reduction in table grapes. Since Sultana grapes are more flexible than other table grapes, the results indicate that farmers do alternate between grapes for exports and grapes for

raisins when the price of table grapes is reduced. It is of course not an optimum market risk reduction strategy since farmers need to produce what the market wants. What the market wants changes over time, and it will therefore not be feasible to produce Sultanias only. However, since Sultanias represent approximately 45% of the total table grape crop mix, they form part of the risk reduction strategy to some extent. The result also corresponds with the observed reaction of table grape farmers in the Orange River.

- The impact of marketing risks on the value of land is extremely difficult to manage. A casual observation is that since 2002, the observed market value of land has been reduced by more than 50%. Farms sold in excess of R150 000 per ha were auctioned for less than R70 000 per ha. The impact on financing should be obvious since financiers react to the observed value of land because their security is reduced. Farms that were solvent became insolvent over a short period just because of a re-valuation of the property. The analysis shows that the model results are consistent with what have been observed. The average capitalised marginal value of the land decreased from R204 000 per ha (Base) to R107 000 ha with a 20% reduction in the price of table grapes. One way of managing this risk is to ensure that financing decisions are very conservative and ability to pay is emphasized more than the value of the property. Proper price and yield sensitivity analysis should accompany any application for production loans. In the opinion of the authors, banks have also been guilty in this regard. They should play an important role in reducing marketing risks by being more conservative and insisting on proper sensitivity analysis.
- The capitalised marginal value of water decreases with a reduction in the price of table grapes. The results are consistent with the micro economic theory that demand for irrigation water is derived from demand for irrigation crops. From a policy point of view, this result is important. The spirit of the New Water Act (1998) is to use water in its highest value. The indirect effect of inability to manage market risks is that it creates a potential for inefficient water usage. It was pointed out that it is extremely difficult to change the farm structure on a farm designed to produce table grapes. However, if farms were designed to be more flexible to cope with marketing risks, they would have a greater ability to absorb marketing risks.
- Finally, it was pointed out that although only one market risk scenario was illustrated in this study, typical farm models can be extremely useful to test risk-aversion strategies for specific typical farms with different farm structures. Although it is

possible to suggest general risk-aversion strategies, very specific strategies will have to be developed for different regions, farm structures, and farm sizes.

8.2.3.2 Regional model table grape scenario

The results of the regional model came to more or less the same conclusions with the table grape scenario plus the following additional conclusions:

- The overall conclusion regarding the regional model is that it is extremely useful to indicate in which direction water will trade to remove inefficiencies from the overall water allocations.
- By analysing scenarios with and without water trade, it is possible to theoretically identify regions with surplus water and inefficiencies in water allocations on the one hand and, on the other hand, regions with water shortages.
- The analysis showed that approximately 10% of total water use right allocation in the Northern Cape was unused during 2002. Most of the unused water was in the Western regions below Boegoeberg. On the other hand, analysis showed that there was a shortage of approximately 8 600 ha (77 million m³) in the Vaalharts region. It can therefore be concluded that farmers either extract more water than their allocation or they do not irrigate optimally (sub-optimal irrigation). The authors believe that the latter is most probably the case since DWAF uses aerial photographs to identify these farmers and the penalty for over abstraction is heavy.
- When the price of table grapes is reduced by 20% and structural changes cannot be made, the total net output of the Northern Cape is reduced by R6.33 billion over 20 years or R316.5 million per annum (this is the cumulative effect of a reduction of 20% in the price of table grapes over 20 years). This figure gives an indication of the cost of "not knowing".
- The analysis also indicates that if farmers can make structural adjustments, they will change their farm structure to adjust to the reduction in the price of table grapes.
- When water trade is possible, trade can contribute to reducing the impact slightly. However, the results indicate that there is no significant difference between scenarios where structural change is possible and the same scenarios but with water trade. This means that inefficiencies will be removed from the system through a combination of structural changes and re-allocation of water.

- When water trade is activated in the model, most of the trade is towards Vaalharts. This result can be explained by the calculations made to determine where water shortages exist. In general, water flows from regions with unused water to those with a shortage.
- It was also pointed out that the wheat/maize double cropping system needs between 9 150 and 15 000 m³, depending on cultivar (early/late). It is therefore obvious that double cropping cannot be done in a region where the average water use allocation is 9 000 m³ unless crops are irrigated sub-optimally.
- The reduction in the Net Farm Income per region is almost identical to that of the typical farm model for Augrabies/Blouputs. This is no surprise since the same data are used in each of the models.
- Significant structural changes are induced by a reduction in the price of table grapes. Although this is not shown in the results, most of the changes in long-term crops are towards olives, pecan nuts, citrus, and lucerne. This result is important since, similar to the typical farm model, it emphasises the importance of a diverse farming structure to cope with market risks.
- It was also pointed out that the impacts of a long-term market trend (such as the reduction in the price of table grapes) pose serious long-term financial problems to farmers. Even if they want to make structural changes, their financial situation and the reduction of the value of their properties prevents them from obtaining finance to make these changes.
- The analysis also shows that a substantial increase in land and water use in the Vaalharts region when trade is possible. Land use increases from 119% to 138% when the calibration restrictions are released and water trade is possible. Overall water use efficiency increases since water can be relocated from water surplus regions to water shortage regions.
- The crop water usage per ha is also an indication of water use efficiency. Although water markets induce an increase in total water usage, water requirements per ha decrease when water trade is activated.
- The results also show that crop water usage per ha increases when the price of table grapes is reduced. This result indicates that the structural changes induced by the reduction in the price of table grapes will not necessarily be more water use efficient.
- An analysis of capitalised marginal water value reveals important information. The analysis clearly shows that water is generally traded towards the regions with the

highest marginal value for water, i.e. from the Western regions to the North Eastern regions.

- Although relatively large volumes of water are traded over the 20-year planning horizon, less than 1% of the total annual water allocation is traded.

8.2.3.3 Regional model water tariff scenario

Water tariffs are a major issue for irrigation farmers and for government. To get some insight on the impact of water tariffs several scenarios - with trade, without trade, and where crop prices are reduced - were analysed. These scenarios falls into the category of the impact of increasing input cost on farm profitability and also on the ability to absorb market risks. The following can be concluded from the analysis:

- Water tariff increases since 2002 to the order of 100-300% are not uncommon in the Northern Cape. Especially the tariff for direct abstraction from the river increased significantly.
- Water costs as a percentage of total production cost varies from less than 1% for most long-term crops to 5-12% for short-term crops. It is therefore obvious that increased production costs will impact more negatively on farm profitability in regions where the majority of crops are short-term.
- The result indicates that without water trade, the impact of a 150% increase in water tariffs is the reduction in total irrigation farming value (objective function value) by about 3.4%. This amounts to a cumulative effect of R290 million in present value terms over the 20-year planning horizon.
- The analysis also indicates that water trade reduces the impact of an increasing water tariff to some extent since water is allocated more efficiently.
- When the price of table grapes is reduced by 20% and grain by 10%, the results are significant since it is a fairly realistic scenario that has unfolded during the last few years. The results indicate that grain farmers cannot absorb more than a 110% increase in water tariffs. However, at the same time, it is also pointed out that not all farms are in the same position. The impact on regions where long-term crops are produced is insignificant.
- The total Net Farm Income is reduced by 9.9% when crop prices are reduced and water tariffs increases by 110%.

- The results also indicate that structural changes are insignificant at the base analysis crop prices when water tariffs are increased. However, when crop prices are reduced, significant structural changes take place, although they are not induced by the higher water tariffs but by the reduction in crop prices.
- At a water tariff increase of 250%, total water usage only declines by approximately 6.8%. This result is consistent with the results of other studies that indicated a very inelastic water demand function for agriculture and specifically for long-term crops.
- Also, the result indicates that when crop prices are reduced and water tariffs are increasing, the net result will not necessarily be a reduction in total water usage since farmers will make structural changes and the new structure may use more water.
- Both the results in the previous two bullets are important from a water demand management point of view. They indicate that water tariffs in agriculture are not necessarily an efficient tool to induce more efficient water use. There are other, market-related factors that carry more weight when farmers make crops production decisions.
- In general, capitalised marginal water value increases in all regions as water tariffs are increased. This result is even clearer when water trade is activated. Table 7.51 shows huge increases in marginal water value, especially when water tariffs are increased by more than 150%. The explanation for this result is that an increase in water tariffs increases the scarcity value of the water.
- The water trade results are similar to the table grape scenarios. Water flows mainly to the Vaalharts region. The result also indicates that more water will trade at higher water tariffs. Also, the results indicate that when crop prices are reduced, there will be a greater reduction in water trade than in a scenario with the same water tariff but base crop prices.
- The results also indicate that when both crop prices are reduced and water tariffs are increased, water trade increases substantially from about 6.8 million m³ to approximately 22 million m³. This result is important since it shows that the reduction in crop prices increases the sensitivity of farms to increasing water tariffs. The result of these scenarios also shows that the water market becomes more active. Although the total volume of trade towards Vaalharts increases (139 million m³ than 104.9 million m³ in BaseC), the relative contribution to total trade decreases. The reason for this (although it is not shown in the analysis) is a significant increase in crops such as citrus, pecan nuts and olives.

The scenario results illustrated the extremely useful role that models can play in farm planning and agricultural policy formulation. The study also illustrated the interaction between the CGE model, farm models, and the regional model. Although it could have added value to analyse several more scenarios, the authors believe that these should be dealt with in a technology transfers project where specific scenarios can be analysed in detail in collaboration with the various stakeholders and the results transferred to all relevant stakeholders.

8.3 *RECOMMENDATIONS*

The following recommendations are a logical outflow from the findings and conclusions:

- The first overall recommendation is that a Technology Transfer Project (TTP) should be formulated and funded by the Water Research Commission. The authors believe that the effort to develop the analytical tools used in this study will all be in vain if there is no effort to implement them in the Northern Cape. Within the scope of this report, it was impossible to analyse and make recommendations regarding all potential risks for irrigation farmers. A technology transfer project can address several more scenarios and be used to refine existing scenarios even more.
- Flowing from this, it was proposed that a Northern Cape Agricultural Risk Management Policy Framework (ARMPF) should be developed and that Marketing Risk Management Forums (MRMF) be established on different levels to discuss marketing risks and develop strategies to manage them. The analytical framework developed in this study can play an extremely useful role in analysing these risks. It is also proposed that innovative ways be found during the proposed TTP to fund these forums. There are several possibilities, for example, funding them through statutory funds such as the WRC levy or through a partnership between government agencies such as the NAMC, industry organisations such as the DFPT and Grain SA, and the financial institutions (see Volume 2).
- The MRMFs should be constituted in such a way that knowledgeable industry representative, financiers, marketing experts, and other experts in the supply chain be represented in order to really make a difference (see Volume 2).

- It was also pointed out that marketing information is the key to managing marketing risks. In this regard, industry organisations such as the Deciduous Fruit Producers Trust and the so-called Joint Marketing Forums (JMF's) should play an important role. In the JMF's, producers and exporters collaborate to share supply (crop estimates, fruit intake, and shipments) and demand (Southern Hemisphere shipments and price information for alternative markets) information. The grain industry and other commodities already have industry organisations and make marketing information available. However, it is proposed that there should be more emphasis on market risk management.
- Timely and accurate crop estimate, crop intake and shipment information, the availability of accurate market compliance information, and price information are obviously the keys to the efficiency of marketing decisions. In this regard, government can play an important role in partnerships with industry organisations to develop information systems to improve the accuracy and timeliness of information, thereby creating an environment where the private sector can take advantage of marketing opportunities and reduce marketing risks. In this regard, the proposed MRMFs could be an important communication vehicle where market data and information are collated, interpreted, and transformed into messages that could be communicated to irrigation farmers.
- The results also clearly indicated that a more diverse farming structure is a key strategy to reduce marketing risks. In this regard there should be a continuous research effort to find alternative crops for the irrigation regions of the Northern Cape.
- One way of managing this risk is to ensure that financing decisions are very conservative and that ability to pay is emphasised more than property value. A proper price and yield sensitivity analysis should accompany any application for production loans. In the opinion of the authors, the major financial institutions have also been guilty in this regard. They should play an important role in reducing marketing risks by being more conservative and by insisting on proper sensitivity analysis. They should also be actively involved in the proposed MRMFs.
- The spirit of the New Water Act (1998) is to use water to its highest value. The indirect effect of inability to manage market risks is that it creates a potential for inefficient water use. Since efficient water allocation and water use is a national

issue, there is a good argument for government to support innovative ways of reducing market risks.

- It was also pointed out that a reduction in the cost structure of farms should be part of marketing risk management. On the one hand, farmers and marketers should continuously strive to reduce production and supply chain costs. On the other hand, government should also play an important role in reducing the cost of doing business. For example, agricultural labour, land, and water policies should consider the risks involved in agriculture (variation in crop yield and price and natural disasters). The proposed MRMF can potentially also make a important input in the formulation of agricultural policies, even if it is just to make policy makers aware of the importance of a low cost supply chain as a strategy to cope with market risk.
- The importance of training farmers in market analysis and market intelligence was pointed out. A casual observation in the region is that there are still many farmers that do not have adequate training to cope with the new marketing environment after deregulation. Especially new, emerging, and older farmers that fall into this category. The Department of Agriculture, in partnership with industry bodies, can play an extremely useful role in educating these farmers to cope with marketing risks. There is also a need to train farmers in whole farm planning and in methodologies to analyse alternative crops and how to introduce them in an existing farm structure.
- By keeping transaction costs low, an active water market should be encouraged. When water trade is possible, it can contribute to reducing the impact of market risks in the long run since it will encourage the relocation of water. However, the results indicate that there is no significant difference between the scenarios where structural change is possible and the same scenarios but with water trade. Therefore inefficiencies will be removed from the system through a combination of structural changes (induced by better market information) and the re-allocation of water.
- The results indicated that high water tariffs in agriculture are not necessarily an efficient tool to induce more efficient water use. There are other, market-related factors that carry more weight when farmers make crop-production decisions. Therefore, the conclusion is that an effort in providing farmers with better market information will better increase the efficiency of water allocation and water use.
- Terms of reference for the TTP should be developed in close collaboration with all stakeholders in agriculture in the Northern Cape. As a minimum, it is proposed that the TTP provide at least for the following:

- The establishment of MRMFs (even if it is just a pilot project) for at least grain and fruit. After the establishment of the MRMFs, it is proposed that the TTP team go through an intensive exercise with these forums to run scenarios that they identify as critical for their industries.
 - An intensive model implementation exercise with the Department of Agriculture of the Northern Cape. In this exercise they should be asked to identify the issues that they would want to analyse and choose, for example, the top three.
 - A similar modelling exercise with the Department of Water Affairs and Forestry.
 - A similar exercise with organised agriculture
- Finally it is recommended that one of the first actions of the proposed TTP should be to inform decision makers at all levels about the extremely useful role that models can play in farm planning and the formulation of agricultural policies. There should also an effort to point out the interaction between the CGE model, the farm models, and the regional model.

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Effective local management of water resources with reference to the middle Orange river.

Viljoen MF; Dudley NJ; Gakpo EFY; Mahlaha JM

A computer-based decision-support model according to the institutional arrangement of capacity sharing, is available for application in off-stream and instream water use management under conditions of uncertainty. This project evaluates the usefulness of this innovative approach under South African circumstances. This must be done within the context of the National Water Act, information requirements on the quantity and quality of water available, levying of water user charges in relation to water values for different uses and regulations for the performance of functions by the to-be-established WUAs. It is envisaged that the model will provide an appropriate tool for water management by irrigation farmers and other water users.

Report Number: 1134/1/04

ISBN No: 1 77005 279 8

Multi-dimensional models for the sustainable management of water quantity and quality in the Orange-Vaal-Riet convergence system.

Viljoen MF; Armour RJ; Oberholzer JL; Grosskopf M; Van der Merwe B; Pienaar P

Salinisation of various irrigation schemes has become a problem in South Africa. One such area that experiences salinisation problems is the Lower Vaal and Lower Riet irrigation areas, upstream from where these rivers converge and flow into the Orange River. From a total irrigation area of 12 556 ha in the Orange-Vaal Water Users Association, 23 % is either slightly or severely affected by salinity problems.

From various management options, drainage installation and consequent leaching is a better option financially, environmentally and socially than changing to more salt tolerant crops at farm, WUA and regional level. At regional level the direct and indirect benefits of modelled improved drainage (and subsequent investment in higher value crops) proved far greater than the costs of drainage, and produced the highest index for socio-economic welfare (ISEW), and an addition of jobs to the irrigation and linked industries over the long term. The total real cumulative cost (2005 basis) of salinisation over a period of 15 years for the whole study area was calculated at R955 million, a good benchmark to use to leverage funds for remediation action.

This above mentioned finding presents an overwhelming case for the full sustainability ("green box") grant assistance of additional irrigation drainage in the interest of increased sustainable regional socio-economic welfare. The main recommendations of this research project is that drainage installation for facilitation of leaching, needs to be promoted in the Orange-Vaal WUA and especially in the Lower Riet Irrigation Blocks in the study area.

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