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 km^2) of the total area (1 219 090 km^2) 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 those 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 multiplies (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 financers 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 m^3) 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 m^3 depending on cultivar (early/late). It is therefore obvious that in a region where the average water-use allocation is 9 000 m^3, 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 (Volume 1) 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 m^3 to approximately 22 million m^3. 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 m^3 compared to 104.9 million m^3 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 (labelled 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 loss 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, financers, 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.

- 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 an 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 Department of Water Affairs and Forestry (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 determent 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.