# The value of irrigation information for decision-makers with neutral and non-neutral risk preferences under conditions of unlimited and limited water supply

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## Abstract

The purpose of this article is to determine the amount that could be paid by irrigation farmers in the Winterton area with non-neutral risk preferences for more sophisticated information on soil water, plant growth and the weather. The maximum amount irrigation farmers with unlimited irrigation water supply on Hutton soil could pay for the highest level of information varied between R136/ha and R330/ha depending on their risk preferences. The value of information increased by at least 49% when irrigation water became limited. It is clear that information is a partial substitute for soil quality in terms of plant-extractable soil water and the availability of irrigation water.

## Introduction

The scheduling of irrigation water in the Winterton area is important to both farmers and irrigation boards. Frequent irrigation water shortages occur, because of an over-utilisation of water resources in the area. An irrigation scheduling service which provides highly sophisticated irrigation information was introduced in the research area in an attempt to increase irrigation efficiency. Bosch et al. (1987) noted that better information about the crop and its environment has potential to help irrigation farmers in improving the economic efficiency of water and energy use. However, irrigation farmers are still using a wide range of irrigation scheduling strategies which differ in terms of the type and amount of soil water, plant growth and weather information used.

Irrigation farmers are hesitant to use more sophisticated irrigation scheduling information, because of uncertainties about the economic value of better irrigation information, especially if the availability of irrigation water is uncertain. Farmers, farm advisers and research institutions need to know the returns from better irrigation information in order to evaluate scheduling services and/or to determine whether public expenditure on information systems should be increased (Bosch and Lee, 1988). This study expands on previous work by using a comprehensive dynamic approach to value irrigation information for decision-makers with different risk preferences under conditions of limited irrigation water.

A previous study (Botes et al., 1994b) presented a model using simulation and optimisation to value information for irrigation scheduling with neutral risk preferences. A study by Botes et al. (1994a) revealed that attitudes towards risk vary considerably about risk neutrality. This study examines the question of how varying risk attitudes affect the value of information.

The objectives of this study are the following:

- To determine how much irrigators with non-neutral risk preferences can pay to obtain more sophisticated information on soil water, plant growth and the weather under conditions of unlimited and limited water supply.
- To determine the extent to which factors such as the availability of irrigation water and the quantity of plant extractable soil water (PESW) influence the value of irrigation information for decision-makers with non-neutral risk preferences.
- To establish the extent to which changes in the absolute risk aversion coefficients (RAC) affect the value of irrigation information.
- To evaluate the effect of perfectly negatively correlated yields and product prices on the value of information.

## Conceptual model

### Calculating the value of information for risk-neutral decision-makers

It is assumed that risk-neutral decision-makers maximise expected profits. Profit $\pi$ is given by a profit function, $\pi(x,\theta)$, where x is inputs into the decision process and $\theta$ is a probability distribution function of stochastic variables (Byerlee and Anderson, 1982). Information on $\theta$ will affect the decision inputs (x), and consequently result in a change in $\pi(x,\theta)$.

A decision-maker that uses little or no information will select decision variables in such a manner that expected profits from using the no-information strategy are maximised. Mathematically this is equivalent to:

$$\text{Max } E[\pi(x,\theta)] = \int_\theta \pi(x^*,\theta)p(\theta)d(\theta) \quad (1)$$

where $x^*$ is the set of decision variables which maximises expected profits, and $p(\theta)$ is the probability distribution function of stochastic variables from using the no-information strategy (calculation procedures are in part adopted from Mazzocco et al. (1992) and Byerlee and Anderson (1982)).

More sophisticated information provides the decision-maker with a predictor which changes the probability distribution function of stochastic variables obtained from using little or no information, to $p(\theta|k)$. The optimisation problem for the better-information strategy is now given by:

$$\text{Max } E[\pi_k(x,\theta)] = \int_k\int_\theta \pi(x_k,\theta)p(\theta|k)d(\theta)d(k) \quad (2)$$

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where $x_k$ is the set of decision variables which maximises expected profits given the prediction k, and $p(\theta|k)$ is the probability distribution function of the stochastic variable $\theta$ given the prediction k.

The expected value of the predictor k is the amount of increase in expected profits resulting from using better information. Thus, the expected value of the predictor k is given by:

$$\text{Value of } k = \int_k\int_\theta \pi(x_k,\theta)p(\theta|k)d(\theta)d(k) - \int_\theta \pi(x^*,\theta)p(\theta|k)d(\theta) \quad (3)$$

where Eq. (3) represents the difference between the expected profits using better information ($E[\pi_k(x,\theta)]$) and expected profits using little or no information ($E[\pi(x,\theta)]$). If $E[\pi_k(x,\theta)] = E[\pi(x,\theta)]$, better information provided by k has no value for a risk-neutral decision-maker.

Botes (1994) developed a simulation optimisation model (SIMCOM) which combines a crop growth simulation model with an efficient search optimiser to maximise the expected profits from using better information.

### Accounting for risk attitudes when valuing information

According to Bosch et al. (1987) the assessment of information for non-neutral risk preferences is a problem, because the difference between expected utility with information and expected utility without information cannot be used directly as the value of information for different decision-makers. The reason is that utility is only unique up to a positive linear transformation (Hey, 1979).

In order to overcome the problem, Lavalle (1968) converted the value of information into a monetary measure. He determined the maximum amount an expected-utility-maximising decision-maker could afford to pay for information as the difference between the minimum the decision-maker having no information would accept in return for not deciding and not receiving a payoff and the maximum the individual, upon receiving the information, would pay to buy back the right to decide and receive a payoff (Bosch and Eidman, 1987). Bosch (1984) and Bosch and Eidman (1987) demonstrated how the value of information could be empirically estimated using generalised stochastic dominance (GSD).

The risk preferences of irrigation farmers in the Winterton area were elicited by Botes et al. (1994a). Absolute risk aversion coefficients (RACs) of between -0.0003 and -0.00003 were identified for risk-seeking decision-makers. RACs of between 0.00003 and 0.0003 were identified for risk-averse decision-makers.

### Conclusions from the literature

Techniques used to determine what decision-makers can pay to obtain better information must take risk preferences of decision-makers into account, since there is almost always a trade-off between risk and returns. Higher levels of returns are accompanied by higher levels of risk (Blake et al., 1988).

The *ex ante* instead of the *ex post* approach should be used to calculate the willingness to pay for better irrigation information (Chavas and Pope, 1984). The reason is that the *ex post* assessment of the value of information deals with the historical values of information and consequently does not account for the uncertainties of making real-time decisions.

The value of irrigation information will depend on the extent to which economic decisions can be improved by the use of better information. The decisions made should maximise the value of information. A comprehensive, dynamic approach is needed to maximise expected utility for decision-makers whose management decisions are made by using specific information strategies.

The value of information must be calculated at farm level, because costs and returns from non-irrigated and livestock enterprises may be correlated with irrigation returns and hence affect the value of information.

This research will expand the literature by developing research procedures to value information under risk when the availability of irrigation water is limited.

## Empirical model

The procedure used to calculate the value of irrigation information under unlimited and limited water supply conditions on two soil types in the Winterton area, for decision-makers with non-neutral risk preferences, required:

- Firstly, the construction and budgeting of a representative irrigation farm in the Winterton area.
- Secondly, the identification of irrigation information strategies.
- Thirdly, the selection of absolute risk aversion coefficients.
- Fourthly, adjusting the SIMCOM model to optimise both the expected profit and utility of the before-tax net income distribution as the principal performance measure.
- Finally, the value of information was estimated.

The GSD program of Cochran and Raskin (1988) was used to calculate the value of better irrigation information.

### A representative irrigation farm in the Winterton area

Fifty-three irrigation farmers in the Winterton area were interviewed by questionnaire. Information about the farmer, farming business, fixed and variable resources, financial situation and production system was obtained. This information was processed and analysed to identify a representative fixed and variable resource situation.

A representative irrigation farm with 170 ha maize under centre-pivot irrigation 50 ha dry-land maize, 30 ha kikuyu/ryegrass pastures under a drag-line irrigation system and 300 ha grazing was identified in the Winterton area. A 100 head cow-calf beef production unit along with 160 head of cattle, bought annually on a speculation basis to utilise the kikuyu/ryegrass pastures and maize stubble, are the other enterprises on the representative farm. A crop growth simulation model capable of simulating ryegrass yields with different irrigation strategies was not available. The irrigation on ryegrass was therefore assumed to be on a fixed cycle. Yield was assumed to be enough to feed the beef cattle and some of the speculation cattle.

One hundred and seventy hectares are irrigated by centre-pivot systems with a gross application capacity of 6.5 mm/d. A 30 ha drag-line system is used to irrigate the kikuyu/ryegrass pastures. An application efficiency of 80% was used to convert gross applications to net irrigation amounts.

The dry-land maize is produced on an Avalon/Bergville soil with a rooting depth of 800 mm and a plant extractable soil-water content (PESW) of 77 mm. Two soils were selected for the irrigation enterprises to determine how the PESW affects the value of irrigation information. The first is the same soil used under dry-land conditions (Avalon) and the second is a Hutton/Doveton soil with a rooting depth of 1050 mm and a PESW of 138 mm.

Total overhead cost was calculated at R401 304, which comprised R140 439 depreciation, R23 116 insurance, R137 576 interest and R100 173 other miscellaneous overhead expenses (electricity, water and labour cost). It was determined that only a small percentage of the irrigation farmers received off-farm income (OFI).

Production variable cost (PC) for dry-land and irrigation maize enterprises was calculated at R822 and R1 198, respectively. The PC for irrigation maize was not adjusted under conditions of limited water supply, because of the high maize yield potential even in years of limited water supply. Irrigation variable cost (IC) and harvesting variable cost (YC) were calculated separately. IC was calculated at 64 cents per millimetre water applied per hectare and harvesting cost at R54.78 per harvesting hour and R0.154/t·km over a distance of 30 km from farm to market. Production cost for the 100 head cow-calf production unit and 60 head of cattle for speculation purposes on kikuyu/ryegrass pastures amounts to R70 117. The production cost for the other 100 head of (speculation) cattle on the maize stubble was calculated at R8 541. Maize used in the feedpen was included in the budgets on a production cost basis, e.g., 800 kg of maize per head of cattle in the feedpen, fattened over a period of 3 months, were transferred from the irrigation maize enterprise to the beef enterprise.

Irrigation water was first assumed to be available in unlimited quantities. The effect of limited water on the value of information was studied by introducing a 50% restriction on the amount of irrigation water used by the irrigation farmers using little or no irrigation information to schedule irrigation water.

## Information levels

Six irrigation scheduling strategies were formulated by using different combinations of information on soil water, plant growth and the weather. **Irrigation Information Strategy 1** used no or very little soil water, plant growth or weather information (no-information strategy). This no-information strategy was used as a benchmark strategy to assess the other more sophisticated information strategies. The no-information strategy used no formal measuring method to determine when and how much to irrigate, but applied enough irrigation water to minimise the chance of plant-water stress occurring during the growth season. Irrigation farmers using the no-information strategy, under limited water supply conditions, reduced the application amount and/or extended the time between irrigations.

**Irrigation Information Strategy 2** (checkbook strategy) used a combination of weather information and soil-water information to schedule irrigations. The amount of water in the soil at the beginning of the season is determined by using the feel or appearance of the soil. Daily information on the potential evapotranspiration (Eo) is collected and used to calculate the amount of water evapotranspired (ET) out of the soil. The soil-water content is corrected by the farmer on a weekly basis. The feel or appearance method is used to adjust the soil-water content to the nearest 10 mm of the actual soil-water content. In addition, soil-water levels are corrected to the upper limit of PESW if the rainfall is more than 25 mm.

**Irrigation Information Strategy 3** based irrigation scheduling decisions on soil-water information, while no or limited information on plant growth and the weather is used. However, Strategy 3 assumed that daily soil-water levels cannot be measured accurately, because of measurement and sampling errors. As a result, Strategy 3 assumed that the error with which the daily soil-water content was measured was uniformly and randomly distributed and not greater than 15% of the PESW.

In contrast, **Strategy 4** used perfect information about daily soil-water levels. Soil-water levels, as calculated by the crop growth model were used. The perfect soil-water information strategy was included to determine the increased returns from providing irrigation farmers with error-free soil-water information.

**Irrigation Scheduling Strategy 5**, in addition to the perfect soil-water information of Strategy 4, used perfect weather information about the amount of rainfall over the next three days. Future rainfall was added to the amount of water in the soil. Irrigation was triggered if the soil-water content and future rainfall values dropped below the trigger levels suggested by the SIMCOM model.

In addition to the information used by Strategy 5, Strategy 6 used information on the expected amount of water that would evapotranspire over the next three days. The amount of water that would be lost over the next three days due to transpiration and evaporation if the plants were cultivated under dry-land conditions was obtained for each of the weather years by running the crop growth simulation model. The ET values obtained from the crop growth model were added for three days and written into the weather files. The future ET values were then used to adjust the soil water estimated used in Strategy 5 by subtracting the amount of water that would be lost under normal dry-land production conditions.

Each time one of the irrigation information strategies indicated that an irrigation should be scheduled, an effective 10 mm of irrigation water was applied the next day. The one-day lag accounted for the day the centre-pivot irrigation system takes to reach halfway around the circle. The next irrigation could not be scheduled within two days of the first decision in order to allow the centre-pivot system to apply the 10 mm of water that had already been scheduled.

## Absolute risk aversion coefficients

Annual income risk aversion coefficients compiled by Botes et al. (1994a) for irrigation farmers in the Winterton area, were used in this analysis. In order to simplify the analysis RAC values of -0.0001 and 0.0001 were used in the optimisation procedure to represent risk-seeking and risk-averse preferences, respectively. Specific RACs were used, because the complex model optimised expected utility at a specific utility point and not over a whole interval as specified by the interval approach (King and Robison, 1981).

In order to determine the extent to which the strength of a decision-maker's risk preference will affect the value of irrigation information, the selected RACs were divided by half, e.g., from ±0.0001 to ±0.00005. The SIMCOM model was rerun only for Information Strategy 4 on both soils, using the reduced RAC.

## The principal performance measure optimised by the SIMCOM model

Three decision variables were optimised ($X_1$, $X_2$ and $X_3$). The decision variables represented the trigger levels (as percentages of PESW) in 3 different growth stages of the maize plant. The first growth stage is from germination to tassel, the second, from silk to early grainfilling, and the third from end grainfilling to physiological maturity.

Weather data for 20 years were obtained from a weather station in the Winterton area. The weather data were used in the SIMCOM model to simulate the yield and water use for the different irrigation information strategies.

The SIMCOM model maximised expected utility of a random before-tax net income (BTNI) distribution. An exponential utility function was used to calculate the expected utility value for each year's BTNI value given the decision-maker's absolute risk aversion coefficient. More specifically, the maximum expected utility for a risk-averse decision-maker was calculated as follows:

$$\text{MAX EU(BTNI)} = \sum_{i=1}^{20} [\, -\text{EXP}\,((NR_{im} + NR_{dm} + NR_{bc} - OC) * - RAC) * Pr\} \quad (4)$$

More detail on the search optimisation procedure used in SIMCOM is provided by Botes (1994) and Botes et al. (1994b).

The BTNI for any given weather year was calculated by summing net returns received from beef cattle ($NR_{bc}$), dry-land ($NR_{dm}$) and irrigated maize ($NR_{im}$). Overhead cost (OC) was then deducted. The negative exponent of the BTNI value, multiplied by the selected RAC, was then calculated, multiplied by its probability (Pr) and summed to similar values calculated from using all 20 of the weather years.

Net returns received from the irrigated maize enterprises for a specific year were calculated as follows:

$$NR_{im} = \sum_{i=1}^{20} [\{(IY_i * P_i) - PC_i - IC_i - YC_i\} * A_i] \quad (5)$$

where the variables represent the irrigated maize yields (IY), the producer price for maize (P), production cost (PC), irrigation variable cost (IC), yield variable cost (YC) and the area under production in a specific year ($A_i$).

The CERES maize (IBSNAT, 1986) crop growth simulation model, which was built into the SIMCOM model, was used to simulate irrigation and dry-land maize yields using 20 years' weather data obtained from a weather station in Winterton. IC and YC were calculated in the economic subroutine depending on the amount of water irrigated and the yield obtained in a specific year.

Stochastic maize and beef prices were incorporated into the analysis to reflect price uncertainty. Beef prices were subjectively obtained, while stochastic maize prices were based on procedures developed by Meiring (1994). A maize-beef price correlation coefficient of 0.321 was calculated and used in the @RISK program along with the maize and beef price distributions to generate 20 correlated maize and beef prices. Each set of output prices was randomly assigned to different weather years. It was assumed that there was a zero correlation between yields which depend on weather and product prices. This assumption was made because of a lack of data and the fact that the weather data collected represented only a very small area, especially considering the total area under maize production in Natal.

A sensitivity analysis was done to determine whether the correlation between yield and product prices affects the value of irrigation information. A correlation coefficient of -1 was used, because intuitively years of high yield would correspond to low product prices. The SIMCOM model was rerun with the negatively correlated yield and product prices for Information Strategy 4, for both soil types and both water availability scenarios.

## Calculating the value of information

The SIMCOM model was used to determine the decision rule that yielded the highest expected utility value for a specific risk preference over the 20 replications. The optimised BTNI distributions for the different irrigation information levels were then read into the GSD computer program which computed the value of information. The GSD program calculated the amount that each BTNI value in the distribution with the highest EU(BTNI) could be lowered before it no longer dominated the EU(BTNI) distribution generated with a lower information strategy for risk-seeking, risk-neutral and risk-averse preferences.

## Results

### The value of information for risk-seeking, risk-neutral and risk-averse decision-makers

The value of better irrigation information for non-neutral decision-makers in the Winterton area under conditions of unlimited and limited water supply on the Hutton (PESW = 138 mm) and the Avalon (PESW = 77 mm) soils is presented in Tables 1 and 2 respectively. The value of information for procedures with neutral attitudes toward risk, i.e those who maximise expected net returns, was discussed in a previous paper (Botes et al. 1994b) but is presented here for comparative purposes.

The maximum amounts risk-seeking, risk-neutral and risk-averse decision-makers farming on the Hutton soil with unlimited

**TABLE 1**
**THE VALUE OF MORE SOPHISTICATED IRRIGATION INFORMATION FOR RISK-SEEKING, RISK-NEUTRAL AND RISK-AVERSE DECISION-MAKERS UNDER CONDITIONS OF UNLIMITED AND LIMITED WATER SUPPLY ON HUTTON SOIL (PESW 138 MM) IN THE WINTERTON AREA, 1993**

| Hutton | Unlimited water | | | Limited water | | |
|---|---|---|---|---|---|---|
| Soil | Risk preferences | | | Risk preferences | | |
| | Seeking (R/ha) | Neutral (R/ha) | Averse (R/ha) | Seeking (R/ha) | Neutral (R/ha) | Averse (R/ha) |
| Strategy 2 | 138 | 124 | 308 | 226 | 168 | 0 |
| Strategy 3 | 142 | 119 | 310 | 230 | 186 | 164 |
| Strategy 4 | 141 | 128 | 311 | 230 | 196 | 320 |
| Strategy 5 | 142 | 129 | 321 | 230 | 202 | 511 |
| Strategy 6 | 143 | 136 | 330 | 230 | 193 | 351 |

Risk-seeking = absolute risk aversion coefficients between -0.0003 and -0.00003
Risk-averse = absolute risk aversion coefficients between 0.00003 and 0.0003
Risk-neutral = 0

**TABLE 2**
**THE VALUE OF MORE SOPHISTICATED IRRIGATION INFORMATION FOR RISK-SEEKING, RISK-NEUTRAL AND RISK-AVERSE DECISION-MAKERS UNDER CONDITIONS OF UNLIMITED AND LIMITED WATER SUPPLY ON AVALON SOIL (PESW 77 mm) IN THE WINTERTON AREA, 1993**

| Avalon Soil | Unlimited water | | | Limited water | | |
|---|---|---|---|---|---|---|
| | Risk preferences | | | Risk preferences | | |
| | Seeking (R/ha) | Neutral (R/ha) | Averse (R/ha) | Seeking (R/ha) | Neutral (R/ha) | Averse (R/ha) |
| Strategy 2 | 205 | 147 | 469 | 637 | 231 | 85 |
| Strategy 3 | 209 | 153 | 475 | 637 | 319 | 381 |
| Strategy 4 | 213 | 157 | 481 | 638 | 330 | 382 |
| Strategy 5 | 212 | 161 | 482 | 638 | 331 | 601 |
| Strategy 6 | 219 | 173 | 503 | 639 | 322 | 362 |

Risk-seeking = absolute risk aversion coefficients between -0.0003 and -0.00003
Risk-averse = absolute risk aversion coefficients between 0.00003 and 0.0003

water (Table 1) could pay for obtaining more sophisticated irrigation information were R143/ha, R136/ha and R330/ha, respectively. When, however, irrigation water was limited, the maximum value of information increased by 60% (R230/ha), 49% (R202/ha) and 55% (R511/ha) for the three types of decision-makers, respectively.

The amount irrigation farmers could pay for obtaining better irrigation information increased as the type and quality of the information on soil water, plant growth and the weather increased. Diminishing returns to better information are however, clearly demonstrated. In the case of risk-averse producers, the checkbook irrigation strategy (Strategy 2) on the Hutton soil with unlimited water (Table 1) was able to account for 93% (R308/ha) of the increase in expected returns generated by Information Strategy 6 (R330/ha). The rest of the information strategies (Strategies 3 to 5) resulted in a mere 7% increase in expected returns.

When water supplies were limited, risk-averse, risk-neutral and risk-seeking decision-makers proved unwilling to pay anything to obtain perfect plant growth information and, consequently, also unwilling to pay for future ET information if they already had perfect soil water and future rainfall information (comparing Strategies 6 and 5). The reason why decision-makers proved unwilling to pay for ET information when water was limited is to be found in the fact that the addition of future ET information did not increase the highest or lowest outcomes, nor did it increase the expected value of the BTNI distribution generated with perfect soil water and future rainfall information. In fact, the use of future ET information caused a decline in the value of information for the risk-neutral and risk-averse decision-makers. The decline in the value of information may have been the result of a slower than anticipated depletion in the soil-water levels. The result was that irrigation was triggered earlier in the growth stage when the effects of water stress on crop yield are less severe, causing severe yield losses later in the growth season when irrigation water became limited. More research is needed to obtain better predictors of future ET when water is limited.

If irrigation water is unlimited, the value of information increases as risk preferences change from risk-seeking to risk-averse on both the soil types. On the Hutton soil (Table 1) for example, the value of information for Strategy 6 increased by 130% from R143/ha to R330/ha when risk preferences changed from risk-seeking to risk-averse. Similarly, the increase in the value of information on the Avalon soil (Table 2) was also 130% (from R219/ha to R503/ha) when risk preferences changed from risk-seeking to risk-averse.

The reason for the significant increase in the value of information is that better information succeeds in increasing the lowest outcomes more than it increases the highest outcomes of the BTNI distribution obtained from the benchmark strategy (Strategy 1). For example, the use of Information Strategy 6 by risk-seeking decision-makers on the Hutton soil with unlimited water resulted in a distribution whose highest outcome was R142/ha greater than the highest outcome of the benchmark distribution. When, however, Information Strategy 6 was used by risk-averse decision-makers, under similar conditions, the lowest outcome of the benchmark strategy increased by R330/ha.

In general, under limited water-supply conditions, the value of information decreases as risk-aversion increases. For example, the value of information for all the information strategies on Avalon soil with limited water (Table 2) was lower for risk-averse decision-makers than for risk-seeking decision-makers. The value of perfect soil-water, future rainfall and future ET information (Strategy 6) was R277/ha lower than the R639/ha a risk-seeking decision-maker could pay. Another example is the fact that risk-averse decision-makers irrigating Hutton soil with limited water (Table 1) proved unwilling to pay anything for obtaining the information used by the checkbook information strategy (Strategy 2), whereas a risk-seeking decision-maker could pay up to R226/ha. Better irrigation information, when irrigation water is limited, succeeds in producing bigger improvements in the highest BTNI values compared to the improvements on the lower end of the BTNI distribution, consequently it has a higher value for risk-seekers than risk-averters.

The importance of the soil is reflected in the fact that the value of information, for all types of decision-makers and information strategies, is higher on Avalon soil (PESW = 77 mm) than on Hutton soil (PESW = 138 mm). For example, the risk-seeking, risk-neutral and risk-averse decision-makers farming on Avalon soil with unlimited water could pay up to 34%, 27% and 52% respectively more than the farmers farming on Hutton soil under similar conditions.

The higher value of information on the lower quality Avalon

TABLE 3
**THE EXPECTED MAIZE YIELDS (kg/ha) AND THE AMOUNT OF IRRIGATION WATER APPLIED (mm/ha) BY THE IDENTIFIED INFORMATION STRATEGIES, OPTIMISED BY THE SIMCOM MODEL, ON AVALON SOIL (PESW 77 mm) UNDER UNLIMITED AND LIMITED WATER SUPPLY CONDITIONS FOR RISK-SEEKING, RISK-NEUTRAL AND RISK-AVERSE DECISION-MAKERS, RESPECTIVELY, IN THE WINTERTON AREA, 1993**

| Avalon | Unlimited water | | | Limited water | | |
|---|---|---|---|---|---|---|
| soil | Risk preferences | | | Risk preferences | | |
| | Seeking | Neutral | Averse | Seeking | Neutral | Averse |
| Strategy 1 | | | | | | |
| Yield (kg/ha) | 9 464 | 9 464 | 9 464 | 8 416 | 8 416 | 8 416 |
| Water (mm/ha) | 306 | 306 | 306 | 148 | 148 | 148 |
| Strategy 2 | | | | | | |
| Yield (kg/ha) | 9 649 | 9 716 | 9 746 | 8 757 | 9 003 | 8 592 |
| Water (mm/ha) | 215 | 240 | 311 | 149 | 144 | 150 |
| Strategy 3 | | | | | | |
| Yield (kg/ha) | 9 355 | 9 645 | 9 732 | 8 842 | 9 231 | 8 712 |
| Water (mm/ha) | 158 | 197 | 342 | 150 | 146 | 116 |
| Strategy 4 | | | | | | |
| Yield (kg/ha) | 9 211 | 9 673 | 9 729 | 7 941 | 9 252 | 8 442 |
| Water (mm/ha) | 139 | 206 | 290 | 150 | 143 | 97 |
| Strategy 5 | | | | | | |
| Yield (kg/ha) | 9 487 | 9 669 | 9 698 | 8 840 | 9 247 | 9 238 |
| Water (mm/ha) | 160 | 197 | 266 | 149 | 135 | 137 |
| Strategy 6 | | | | | | |
| Yield (kg/ha) | 9 547 | 9 695 | 9 732 | 7 812 | 9 238 | 9 016 |
| Water (mm/ha) | 171 | 196 | 252 | 150 | 145 | 120 |

soil is based on its ability to raise net returns relatively more on the Avalon soil compared to the Hutton soil. Irrigation farmers, by using better irrigation information, can reduce the adverse effects of irrigating poor soils. Information, therefore, is a partial substitute for soil quality.

Better irrigation information does not succeed in increasing the expected values of BTNI to the same extent as it does the highest or lowest values of the benchmark BTNI distributions. Consequently, the values of better irrigation information for risk-neutral decision-makers are lower than the values of information for either the risk-seeking or risk-averse decision-makers.

## The effects of risk attitudes on yields and irrigation applications

The expected maize yields and the amount of irrigation water applied by the different information strategies on Avalon soil under conditions of unlimited and limited water supply for non-neutral decision-makers are presented in Table 3. The results presented in Table 3 (also Table A1, **Appendix A**) indicate that information and risk attitudes affect the expected yields and amounts of water applied differently, depending on whether irrigation water is unlimited or limited.

The expected amount of irrigation water applied under unlimited water-supply conditions increases as risk preferences change from risk-seeking to risk-averse. The expected amount of water applied by a risk-neutral decision-maker using perfect soil-water information (Strategy 4) increased by 48% from the 139 mm applied by a risk-seeking decision-maker, to 206 mm. The expected irrigation amount increased by another 41% to 290 mm when risk preferences changed to risk-averse.

The yields obtained with unlimited water increased slightly as risk aversion increased. Expected yields generated by the perfect information strategy increased from 9 211 kg/ha for the risk-seeking decision-maker, to 9 673 kg/ha for the risk-neutral decision-maker and to 9 729 kg/ha for the risk-averse decision-maker. The rise in expected yields reflects the risk-averse decision-maker's willingness to adjust the depletion levels of the information strategies so that enough irrigation water is applied in the dry weather years so as not to adversely affect the expected yield.

The expected yields stayed close to the maximum potential yield under unlimited water conditions, as the type and quality of soil water, plant growth and weather information improved. In contrast, the amount of irrigation water applied, decreased by 44%, 36% and 18% for risk-seeking, risk-neutral and risk-averse decision-makers, respectively, relative to the benchmark (Strategy 1) as the sophistication of the irrigation information increased.

Contrasting results are obtained when irrigation water is limited. The yields and irrigation water amounts are more variable and the effects of risk preferences less visible. However, yields generated by the more sophisticated information strategies (Strategies 4 to 6) tend to be higher for risk-averse than for risk-seeking decision-makers. The expected amount of irrigation water applied, on the other hand, tends to decrease if risk preferences change from risk-seeking to risk-averse. The rise in expected yields, notwithstanding the fact that less water is applied, reflects the risk-averse decision-maker's willingness to adjust the depletion levels of the information strategies used, so that enough irrigation water is applied later in the growing season. By delaying the application of irrigation water, risk averters make sure that they have adequate irrigation water supplies left for irrigation in the very dry weather years, thus increasing income at the lower end of the CDF.

**TABLE 4**
**A SENSITIVITY ANALYSIS ON THE EFFECT OF MODERATE RISK PREFERENCES (RAC = ±0.00005) ON THE VALUE OF PERFECT SOIL-WATER INFORMATION (STRATEGY 4) ON AVALON SOIL (PESW = 77 mm) IN THE WINTERTON AREA, 1993**

| Strategy 4 on Avalon soil | Unlimited water | | Limited water | |
|---|---|---|---|---|
| | Risk preferences | | Risk preferences | |
| | Seeking (R/ha) | Averse (R/ha) | Seeking (R/ha) | Averse (R/ha) |
| RAC = ±0.0001 | 213 | 481 | 638 | 382 |
| RAC = ±0.00005 | 214 | 445 | 631 | 378 |

**TABLE 5**
**THE EFFECT OF PERFECTLY NEGATIVELY CORRELATED YIELD AND PRODUCT PRICES ON THE VALUE OF PERFECT SOIL-WATER INFORMATION (STRATEGY 4) ON AVALON SOIL (PESW 77 mm) IN THE WINTERTON AREA, 1993**

| Strategy 4 on Avalon soil | Unlimited water | | | Limited water | | |
|---|---|---|---|---|---|---|
| | Risk preferences | | | Risk preferences | | |
| | Seeking (R/ha) | Neutral (R/ha) | Averse (R/ha) | Seeking (R/ha) | Neutral (R/ha) | Averse (R/ha) |
| correlation = 0 | 213 | 157 | 481 | 638 | 330 | 382 |
| correlation = -1 | 163 | 165 | 325 | 234 | 348 | 467 |

## The effect of risk preferences on the value of perfect soil-water information

In Table 4 and Table A2 in **Appendix A** the values of perfect soil-water information (Strategy 4) on Avalon and Hutton soil for decision-makers with moderate risk preferences (RAC = ±0.00005) are compared with the amounts a decision-maker with strong risk preferences (RAC = ±0.0001) could pay.

The value of perfect soil-water information for risk-seeking decision-makers proved to be not very sensitive to the size of the RAC. The value of information decreased slightly for moderate risk-preferring decision-makers if irrigation water supplies become limited. The biggest decline in the value of perfect soil-water information is for moderately risk-averse decision-makers under unlimited water who proved willing only to pay R445/ha compared to the R481/ha the strongly risk-averse decision-maker could pay. A similar pattern is observed as regards Hutton soil (Table A2) where the decline was also about 7% under unlimited water supply conditions and about 18% when irrigation water was limited.

## The effect of perfectly negatively correlated yield and product prices on the value of perfect soil-water information

In Table 5 and Table A3 in **Appendix A** the values of perfect soil-water information (Strategy 4) on Avalon and Hutton soil, when no correlation between product prices and weather years was assumed, are compared with the value of perfect soil-water information when a perfectly negative correlation between yield and product prices was assumed (correlation = -1).

The value of information for decision-makers with non-neutral risk preferences is sensitive to the correlation used between yields and product prices. For example, the value of perfect soil-water information proved to decrease by 23% and 32%, respectively, for risk-seeking and risk-averse decision-makers if irrigation water is not limited. The reason for the decrease in the value of information for risk averters is that low yields are now accompanied by higher prices. Thus, the lower end of the BTNI distribution is now higher than it was before and the relative impact of information on lower incomes is now less. A similar explanation can serve to explain the decline in information value for risk seekers. However, the impact of correlated yield and prices is now at the higher end of the BTNI distribution.

However, the negatively correlated yields and product prices do not always diminish the value of information. The value of information for a risk-averse decision-maker proved to increase by 22% under limited water from R382/ha to R467/ha if yield and product prices are perfectly negatively correlated.

On the other hand, the value of information to risk-neutral decision-makers is not very sensitive to the correlation between yield and product prices. Negatively correlated yield and product prices resulted in a small increase in the value of information to the risk-neutral class for all the production conditions evaluated.

The effect of price-yield correlations on the value of information can be affected by the specific price vector drawn and this effect should therefore be evaluated further by drawing multiple price vectors under alternative assumptions about the price-yield correlations in order to see if statistically significant patterns emerge.

## Conclusions

The amount that irrigation farmers could pay for better irrigation information increased as the level and quality of information increased; however, the value of information increased at a diminishing rate.

The maximum amounts irrigation farmers in the Winterton area farming without any water restrictions could pay for obtaining the highest level of information on soil water, plant growth and the weather varied between R136/ha and R330/ha, depending on risk preferences. If however, irrigation water becomes limited, the value of better irrigation information was shown to increase by at least 49% to vary between R202/ha and R511/ha. If the PESW is lowered (Avalon soil), the value of better information with unlimited water increases by at least 27% to vary between R173 and R503.

The amount irrigation farmers are willing to pay for better irrigation information depends on their risk attitude. Under unlimited water supply conditions, the amount irrigation farmers can pay for the highest level of information (Strategy 6) on Hutton soil increases by 130% if risk preferences change from risk-seeking to risk-averse. With limited water and the Hutton soil the value of information tends also to be higher for risk-averters than risk-seekers. However, with the Avalon soil and limited water the value of information is higher for risk-seekers than for risk-averters. The lower information values for risk-averse decision-makers may be due to the fact that better information produces larger increases in the highest outcome values compared to the lowest outcome values of the benchmark BTNI distribution.

The amount irrigation farmers could pay for obtaining better irrigation information increased substantially if the availability of water is limited. However, the value of information becomes much more sensitive to the soil PESW, the risk preferences of the decision-makers and the level and quality of irrigation information used. The interaction between timing of irrigation water and yields has more important impacts on expected net returns and expected utility if irrigation water is limited.

Better irrigation information greatly reduces the adverse affects of limited water by facilitating better irrigation scheduling. Better information, therefore, can be used as a partial substitute for the availability of irrigation water.

The value of information for all information strategies and risk preferences proved to be higher on the lower quality Avalon soil than the Hutton soil. Better irrigation information allows the timing of irrigation to be adjusted so that maize yields, and consequently net returns, are less adversely affected by the low PESW. Better information, therefore, can be used as a partial substitute for the quality of irrigation land.

The value of irrigation information was not very sensitive to changes in the absolute RACs used to represent risk-seeking or risk-averse preferences. The effect of perfectly negatively correlated yield and product prices on the value of information was found to depend on the risk attitudes of the decision-makers. The value of irrigation information for risk-neutral decision-makers is not greatly affected by assuming a perfectly negative correlation between yield and product prices. By comparison, the value of information for non-neutral risk preferences is affected more by the assumption of negative price and yield correlations.

## Implications for further research

The value of information for other farm types and areas should be determined. The sensitivity of the value to changes in irrigated crops, farm size, irrigation system, pumping costs and other important economic variables should be determined. The selection of optimal irrigation strategies with limited water may be sensitive to the search procedures employed. Further work should be done to determine the effects of alternative search procedures and optimisation methods on the value of information with limited water.

The effect of price-yield correlations on the value of information should be further investigated by drawing multiple price vectors under alternative assumptions about the price-yield correlations and then determining whether statistically significant patterns emerge.

These findings regarding the value of information might be verified by using, for example, the contingent valuation method (Brookshire and Crocker 1981). The farmers in the Winterton area might be asked questions (by playing a bidding game) in an attempt to determine their willingness to pay for better irrigation information.

Greater research attention needs to be given to the decision-making process of farmers. For example, do decision-makers use the information they receive in an optimal manner? What are the information needs of the decision-maker to successfully implement and operate a better irrigation information strategy? Synthesising information in this manner can also contribute to understanding why irrigation farmers often do not use socially desirable and economically productive management practices.

The focus of this study was to assess irrigation information on an annual basis, ignoring the possibility of learning over time. An extension of this work is to assess irrigation information on a real-time, multi-year basis to determine how the net present value of an irrigation decision is affected. The wealth risk preferences produced by Botes et al. (1994a) can be used to assess irrigation information in such a setting.

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## APPENDIX A
## Research results of the value of information on the Hutton soil

**TABEL A1**
**EXPECTED MAIZE YIELDS (kg/ha) AND THE ASSOCIATED IRRIGATION WATER APPLIED (mm/ha) BY THE IDENTIFIED INFORMATION STRATEGIES, AS OPTIMISED BY THE SIMCOM MODEL, ON HUTTON SOIL (PESW 138 mm) UNDER UNLIMITED AND LIMITED WATER SUPPLY CONDITIONS FOR RISK-SEEKING, RISK-NEUTRAL AND RISK-AVERSE DECISION-MAKERS, RESPECTIVELY**

| Hutton soil | *Unlimited water* | | | *Limited water* | | |
|---|---|---|---|---|---|---|
| | Risk preferences | | | Risk preferences | | |
| | Seeking | Neutral | Averse | Seeking | Neutral | Averse |
| Strategy 1 | | | | | | |
| Yield (kg/ha) | 9 672 | 9 672 | 9 672 | 9 021 | 9 021 | 9 021 |
| Water (mm/ha) | 306 | 306 | 306 | 148 | 148 | 148 |
| Strategy 2 | | | | | | |
| Yield (kg/ha) | 9 669 | 9 693 | 9 749 | 9 401 | 9 416 | 9 360 |
| Water (mm/ha) | 151 | 153 | 213 | 129 | 129 | 133 |
| Strategy 3 | | | | | | |
| Yield (kg/ha) | 9 513 | 9 710 | 9 747 | 9 386 | 9 461 | 9 372 |
| Water (mm/ha) | 131 | 168 | 212 | 118 | 128 | 114 |
| Strategy 4 | | | | | | |
| Yield (kg/ha) | 9 304 | 9 680 | 9 751 | 9 274 | 9 470 | 9 265 |
| Water (mm/ha) | 104 | 141 | 220 | 103 | 117 | 100 |
| Strategy 5 | | | | | | |
| Yield (kg/ha) | 9 333 | 9 708 | 9 734 | 8 313 | 9 491 | 9 285 |
| Water (mm/ha) | 101 | 153 | 208 | 84 | 118 | 94 |
| Strategy 6 | | | | | | |
| Yield (kg/ha) | 9 476 | 9 726 | 9 748 | 9 373 | 9 458 | 9 538 |
| Water (mm/ha) | 118 | 153 | 178 | 113 | 115 | 107 |

**TABLE A2**
**SENSITIVITY ANALYSIS OF THE EFFECT OF MODERATE RISK PREFERENCES (RAC = ±0.00005) ON THE VALUE OF PERFECT SOIL-WATER INFORMATION (STRATEGY 4) ON HUTTON SOIL (PESW = 138 mm) IN THE WINTERTON AREA, 1993**

| Strategy 4 on Hutton soil | Unlimited water | | Limited water | |
|---|---|---|---|---|
| | Risk preferences | | Risk preferences | |
| | Seeking (R/ha) | Averse (R/ha) | Seeking (R/ha) | Averse (R/ha) |
| RAC = ±0,0001 | 141 | 311 | 230 | 320 |
| RAC = ±0,00005 | 143 | 288 | 230 | 262 |

**TABLE A3**
**THE EFFECT OF PERFECTLY NEGATIVELY CORRELATED YIELDS AND PRODUCT PRICES ON THE VALUE OF PERFECT SOIL-WATER INFORMATION (STRATEGY 4) ON HUTTON SOIL (PESW 138 mm) IN THE WINTERTON AREA, 1993**

| Strategy 4 on Hutton soil | Unlimited water | | | Limited water | | |
|---|---|---|---|---|---|---|
| | Risk preferences | | | Risk preferences | | |
| | Seeking (R/ha) | Neutral (R/ha) | Averse (R/ha) | Seeking (R/ha) | Neutral (R/ha) | Averse (R/ha) |
| Correlation = 0 | 141 | 128 | 311 | 230 | 196 | 320 |
| Correlation = -1 | 192 | 134 | 202 | 80 | 218 | 313 |