THE TRUE VALUE OF IRRIGATION WATER IN THE OLIFANTS RIVER BASIN: WESTERN CAPE

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The true value of irrigation water in the Olifants river irrigation system is determined using a static deterministic linear programming model. This paper illustrates that a water market will generate price signals which will reflect the true scarcity of water. If the water market is left to operate pareto optimality will be reached and the general welfare of the nation will increase. What is more, water which is a true scarce resource in South Africa will be used more effectively.

DIE WERKLIKE WAARDE VAN BESPROEIINGSWATER IN DIE OLIFANTS-RIVIERKOM : WES-KAAP

Die werklike waarde van besproeiingswater in die Olifantsrivierkom is bepaal met die gebruik van 'n statiese deterministiese lineêre programmeringsmodel. Die referaat toon dat 'n watermark prysseine wat die werklike skaarsheid van water reflekteer, sal genereer. As die watermark toegelaat word om Pareto-optimaal te fungeer, sal optimaliteit bereik word en die algemene welvaart van die volk sal verhoog. Bowendien sal water, wat 'n ware skaars bron in Suid-Afrika is, meer effektief benut word.

1. INTRODUCTION

Water resource management throughout the nation is looming as one of the most important political, social, and economic issues of the future. While water allocation and water quality describe the issues of the past and the future, growing and changing social demands for available water, changing technologies and outdated laws and institutions for water allocation combine to create new opportunities for the attention of economists for the next several decades. Many current problems in water allocation policy are due to a failure to recognize the connection between institutional settings, states of technology and the hydrology of water systems. These problems will only grow more in future until these connections are specifically acknowledged and addressed in water policy decisions (Whittlesey & Huffaker, 1995).

Following the democratic change to a new constitutional dispensation, problems arising from previous political inequalities require urgent attention. Unequal political power in the past has given rise to imbalances in the

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currently apportioned water rights and to a skewed distribution of income. Land, water and irrigation policy reform is therefore necessary to address justifiable claims that are made to gain access to water resources (Backeberg *et al.*, 1996). In doing so, however, it must be recognized that water resources are scarce and water rights are an economical valuable asset. According to SANCID (1995) irrigation policy must clearly specify the rules and processes according to which change is to be negotiated in order to reduce uncertainty in a competitive economic environment. Individual entrepreneurs must be enabled, through private initiative, to continue creating wealth through profitable irrigation farming. Balanced economic growth in irrigated agriculture must be achieved through a combination of increased productivity, reallocation of rights to water resources and redistribution of income. In this process consideration should be given to productive investment, increased employment and income generation on the one hand, and to consumption investment, provision of basic services and humanitarian relief measures on the other.

All new policies which have an effect on the South African agriculture can be accepted only if it enhances the competitiveness of the agricultural sector and increases the general welfare of the population in the long run. South Africa's water policy is therefore naturally a factor which might impede or improve South Africa's international competitiveness.

The current debate focus more on the "macro" economic issues such as the socio-economic and political aspects, reallocation of water rights and the management of River Basins (Department of Water Affairs and Forestry, 1994; Backeberg, 1996; Agricultural News, 1997). Many researchers in agricultural economics believe that the allocation of water rights should be left to a water market (Backeberg *et al.*, 1996; Van Schalkwyk, 1997). According to them the value of water rights will only reflect the true scarcity of water if water is tradeable. They continued by stating that water will only be utilized effectively if water is priced correctly. This paper attempts to contribute to the debate by presenting a way in which the true value of water could be estimated. The paper uses the Olifants River Basin as a case study. The Olifants river originates in the Sederberg near Ceres and runs past Citrusdal, Clanwilliam, Vredendal and Koekenaap where it mouth, into the sea. The only major dam in the River is the Clanwilliam Dam. According to Troskie (1996) the Olifants River Basin has about 21 503 ha of irrigated land.

In this paper an attempt is made to calculate the true value of irrigation water in the Olifants River Basin. The value of water for agriculture (VWA) is calculated by subtracting the net value of agricultural output without irrigation from the net value of agricultural output with irrigation and dividing the result by the amount of water diverted to agriculture. The net value of agricultural output is estimated by using a linear programming approach.

2. METHODOLOGY

According to Rogers *et al.*, (1996) the full economic cost of water is the sum of the of the full supply cost, the opportunity cost associated with the alternate use of the same water resource and the economic externalities imposed upon others due to the consumption of water by a specific actor. The full cost of consumption of water is the full economic cost plus the environmental externalities. These costs have to be determined based upon damages caused where such data are available or as additional costs of treatment to return the water to its original quality. The value in use of water are the sum of the economic and intrinsic values.

According to Rogers *et al.*, (1996) the value of water in agriculture (VWA) can be calculated with the following formula:

$$\text{VWA} = \frac{\text{Net value of output with irrigation - that without irrigation}}{\text{Volume of water diverted for irrigation}}$$

The net value of output with and without irrigation was obtained by using a linear programming model which was originally developed by Van Zyl & Louw (1996) for the Olifants River Basin. The model had to be adapted in order to be able to estimate the value of water. Data for the with and without scenarios for the OlifantsRiver Basin was obtained from the Directorate of Agricultural Economics (1995) and budgets developed for the SM3project.

The model can be described as static deterministic in that no specific provision is made for stochastic elements. The model used in the case study consists of three different but integral parts, the goal function, the activities and the resource restrictions. Backeberg (1988) describes the goal for irrigated agriculture as "the satisfaction of increasing household expenditure over time and the optimization of the present value of the net cash balance for reinvestment in agriculture to provide for growth and unknown setbacks". The objective function used for the development of the Olifantsriver model is in accordance with that of Backeberg (1988). The end result gives disposable income after provision for overhead costs, household expenses and the payment of capital and interests on loans. The net cash balance can be used as operating capital or it can be invested in a savings account where it can earn interest.

The model assumes a linear relationship between the amount of water applied and yields. This was overcome by decreasing yields for each different amount of water application. Data for this was obtained from the Directorate of Agricultural Economics, (1995). An improved approach would be to develop production functions for each of the products included in the model. The production elasticity of water could then be used to change the yields of the products for every different water allocation. Due to a shortage of data this was not attempted in this document.

Although there are approximately 1 200 activities and 574 resource limitations and transfer activities in the complete model, only the activities that were used in the case study are listed. For simplicity and to get an average figure the whole OlifantsRiver Basin was treated as one big farm. The main crops produced in the area are given in Table 1:

Table 1: Irrigated crops in the Olifantsriver

Crop	Ha
Citrus	5 000
Peaches	170
Apricots	42
Sultanas	525
Table grapes	444
Wine grapes	8 213
Lucerne	500
Potatoes	4 246
Tomatoes	933
Onions	132
Watermelon	347
Melon	50
Gem squash	200
Greenbeans	300
Sweet potatoes	157
Sweet corn	200
Pumpkins	300

The total area under irrigation is 21 503 ha. Although some of the farmers in the area grow dryland as well as irrigated crops, only the irrigated crops were included in the model in order to exclude the influences of non-irrigated agriculture. No data is available for peaches, sultanas, sweet melon, apricots and vegetable seed production. However these products only 1031 ha from a total of 21 503 ha (4.7%). Only 20 472 ha of irrigated was therefore made available in the model. The area is ideally suited for the case study due to the large variety of irrigation crops in the area and the fact that very few crops can be grown under dryland conditions. The amount of data needed to calculate the net value without irrigation water is therefore reduced.

4. ASSUMPTIONS AND UNDERLYING PROPERTIES OF THE MODEL

The following must be taken into account when the results are interpreted:

- The price of water in the base analysis is 0.038 cent per m^3, i.e. the current water price.

- The water price increases with 30% to 0.043 cent per Cubm. in all the other scenario's. This is the latest price for water in the area.

- Because of the static nature of the model the following is assumed for all perennial crops: 10% are in the establishment phase, 25% are young trees, and 65% are full grown trees.

- Due to market considerations, a maximum area restriction was placed on most of the vegetables.

- The overhead costs are calculated per ha and aggregated for the irrigation area only. It is assumed that the overhead costs of irrigation farming are twice the size of dryland farming.

- The average farm consists of four irrigation units of 17 ha each, totaling 68 ha. This amounts to 300 units on 20 472 ha. It is assumed that a households' living expenses will amount to R100 000 per year.

- The listed water quota is 12 200 cubm at a price of 3.852 cent per cubm.

- No provision was made for income tax, opportunity cost of own capital and the risk of uncertain water supply.

- The interest cost on medium and long term loans is included in the overhead expenses.

- No provision was made for technological changes with regard to water saving technology.

5. WATER AVAILABILITY

The following analysis were done for each of the area restrictions:

- Base analysis
- Optimal solution
- 10%, 15%, 20%, 25%, 28.7% and a 30% decrease in the water available.
- A test on the water and land value curve calculations

The base analysis represents the present situation with regard to irrigation farming. The optimal situation represents the way the present situation should have looked if everyone had perfect knowledge and if they were rational decision makers. In order to be able to calculate the difference of the net value of output with water and the net value of output without water the water availability was decreased and its effect brought through to the farm profits. A decrease in the availability of water is therefore associated with lower farm margins. For every decrease in the water volumes overhead costs were also decreased.

6. RESULTS

The results of the calculation of the VWA are summarized in Table 2.

Table 2 clearly shows that there is a substantial difference between the base analysis and the optimal analysis with regard to almost all the parameters. The objective function increased with almost 50%. This is due to the fact that the model always chooses crops with the highest marginal value first and it applies resources optimally. More long term crops and less vegetables are produced in the optimal solution. The volume of water used increases by 13% and employment by 5%.

When the volume of water available to irrigation agriculture decreases by 10% the value of the objection function decreases by approximately 38% from the optimal solution and employment by 5%. The VWA increases to 65.5 cent per m^3 compared to the 59.1 cent of the optimum solution. The agricultural use value of the land decreases from R 4 760 to R 3 962. When water is restricted, structural changes happen which results in a loss in product volumes and income. Less potatoes and more winegrapes and citrus are produced in this scenario. The income per unit of water is higher for long term crops.

Table 2: Calculation of the Value of Water for Agriculture

Item	Base Analysis	Optimal Solution	Water volume decrease					Test
			10%	15%	20%	25%	28.7%	
Citrus establishment	500	995	1066	1009	961	910	869	941
Citrus Young	1250	2489	2665	2522	2402	2274	2174	2352
Citrus fullgrown	3250	6471	6928	6556	6246	5913	5651	6115
Table grapes establishment	44	.	.	.	.	.	.	.
Table grapes young	111	.	.	.	.	.	.	.
Table grapes fullgrown	289	.	.	.	.	.	.	.
Wine grapes establishment	821	609	724	782	829	881	921	849
Wine grapes young	2053	1523	1811	1954	2074	2201	2302	2124
Wine grapes fullgrown	5338	3960	4709	5081	5391	5724	5986	5521
Summer potatoes	1731	1483	910	.	.	.	.	.
Winter potatoes	2515	1855	.	.	.	.	.	.
Greenbeans	300	.	.	.	.	.	.	.
Pumpkin	300	.	.	.	.	.	.	.
Gemsquash	200	.	.	.	.	.	.	.
Sweetcorn	200	1347	1347	1347	1347	1347	1347	1347
Sweet potatoes	157	.	.	.	.	.	.	.
Tomatoes	933	1222	1222	1222	1222	1222	1222	1222
Onions	132	.	.	.	.	.	.	.
Objective function value (mill)	98.58	147.01	90.89	64.88	40.49	16.92	0.08	30.96
Monetary value change from optimal	NA	NA	-56.12	-82.12	-106.52	-130.08	-146.92	-116.05
% differance from base	NA	49%	-8%	-34%	-59%	-83%	-100%	-69%
% differance from optimal	NA	NA	-38%	-56%	-72%	-88%	-100%	-79%
Volume of water used	220.26	248.50	224.78	201.73	189.20	176.70	167.48	184.19
Volume per ha (m^3)	10759	12138	10980	9854	9242	8631	8181	8997
% differance from base	NA	13%	2%	-8%	-14%	-20%	-24%	-16%
% differance from optimal	NA	NA	-10%	-19%	-24%	-29%	-33%	-26%
Labour hours used	13.00	13.69	13.02	12.41	12.35	12.29	12.24	12.33
% differance from base	NA	5%	0%	-5%	-5%	-5%	-6%	-5%
% differance from optimal	NA	NA	-5%	-9%	-10%	-10%	-11%	-10%
VWA/ Cubm of water (Rand/Cubm)	0.448	0.591	0.654	0.728	0.777	0.832	0.877	0.798
Value of water for agriculture /ha	5460	7213	7974	8885	9474	10144	10703	9732
Productive value of land		4760	3962	3776	2856	1978	1357	2500

Value of Water in Agriculture (VWA) = (OW - OL) / Volume of water diverted for agriculture
Optimal objective function value with optimal water (OW)
Objective function with less than optimal water(OL)
NA = Not applicable

When the water decreases by 20%, the situation deteriorates considerably. No potatoes are produced, citrus production decreases and wine production increases. There is a shift away from crops using large volumes of water to crops with higher outputs per unit of water. The VWA, i.e. the price which a rational decision maker would be willing to pay for an additional unit of water, increases because of the increasing difference between the objective function values of the optimal solution and this solution. The value of water diverted to agriculture is R9 474 per ha in this scenario. This value indicates the opportunity cost in terms of the loss in the objective function value due to the shortage of water for optimal production. In other words the true value of water.

When the water available for irrigation decreases with 28.7%, crops are still produced but the income derived from production is now close to even with the costs. The objective function value is only R80 000 and the VWA increases to R10 703. The agricultural use value of the land is now only R1 357 compared to the R 4 760 in the optimal solution. It should be noted that virtually no crop production is done outside the irrigation areas in the Olifants River Basin. The agricultural use value of land on which irrigation is not possible is therefore very low.

When a further restriction of 1.3% is imposed (30% less than the optimum), the solution is infeasible and the Olifants river system can not generate enough operating capital to cover the overhead costs, the payments on the short term loans, and the household expenses.

The VWA and the shadow price (agricultural use value) of the land of the different scenarios given above is illustrated graphically in Figure 1. This figure can be used by Olifants river farmers to determine what price they should be willing to pay for the water at different quantities.

6. CONCLUSION

The methodology developed in this paper can be used to calculate the true value of water (scarcity value) for agriculture. If a water market were functional in the Olifantsriver this market will generate price signals which will reflect the true scarcity of water. The price of water will therefore increase within a free market system. If the water market is left to operate pareto optimality will be reached and the general welfare of the nation will increase because farmers will be forced to plant crops with a higher value. What is more, water which is a true scarce resource in South Africa will be used more effectively. The model could be used by farmers to determine what price they

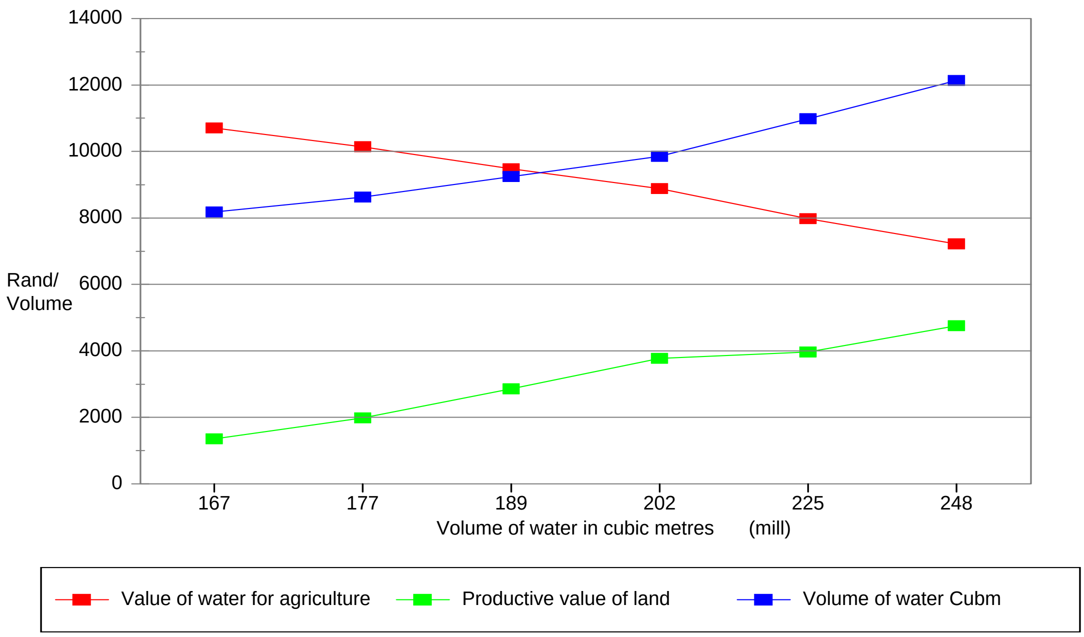

Figure 1: The value of irrigation water of the Olifants river at different levels of supply

should be willing to pay for their water rights. It should be noted however, that water can only be traded if the buyer of the water right will get property rights to the water right which he bought. The property right should be protected by law if a water market is to operate effectively.

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