WATER MARKETING IN THE CROCODILE RIVER, SOUTH AFRICA

WL Nieuwoudt[1], CG Gillitt [2] & GR Backeberg[3]

Abstract

Transfers of water in the Crocodile River above and below the gorge (near Nelspruit and Malelane) were studied based on a survey in the area during November 2003, followed up by telephonic interviewing during March 2004. Almost all the water trades (permanent and rentals) observed in this study were from farmers above the gorge to farmers below the gorge. In order to study whether the water market promotes efficiency the data were subjected to several statistical analyses (Principal Components, Ridge Regression, Logit). It is concluded that in the transfer of water some attributes in the purchasing area such as lower production risk (sugar cane) and lower financial risk and better cash flow (bananas and sugar cane) were more important than the income per cubic meter of water. Water supply in this area is highly irregular while farmers were found to be extremely risk averse especially as far as down-side risk is concerned. The average water price in this area in recent years (2002 to 2003) was between R2,000 and R3,000 per ha (1ha = 8,000 cubic meter). Buyers are large progressive farmers that purchase (and rent) from many sellers (or lessees). It is concluded that information (sale prices and rents) is asymmetrical. Few permanent transfers have taken place in the Crocodile River in recent years. It is concluded that there are reasons why transfers at present are not processed and role players should discuss these reasons and possible solutions before further action is taken.

1. INTRODUCTION

In the study the performance of water markets in the Crocodile River in the Mpumalanga Province is studied as this river has had an active water market. While an active water sales (permanent) market has developed, water renting is common. The flow of the Crocodile River is highly irregular and the major dam in this river (Kwena) is presently (August, 2004) only used for residential and industrial use (Comrie, 2004). Risk management in water use must therefore be an important strategy in this area. The markets will be studied not only as they function today but also dynamic features will be researched by

[1] *Professor, Department of Agricultural Economics, University of Natal, Pietermaritzburg.*
[2] *SA Cane Growers Association and postgraduate student in Agricultural Economics, University of KwaZulu-Natal.*
[3] *Director, Water Research Commission, Pretoria.*

comparing the present situation with a past study by Bate *et al* (1999) in the same river. Farmers at the time when the studies by Bate *et al* (1999) in the Crocodile River and by Armitage (1999) in the Lower Orange were undertaken were concerned about the application of the National Water Act (No 36 of 1998).

The study links up with the WRC study on the supportive role of the market mechanism in implementing the provisions of the new Water Act (WRC, 2004). This study is also complementary to a recent study in the Orange River (Gillitt *et al*, 2004). The research objective in this study is to study whether water marketing in the Crocodile River has promoted efficiency and whether efficiency objectives are realised that were envisaged in 1999 Bate *et al* study. Few permanent transfers have occurred in recent years and the constraints and problems in this water market will be researched.

It would be instructive to revisit the same areas as in the Bate *et al* (1999) study and possibly the same farmers. A list of farms that have transacted water in the Crocodile (Mpumalanga Province) where Bate *et al* (1999) study was undertaken was obtained from the Regional Director at Nelspruit (Van Aswegen, 2004).

2. BACKGROUND

Efficiency implications of a water market will be studied in this paper using Principal Components, Ridge Regression (Neter *et al*, 1996) and Logit and Linear Probability Models.

2.1 The National Water Act 36 of 1998 and lawful water use

All water uses will eventually be authorised by way of licenses. As an interim measure the National Water Act (NWA) permits the continued use of water that actually has taken place when the NWA came into operation and was lawfully used under any law that preceded the NWA. Existing lawful use is defined in section 32 of the NWA and refers to use which had been taking place during a period of two years before the commencement of the NWA or which has been declared an existing lawful use under section 33 (Joubert, 2004). An amendment to this allows for certain discontinued and contemplated uses that do not fall within the two-year period to be declared existing lawful use. The implication is that a user who has not exercised his/her water use entitlement in the qualifying period may apply for a verification of his/her water use as an existing use and if successful may transfer it (WRC, 2004).

2.2 Theoretical comments

The main purpose in a water market is to improve the efficiency of use of this scarce resource. This issue is complicated as all the water applied is not used by the plant (consumptive use) since some may return to the stream as return flow. A water market may thus not promote water conservation as is envisaged if only the water that is applied is considered. Some contend that increased on-farm efficiency such as water saving technology creates the illusion of water conservation when in reality consumptive use of water increases (Huffaker and Whittlesey, 1995; Nieuwoudt and Armitage, 2004). This is especially relevant in South Africa and Australia as water is measured based on diverted use (volume applied). This problem is greater in South Africa as farmers are permitted to irrigate larger areas if they use water conservation strategies such as drip. This issue will be studied in this paper. For recent literature on international water markets the reader is referred to the September 2004 edition of Water Resources, which included a special edition on water marketing.

2.3 Past local research

Water markets in the Western USA have a long history and date back to 1882 (Howe, 1997). Water marketing in South Africa is relatively more recent. Several local researchers have strongly recommended the strengthening and support for these markets in South Africa (Backeberg, 1995; Conradie, 2002; Louw, 2001; Bate *et al*, 1999; Armitage, 1999, Mirrilees *et al*, 1994; Nieuwoudt, 2000). As the present research is a follow-up on the research by Bate *et al* (1999) their findings will be referred to in this study.

3. SURVEY AREA AND NATURE OF WATER TRANSFERS

3.1 Study area and characteristics of buyers and sellers

The Inkomati Water Management Area is situated in the north-eastern part of South Africa in the Mpumalanga Province and borders on Mozambique and Swaziland. Topographically, the Great Escarpment (referred to as the gorge section of the river) divides this area into a western plateau and sub-tropical Lowveld in the east. Rainfall varies from 400mm to over 1200mm per year in the mountains (RSA, 2002). The study was undertaken amongst irrigation farmers along the Crocodile River above the gorge, and below the gorge towards Komatipoort during November 2003 with additional interviews conducted in March 2004. The climate in the study area varies from warm subtropical at Nelspruit, above the gorge, to hot subtropical downstream from the gorge. The area below the gorge falls within the Nkomazi/Onderberg region of Mpumalanga an area that has been thoroughly researched in recent times (Nowac, 1999). The most common crops below the gorge are sugar cane, bananas and citrus while above the gorge macadamias, pecans and citrus are produced. The target population was identified using documents supplied by the Department of Water Affairs and Forestry (DWAF), which record the names of buyers and sellers of water entitlements from 1998 to 2003. The study was undertaken in the same area visited by Bate *et al* (1999) in order to study dynamic features of the market.

3.2 Nature of water transfers

In a water market it is expected that water will move from less desirable land to land where the return per unit of water (allowing for risk) is higher. It is thus essential to understand the climatic conditions in this area in order to draw conclusions regarding the desirable outcomes of transfers of water.

All but one of the trades (permanent and rent) observed in the Lower Crocodile River occurred from farmers above the gorge to farmers below the gorge and all transfers were from up- to down-stream. The reasons for this phenomenon are explored in section 7. Only water that was not used was sold or rented out.

Wolstenholme (2004) and Bower (2004) attribute the movement of water from above to below the gorge to better growing conditions below. All the information regarding growing conditions provided in this section is from Wolstenholme (2004).

The soils above the gorge from Schagen down are sandy, which means that water, and minerals cannot be stored to any significant degree. Temperatures above the gorge are also not hot enough for the heat loving crops under irrigation (sugar cane, mangoes, grape fruit, Valencia's and bananas) while on the other hand it is not cool enough for temperate crops that require coolness (pecans). The heat loving crops achieve greater yields below the gorge. Under good husbandry (irrigation and fertilization), orcharding is possible above the gorge but conditions are not as favourable as below (Wolstenholme, 2004).

It is of interest why the major area under the gorge is under sugar cane as incomes from other crops are higher. Farmers see sugar cane as a lower risk crop than other crops, which partly explains the choice of the crop (Nowac, 1999). Sugar cane has fewer pests, is reasonably drought resistant, has an established marketing and service structure that exists once a milling facility has been established, has faster cash flows and smaller fluctuations in market prices, and requires lower expertise and management inputs (Wolstenholme, 2004; Bower, 2004; Conningarth Consultants, 1998).

3.3 Characteristics of buyers and sellers

A total of 18 farmers were interviewed, consisting of six buyers, nine sellers (six permanent and three temporary), and three that were neither buyers nor sellers. Although the number of farmers is small, some of these farmers entered into several contracts, for instance, one farmer leased from 12 lessors. The respondents were classified as either buyer or non-buyer for the analysis. Due to the low number of permanent transfers encountered, short-term leases of water were included in the analysis. Participants who had both purchased or sold, and leased water were only included once for the summary data. This classification resulted in six buyers and 12 non-buyers (6 permanent sales, 3 temporary leases, and 3 non-participants).

3.4 Crop production

Table 1 summarises the land use of the respondents. The main crops produced by the buyers were sugar cane, bananas, and citrus while non-buyers produced more macadamia nuts, mangoes, and avocados. The large size of buyers compared with non-buyers is also evident in Table 1.

Table 1: Crop production of respondents in the Crocodile River Basin, November 2003 and March 2004

	Sugar	Banana	Citrus	Nut Trees(1)	Other Trees(2)	Crop Rotation	Vege-table
Buyer Area (ha)	9900	1256	862	37.2	61	40	0
Number of Buyers	4	4	2	1	2	1	0
Average Buyer Area (ha)	2475	314	431	37.2	30.5	40	0
Std Dev (ha)	3715.7	134.22	295.57	NA	41.72	NA	NA
Non-Buyer Area (ha)	55	0	102	132	70.6	50	48
Number of Non-Buyers	2	0	4	6	4	1	2
Average Non-Buyer Area (ha)	27.5	0	25.5	22	17.65	50	24
Std Dev (ha)	10.61	NA	19.67	16.91	21.68	NA	8.49

Notes: 1) Macadamia and pecan nuts.
2) Litchi, mango and avocado trees.

The median area under sugar cane is 907.5 hectares. The median is a better indication of the situation because of the large area (8,000ha) of sugar cane operated by a company that was surveyed. Buyers grow relatively large areas of sugar cane, banana, and citrus, while non-buyers produce on relatively small parcels of land. This is probably due to the fact that most (5 of 6) buyers are located below the gorge. The buyer located above the gorge purchased more water entitlements so that he could sell a portion of his land. The buyers from below the gorge mostly used purchased water for crop production and one farmer used the purchased water for assurance of supply (security). The area below the gorge seems more suited to large scale farming enterprises, since there are more relatively flat areas, hotter climate, and better soils. The crop types grown by buyers and non-buyers are consistent with the earlier discussion of crops, given that most buyers were located below the gorge and most of the non-buyers were located above the gorge (11 of 12). Sellers of water did not cease production of crops in order to sell water but sold water that was not used for irrigation. The reason for having an unused water entitlement was that it was too costly to pump the water to the productive land.

4. PROBLEMS WITH WATER TRANSFERS IN THE CROCODILE RIVER

Table 2 shows water market transactions that occurred in the Crocodile River from 1998 to 2003. The table was compiled from records received from the DWAF, which records all transfers of water allocations.

Table 2: Water market transactions in the Crocodile River: 1998 – 2003

Year	Transactions
1998	8
1999	27
2000	41
2001	1
2002	2
2003	0

Source: C Ceronio, 2003.

According to Table 2, the water market was active during the period 1998 to 2000, which was also the case during 1994 to 1995 when Bate *et al* (1999) conducted their study. Few transactions have been approved from 2001 onwards. Transfers of permanent water rights in the Crocodile River area have come to a standstill and some farmers say that the situation is chaotic as no applications are currently (2004) being processed. The only transfers that currently take place in the Crocodile River are rental agreements. The reasons for the lack of permanent transfers are explored in this section.

The total land areas farmed and summary of water entitlements owned by respondents are presented in Table 3. Table 3 shows that buyers farm a larger area than non-buyers, but do not have enough permanent water entitlements for the area planted, and have to lease or purchase a large amount of water to irrigate their crops. There is also a wide range of sizes of buyers indicated by the mean and the median. Non-buyers tend to own an excess of water entitlements, which they might hold for times of drought, lease to other farmers, or sell to other farmers.

Table 3: Area farmed and water entitlements before and after sampled transfers

		Farmed area (ha)	Surplus (Deficit) entitlements – after transaction (ha)	Surplus (Deficit) entitlements – before transactions (ha)
Buyers (n=6)	**Total**	12156	(592)	(1584)
	Mean	2 026	(99)	(264)
	Median	809	(13)	(89)
Non-Buyers (n=12)	**Total**	458	136	301
	Mean	38	11	25
	Median	40	1	19

Table 3 indicates that buyers (situated below the gorge) had significantly exceeded their water use entitlements. These data include permanent water entitlements only, and temporary arrangements could lessen the excess. Farmers downstream from the gorge have rented and purchased in recent years to make up some of their deficit.

The excess use of water without enough water rights as shown in Table 3 is particularly a problem below the gorge according to Deacon (2004) as in his view farmers simply expanded production even though they did not have entitlements to the water to support the expansion. He does not have a problem with farmers who irrigate a larger area than their allocation if they use drip irrigation as long as their volumetric entitlements are not exceeded. He contends that many farmers far exceed their volumetric entitlements and that this has put the system under stress. He, however, thinks that there is enough water in the system to justify current entitlements if every farmer only uses what he is entitled to. This view is somewhat different from that of Comrie (2004) who is of the opinion that demand exceeds supply in the system.

Although Deacon (2004) has no problem with farmers who irrigate a larger area if they use drip irrigation, this practise reduces return flow and reduces water available for other uses (Huffaker and Whittlesey, 1995). Farmers using drip and other advanced irrigation systems indicate that their usage is below the prescribed allocation of 13000 cubic meters per annum, which implies that they can irrigate a larger area. For example, a one-hectare entitlement ($13000m^3$) could be used to irrigate 1.3 hectares if the irrigation method only uses 10,000 cubic meters per year.

Joubert (2004) and Comrie (2004) see the problem as consumption exceeding availability. According to Joubert (2004) the problem is that in many cases there is no existing lawful use to transfer and the seller must first apply in terms of article 33 of the NWA for the use to be classified as an existing lawful use. Alternatively, the seller can apply for a license. The seller must have been an existing lawful user for at least two years before October 2002 (the legal application of the Act).

Joubert (2004) considers that the following two reasons may explain the lack of approval of permanent transfers in the Lower Crocodile River: (1) Availability of water in the Crocodile River is a problem as the Crocodile River flow is irregular. The normal flow of the river must be considered while other commitments such as international obligations must be honoured. Transfers at present complicate the water scarcity problem as all sales have been from farmers who did not use the water for irrigation. (2) Farmers pay water tariffs for the area listed under irrigation (usually where the State built a dam). The irrigation area under such a dam is called a Government Water Scheme. Only a relative small part of the Crocodile River is a Government Water Scheme as other parts of the river (including tributaries such as the Lomati and Komati) are Government Water Control Areas. The latter mechanism is created to control the water use in areas where over-use is a problem. Farmers pay water rates under Government Water control Areas but less information is available on these areas. The payment of a water tariff is an aid to establish a lawful use but it does not make the use lawful automatically. Other regional problems are lack of qualified staff, which may explain delay in processing of applications, as the region must visited and volume of transfers verified.

Joubert (2004) further states that a farmer may keep more water rights than what he actually uses in a particular year because he needs it as a security for drought. The point is that water must not be wasted and use must be beneficial. As licenses are not specifically described in the NWA he prefers to issue licences in terms of Chapter 4 of the NWA.

Comrie (2004) at the regional office of DWAF in Nelspruit supports the view of Joubert (2004). Comrie (2004) states that demand exceeds availability during dry periods. The Kwena dam contributes a relatively small part of the water needs of the entire area (Government Water Scheme), which means that a large part of the catchment area falls outside DWAF direct control. All permanent water transfers must be verified and supported by the regional DWAF office at Nelspruit. Transfers of water from tributaries of the Crocodile River would be irresponsible, as this will aggravate the situation of water scarcity and the only route that Comrie (2004) sees is compulsory licensing. The reason why no transfers take place is because there is no unused water to transfer. In future one would expect that used water would be transferred. He concurs with Joubert (2004) that a farmer could retain surplus water for dry periods.

5 ANALYSIS OF PRICES OF PERMANENT TRANSFERS AND RENTALS

5.1 Price trends of permanent transfers

Table 4 shows average trading prices of water from 1994 to 2003. Data for 1994 and 1995 were obtained from Bate *et al* (1999), which also included two transactions in 1995 recorded during this study. The table shows both average price of the transactions, and average price of water weighted by area. The size of transactions (ha) and prices are defined in terms of area above the gorge, which allocates water at a rate of 8000 cubic meters per hectare per annum. Below the gorge the water allocation is 13000 cubic meters per hectare. The range, standard deviation, and coefficient of variation show that there has been a large variation in prices paid per hectare. It appears as if the coefficient of variation in prices has fallen over time, which will occur if information improves.

Prices paid by each *individual* buyer also vary substantially. Two respondents purchased water from 12 and 9 different sellers. The average price received was R3,245 and R4,468. The standard deviation was R1,418 and R2,221 respectively. Since there are few buyers and many sellers, it is likely that there is an asymmetrical distribution of information as buyers have better knowledge about availability and prices than sellers. The price is higher for larger transactions, which may indicate that the bigger the area offered by the seller, the more bargaining power the seller has and can thus negotiate a higher price. There is expected to be transaction costs involved during trading of water. The buyer may also pay a higher price per ha for a larger transaction than for many small transactions due to relatively fixed transactions costs. Some of these transaction costs include lawyer's fees, DWAF administration fees, search costs, and the cost of time spent on setting up the trade (negotiation, search, administration, etc).

Table 4: Trading prices of water in the Crocodile River, 1995 to October 2003

Year	Transactions (Number)	Average Size (ha)	Min (R/ha)	Max (R/ha)	Average Water Price/Ha(1) (R/ha)	Coefficient of variation (%)(2)
1994(3)	9	5.9	688	7164	4065	77.3
1995(3)	10	14.6	848	5064	2446	45.1
1996	1	141.4	6291	6291	6291	NA
1997	5	59.2	2896	5430	3276	30.1
1998	1	28.5	4064	4064	4064	NA
1999	3	80.0	6310	7924	6922	13.0
2000	10	505.5	2444	7520	5864	38.9
2001	1	7.7	2312	2312	2312	NA
2002(4)	5	230.6	2118	3138	2860	14.0
2003(4)	1	27.0	2500	2500	2500	NA

Notes: 1) Weighted average price: total price (R) divided by total area (ha).
2) Standard deviation divided by mean (Spiegel, 1961:73).
3) Data from Bate *et al* (1999) included for these years. Two transactions for 1995 are from the current study.
4) The number of transfers shown in Table 2 for 2002 and 2003 are lower than the number of transactions observed in Table 4 for these years. These transactions in Table 4 have not necessarily been processed by the DWAF; the actual contracts between farmers have, however, been drawn up and signed.
All prices are expressed in real (2003) terms.

5.2 Rental price, water tariff, opportunity cost, and rate of return

Farmers enter into legal contracts for rental agreements usually for a period of one year although in one case the rent period was stated as at least 40 years. One large lessee rented from 12 lessors. The average lease paid for the 12 contracts was R95.0 per hectare with a standard deviation of R21.3 per hectare. This is the price that the lessor receives for an entitlement of one hectare at 8,000 cubic meters per annum[4], which is a price of 1.188 cents per cubic meter. In addition to this, the lessee pays the tariff that applies to the entitlement. The water tariff at present (2004) is R104.88 per hectare per year or 0.777 cents per m^3 below the gorge, and R68.40 per hectare per year or 0.855 cents per m^3 above the gorge. The following interesting economic conclusions can be derived from these data: (a) It is clear that the lessee has asymmetric information as rentals prices vary; (b) The opportunity cost of the water is 1.965 cents per cubic meter (1.188 cents plus 0.777cents) for a water user below the gorge or R255.45 per year per ha (1ha=13,000 cubic meter of water). This is the gain that the market attributes to the scarce resource water at the margin;

[4] *The water allocation above the gorge is lower as rainfall is higher. As cubic meters of water are transferred, a buyer below the gorge needs to purchase 1.625 hectares of water entitlement above the gorge in order to obtain one hectare of water entitlement.*

and (c) With a water rental of R95.04 and a water price of R2,573.5 (average for 2002 to 2003), the real rate of return on an investment in water is 3.7% (from this calculation water tariff is excluded as it is a cost to the lessor). This statistic may be on the low side as farmers may pay more for permanent transfers in this area as it gives them more security of future use. This statistic, however, questions real discount rates in water studies of often as high as 13 percent (Louw, 2001:204).

6. STATISTICAL ANALYSIS

6.1 Principal Component Analysis of variables

Variables associated with areas under irrigation by buyers and sellers were studied using Principal Component Analysis (PCA). The first two components are shown in Table 5. The variable name is given together with a description of what it measures and the loadings of the variable for each component.

Table 5: Definition of variables and their principal component loadings

Variable	**Definition**	**Component**	
		1	**2**
TYPE	= 1 if participant is a buyer; 0 if non-buyer (Dependent variable)	**.740**	.443
CANE	Percentage of total crop planted to sugar cane	**.806**	.246
BANANA	Percentage of total crop planted to banana	.320	.184
CITRUS	Percentage of total crop planted to citrus	.188	.062
NUT	Percentage of total crop planted to macadamia or pecan trees	**-.747**	.417
VEGETBLE	Percentage of total crop planted to vegetable crops	-.046	**-.682**
OTHTREE	Percentage of total crop planted to avocado, litchi and/or mango trees	-.248	-.253
SURPLUS	The difference between total water entitlements owned and irrigated area prior to market transactions	**-.647**	-.206
CROPDI	Index measuring degree of crop diversification	-.438	**.690**
NPV	Net present value of gross margin stream of crops per cubic meter of water used	-.561	**.743**
SIZE	Size of cropped area in hectares	**.647**	.321
Eigenvalue		3.301	2.171
Percentage of variance		30.010	19.734

The first component shows that TYPE, CANE, and SIZE each have strong positive loadings. The NUT and SURPLUS variables have negative loadings. This indicates that observations that score a one for type (buyers) also score highly for CANE and SIZE, which means that buyers are likely to be large sugar cane producers. At the same time buyers are less likely to produce nuts (macadamias and pecans). The PCA also shows that buyers are large sugar cane producers. As discussed in section 4.2, sugar cane is an appealing crop to farmers because of the drought resistance, liquidity and marketing properties that sugar cane provides. In addition, due to the revealed risk averseness of the respondents, these properties of sugar cane are even more appealing because they serve to lower the risk faced from the farming operation by providing a stable source of income and allowing some production of more risky alternatives. The NPV variable has a relatively weak negative loading in this component. This indicates that farmers with a relatively high Net Present Value (NPV) from crop gross margins per cubic meter of water are more likely to be sellers of water entitlements. The NPV variable reflects future expectations of incomes, costs and a discount rate.

It appears as if water moves to lower risk users and that some income may be sacrificed. This supports Bate *et al* (1999) conclusion. The remaining component does not indicate any further relationships with TYPE. The second component suggests that farmers who have a higher NPV are more specialized and produce less vegetables, with some evidence that they may produce more nuts (macadamia and/or pecan).

6.2 Arrow-Pratt Absolute Risk Aversion

Arrow-Pratt Absolute Risk Aversion (APARA) coefficients were calculated for five farmers. The elicitation of responses that were needed for calculation of these scores had to be done during personal interviews due to the nature of the questions. Of the seven farmers personally interviewed, one respondent was not the chief decision maker, and another farmer refused to answer the question. With this limited data, no comparisons between buyers and non-buyers can be made. The median APARA coefficient for the five Crocodile River farmers measured 1.28, which was lower than the estimate of 2.44 for the Orange River Study (Gillitt *et al*, 2004). It is clear that irrigation farmers are risk averse, and when downside risk is measured, the farmers are more risk averse than anticipated in the questionnaire as almost all the farmers in the Crocodile study and in the Orange River study picked the most risk-averse category (an APARA coefficient of 3.28). Farmers would rather receive nothing (choice 1) than being given a 50 percent chance of winning R800,000 and 50 percent chance of loosing R200,000 (choice 2). A risk neutral person will be indifferent between choice 2 and receiving R300,000 with certainty. It is possible that only those who are risk averse have been able to survive in an uncertain environment.

When faced with the chance that money could be won or lost, the farmers chose not to take the risk but would rather take a certain amount with zero gain. They were not asked whether they would pay money to avoid taking the risk. The importance of these findings is that a great cost is attached to risk and whether weather induced or policy induced (insecurity of licenses) this risk will negatively affect investment in irrigation.

7. REGRESSION PROCEDURES

Due to the dichotomous dependent variable, a Linear Probability Model (LPM) was used to estimate the relationship between explanatory variables and the dependent (TYPE) variable. Due to likely collinearity between the explanatory variables mentioned, ridge regression was employed in conjunction with the LPM. Once lease observations were included, the data consisted of eight buyers and 13 non-buyers.

7.1 Linear Probability Model (LPM) of buyers versus non-buyers

Although there are problems with this technique, it is applied as a first step in the analysis[5]. The variables in Table 5 were regressed against TYPE using ridge regression. The ridge trace indicated that regression coefficients stabilize after K=0.15 while the multiple regression coefficient declines by only one percent before this point. Table 6 shows the results of the ridge regression. All the variables except CANE were significant at the one percent level. The R squared value for the model is 76.5 percent and the adjusted R squared value is 70.6 percent. This indicates a very good fit for a LPM. For most practical purposes, the R squared ranges between 0.2 and 0.6 (Gujarati, 1995:546). The F value for the model is 13.00, which is significant at the 1 percent level, indicating that all the variables are jointly significantly different from zero.

Table 6 shows that the most important variable distinguishing whether the farmer will be a buyer or non-buyer is BANANA. The SURPLUS variable shows that farmers who have a surplus of water entitlements prior to the transaction are likely to be non-buyers and farmers with no surplus or deficit are buyers. Buyers tend to farm a larger area (SIZE), and are likely to produce sugar cane (CANE). In short, buyers farm larger areas with relatively more banana and sugar cane crops and do not have a surplus of permanent water entitlements, and probably have a deficit.

---

[5] The problems in estimation of LPM are non-normality of disturbances (the error term follows a binomial distribution), heteroscedastic variances of disturbances, and predicted Y values do not necessarily fall within the range of zero to one. In addition, the computed R^2 value is not a good indication of model fit and is likely to be much lower than one.

Table 6: Ridge regression of LPM variables – buyers versus non-buyers

Variable	B	SE(B)	Standard Beta	B/SE(B) = t
BANANA	0.923	0.199	0.490	4.643
SURPLUS	-0.001	0.000	-0.337	-3.001
SIZE	0.0001	0.000	0.290	2.380
CANE	0.208	0.198	0.133	1.050
Constant	0.108	0.073	0.000	1.480

Note: Dependent variable = TYPE.

It is interesting that the coefficient for the NPV variable was not significantly different from zero. This measure is not collected from individual data due to the time-span of the survey and the volume of information required, but derived from the areas of crops produced by respondents, and projected incomes and costs for each crop from the NOWAC (1999) study and from the Macadamia Growers Association (2004). The model suggests that there is no significant difference in the NPV of gross margins per cubic meter of water between buyers and non-buyers. This finding implies that the market does not lead to a higher value use of water[6]. However, the market does allow farmers to transfer water entitlements in order to plant more crops that are more suited to their risk preference (sugar cane has lower income but less risk) thus allowing better management of risk.

7.2 Logit model of buyers versus sellers

A logit model using the variables from the ridge regression model fails due to a near perfect fit. The crop variables were used in the logit model to determine the crop production patterns of buyers and sellers. Since there is correlation between crops grown, these variables were combined using a PCA. Table 7 shows the component loadings of the crop variables.

The first crop PC has higher loadings for farmers that produce relatively more sugar cane and, to a lesser extent, citrus and lower loadings for farmers that produce relatively more macadamia and pecan nuts. The second crop PC scores highly for farmers with a higher proportion of banana, and a lower proportion of litchi, mango, and avocado trees. These crop PC's were regressed on the dependent variable TYPE using a logit regression model. The

[6] *This finding should be considered cautiously due to problems in measuring the NPV of crops per cubic meter of water. Problems encountered were the different time horizons of crops, rainfall differences between areas, yield variation, differing costs of abstraction of water in different areas, and different irrigation systems. In order to collect the relevant data, individual information about areas and yield, cost and marketing data are required. This may yield a different result in the analysis.*

Cox and Snell R-Square value is 40.6 and the Nagelkerke R-Square value is 55.2 percent. The model chi-square value is 16.972 with two degrees of freedom, which is significant at the one percent level, and thus there is a significant relationship between the dependent variable and the set of independent variables. The Hosmer and Lemeshow (H-L) test chi-square value is 9.892, which yields a p value (significance) of 0.195. This tests the null hypothesis that the data were generated by the model fitted. If the H-L goodness-of-fit test statistic is greater than .05, the null hypothesis that there is no difference between the observed and model-predicted values of the dependent is not rejected, implying that the model's estimates fit the data at an acceptable level. This does not mean that the model necessarily explains much of the variance in the dependent, only that however much or little it does explain is significant. This indicates that the model fits the data moderately well, and the variation explained by the model is significant.

Table 7: Component matrix of crop variables

Variable	Component	
	1	2
CANE	**.758**	-.004
BANANA	.293	**.670**
CITRUS	**.603**	-.433
NUT	**-.825**	-.110
VEGETBLE	-.243	.482
OTHTREE	-.160	**-.593**

The overall classification rate is 91.4 percent, with 95 percent of sellers and 86.7 percent of buyers being correctly classified. The aim of this model is not prediction, so this information is only useful as an indication of fit of the model. Table 8 shows the results of the logit regression of these two crop PC's on the dependent variable TYPE.

Table 8: Logit regression of buyers and non-buyers of water rights

Variable	Beta Coefficient	Standard Error (B)	Wald	Degrees of Freedom	Significance
CROPPC1	1.640	.789	4.321	1	.038
CROPPC2	1.433	.794	3.255	1	.071
Constant	-.983	.731	1.808	1	.179

Note: Dependent variable = TYPE.

CROPPC1 is significant at the one percent level, and CROPPC2 is significant at the 10 percent level. The beta coefficient for CROPPC1 is positive which indicates that farmers that produce relatively more sugar cane and banana, with relatively less macadamia and pecan nuts are likely to be buyers of water entitlements. The beta coefficient for CROPPC2 is also positive and shows that farmers with relatively more banana crop and less other tree crops (litchi, mango, and avocado) are also likely to be buyers of water entitlements in the market. This supports the findings of the ridge regression model shown in Table 5.

8. CONCLUSION COMMENTS

The water market in the Crocodile River above and below the gorge in the Mpumalanga Province was studied based on a survey in the area during November 2003, which was followed up by telephonic interviewing during March 2004. Information was also obtained from various other role players (horticulturists, DWAF, legal experts and the Irrigation Board). The study was undertaken in the same area as the Bate *et al* (1999) study in order to observe dynamic changes in the market.

Almost all the water trades (permanent and rentals) observed in this study were from farmers above the gorge to farmers below the gorge. Horticultural experts familiar with this area attribute this movement of water to the better growing conditions above the gorge. Temperatures above the gorge are not hot enough for the heat loving crops (sugar cane mangoes, grapefruit, Valencia's and bananas) and not cool enough for temperate crops that require coolness. A major problem in citrus orchards above the gorge is the bacteria *Citrus psylla* causing greening in citrus. Crops that do well above the gorge are tobacco and macadamias (although White River appears more suited for Macadamias).

The average water price in this area in recent years (2002 to 2003) was between R2,000 and R3,000 per ha (1ha = 8,000 cubic meter) with no clear trend in real prices of water during the period 1994 to 2003. It appears as if the coefficient of variation in prices has fallen which is attributed to better information about market prices in more recent years. The buyers are large progressive farmers that purchase (and rent) from many sellers (or lessees). Two respondents purchased water from 12 and 9 sellers while one farmer leased from 12 lessors. As the prices paid by a single buyer (or lessee) vary it is concluded that information is asymmetrical. Prices are higher for larger deals, which may indicate better information by larger sellers and probably lower transaction cost on larger deals.

In order to study whether the water market promotes efficiency the data were subjected to several statistical analyses (Principal Components, Ridge

Regression, Logit). It is concluded that in the transfer of water some attributes in the purchasing area such as lower production risk (sugar cane) and lower financial risk and better cash flow (bananas and sugar cane) were more important than the income per cubic meter of water. Water supply in this area is highly irregular while farmers were found to be extremely risk averse especially as far as down-side risk is concerned. The standardised Arrow/Pratt absolute risk aversion coefficient for down-side risk was at least 3.28. The latter number means that a respondent would rather receive nothing (choice 1) than being given a 50 percent chance of winning R800,000 and 50 percent chance of loosing R200,000 (choice 2).

Ridge Regression indicates that buyers of water are associated with deficit farmers, large farmers, and producers of sugar cane and bananas. Although this conclusion is self-evident it is interesting that the net present value of gross margin per cubic meter of water used (NPV) was not significant. In a Principal Component Analysis the NPV was mildly negative associated with buyers of water, which implies that buyers have a lower NPV than non-buyers.

Almost no permanent transfers have taken place in the Crocodile River in recent years and the process has stalled. Some experts are of the opinion that due to the irregular flow of the Crocodile, the demand for water sometimes exceeds supply and that there is no water to transfer. Another expert is of the opinion that farmers below the gorge simply expanded production without having allocations to support it. His view is that water allocations are not greater than availability. Data collected show that buyers below the gorge indeed significantly exceeded their water entitlements and a main reason for buying and renting in water was to reduce this deficit. Only a relatively small part of the Crocodile River is a Government Water Scheme and the verification of existing lawful use of water is more complicated according to DWAF officials. Other parts of the river fall under the (old) Government Water Control Areas (less is known about water use in these areas). It is concluded that there are reasons why transfers at present are not processed and role players should discuss these reasons and possible solutions before further action is taken. This situation is clearly sensitive and should be treated in such a manner. Allowing more trades from previously unused water in the wake of possible water scarcity may aggravate future shortages. The current concession that farmers may irrigate larger areas (30% more) if they use drip irrigation or other water conservation strategies reduces return flow and increases the consumptive use of water. This further aggravates the water shortage problem and it is recommended that the hydrological implications be studied.

REFERENCES

Armitage RM (1999). *An economic analysis of surface irrigation water rights transfers in selected areas of South Africa*. WRC Report No 870/1/99.

Backeberg GR (1995). *Towards a market in water rights: A pragmatic institutional approach.* Discussion paper, Land and Agricultural Policy Centre.

Bate R, Tren R & Mooney L (1999). *An econometric and institutional economic analysis of water use in the Crocodile River catchment, Mpumalanga Province, South Africa*. WRC Report No 855/1/99.

Bower J (2004). *Personal communication*. Discipline of Horticultural Science, University of KwaZulu-Natal, Pietermaritzburg.

Ceronio C (2003). *Personal communication*. Department of Water Affairs and Forestry, Pretoria. Tel: 012-336 8427.

Comrie W (2004). *Personal comment*. Regional DWAF Office, Nelspruit. Tel: 013-759 7313.

Conningarth Consultants (1998). *Database - Economic and financial issues.* Nkomazi/Onderberg Water Action Committee, Pretoria. congarth@global.co.za.

Conradie B (2002). *The value of water in the Fish-Sundays Scheme of the Eastern Cape.* WRC Report No 987/1/02.

Deacon E (2004). *Personal communication*. DWAF, Nelspruit. Tel: 013-759 7300.

Gillitt CG, Nieuwoudt WL & Backeberg GR (2004). *Water markets in the Lower Orange River catchment of South Africa*. Agrekon 44(3):363-382.

Gujarati DN (1995). *Basic econometrics.* Third Edition. McGraw-Hill Inc, New York, USA.

Huffaker RG & Whittlesey NK (1995). Agricultural water conservation legislation: Will it save water? *Choices* 4:24-27.

Howe CW (1997). *Increasing efficiency in water markets: Examples from the Western United States*. In Anderson TL & Hill PJ (eds), Water marketing - the next generation. Roman & Little Field Publications, New York, USA.

Joubert J (2004). *Personal communication*. DWAF Pretoria. Tel: 012-336 8450 Ext 8540.

Louw DB (2001). *The development of a methodology to determine the true value of water and the impact of a potential water market on the efficient utilisation of water in the Berg River Basin*. WRC Report No 943/1/02.

Macadamia Growers Association (2004). *Personal communication*. White River. Tel: 015-307 1520.

Mirrilees RI, Forster SF & Williams CJ (1994). *The application of economics to water management in South Africa*. WRC Report No 415/1/94.

Neter J, Kuntner MH, Nachtsheim CJ & Wasserman W (1996). *Applied linear statistical models*. Fourth Edition, McGraw-Hill Co, New York, USA.

Nieuwoudt WL (2000). Water market institutions in Colorado with possible lessons for South Africa. *Water SA* 26:27-34.

Nieuwoudt WL & Armitage RM (2004). *Water markets in South Africa: Two case studies*. Water Resources Research 40(9), W09S05.

NOWAC (1999). *The role of irrigated agriculture and agro industries in the Nkomazi/Onderberg region of Mpumalanga*. Published by Nkomazi/Onderberg Water Action Committee, Malelane.

RSA (2002). *National Water Resource Strategy, Summary*. Proposed First Edition, Department of Water Affairs and Forestry (August).

Spiegel M (1961). *Theory and problems of stati*stics. Schaum Publishing Co, New York, USA.

Van Aswegen J (2004). *List of farmers who transferred water in the Crocodile River*. Regional Director, DWAF, Nelspruit.

Wolstenholme BN (2004). *Personal communication*. 30 Wavel Drive, Pietermaritzburg.

WRC (2004). *The facilitation of trade in water use entitlements by the National Water Act in South Africa*. WRC Report No 1297/1/04, Pretoria, South Africa.