Establishing tradable water rights: Case studies of two irrigation districts in South Africa

RM Armitage[1]*, WL Nieuwoudt[1] and GR Backeberg[2]
Department of Agricultural Economics, University of Natal, Pietermaritzburg, South Africa
Water Research Commission, PO Box 824, Pretoria 0001, South Africa

Abstract

The study revealed that a market for unused "outer land" water rights had emerged along the Lower Orange River. A discriminant analysis showed that water rights were transferred to farmers with the highest return per unit of water applied; producing table grapes; and with high-potential arable "outer land" without water rights. The institutional arrangements facilitating market development were well defined, reliable, enforceable water rights, that were transferable between irrigable properties; a large number of willing sellers, and an administrative function performed by the Department of Water Affairs and Forestry defining a transparent transfer process, supervising and recording transactions. A second study in the Nkwaleni Valley in Northern Kwa-Zulu-Natal found that no water market had emerged despite the scarcity of water in the area. While 41% of farmers wanted to purchase water rights, no willing sellers of water rights existed. Demand for institutional change to establish tradable water rights seems unlikely since crop profitability in this area is similar for potential buyers and non-buyers, whereas in the Lower Orange region buyers invariably produced highly profitable table grapes. Farmers generally use all their water rights in their farm operations, and may be unwilling to sell water rights for land they have developed as this involves sacrificing capital investment in this land. Farmers pay only for the portion of water they extract in terms of their water rights, but lose income from potential water rentals or sales to industry.

Introduction

Water marketing has been advocated as one means of reallocating scarce water supplies in South Africa (Backeberg, 1997). Allocation of water through a market offers a number of potential advantages. Firstly, it promotes efficiency in allocation by placing water in the most highly valued uses in a flexible manner. Property rights to water empower water users as their consent is required for any reallocation of water and compensation is required for any transferred water. Decentralised information is brought to bear on water-management decisions by enabling individual users to apply first-hand knowledge in determining how much water to apply and which crops to produce. The market process establishes flexibility in response to changes in crop prices and water values as demand patterns and comparative advantage change and crop diversification proceeds. Within a water market, individual users are forced to consider the full opportunity cost of their water use, as well as some external costs related to their water use or transfer. Finally, a water market requires well-defined and enforceable water rights, providing for secure tenure of water and in turn stimulating investment in water-saving technology (Cummings and Nercissiantz, 1992; Howe et al., 1986; Anderson and Leal, 1989; Pingali and Rosegrant, 1995).

In a water economy, the institutional framework determines the feasibility of water-market transactions. Appropriate institutions reduce uncertainty by providing a structure to human relations in the exchange process, and affect economic performance through their impression on costs of exchange and production (North, 1990). The ability of a property institution to foster desired behaviour depends on how exclusively property rights are defined and how effectively it reduces transaction costs (Nieuwoudt, 1990). North (1994) states that deliberate institutional change towards transferable water rights will result from demand by individual users to alter the existing institutional framework. Hayami and Ruttan (1985) contend that the new institution will be implemented if the resulting returns exceed the marginal cost of mobilising the resources needed to introduce the innovation. Implicit in this argument is that individuals are able to take collective action and that their lobby will succeed politically. Individuals do not always act in the interests of the group (Popkin, 1979: 252), therefore institutional change may not be forthcoming owing to problems of collective action or political resistance. This depends on the power balances among vested interest groups and their ability to act collectively to express their lobby (Olsen, 1971; Stiglitz, 1989). If individuals agree to institutional changes, and trade is voluntary, then the new institutional framework can be considered more efficient than the old. Since individuals are driven by self-interest, the institution that evolves as a result of change will allocate resources more efficiently (Buchanan, 1986).

The purpose of this research is to study demand-side responses to water allocation in two irrigation districts in South Africa, by investigating how water markets can lead to more efficient water allocation and use. In the first study area, the Lower Orange River, where water is a scarce resource and production is entirely dependent on irrigation water, one of the highest incidences of market trading of water rights in South Africa has occurred. In the second study area, the Nkwaleni Valley, water is similarly a scarce resource with production wholly dependent on irrigation, but no trading of water rights has occurred. This paper endeavours to highlight the benefits from, and institutional arrangements facilitating, market trading of water rights along the Lower Orange River, as well as the potential for, and institutional changes necessary, to facilitate the operation of a water market along the uMhlatuze River in the Nkwaleni Valley.

Tradable water rights

Requirements for a market in tradable water rights

An efficient water market requires:

- Well-defined rights that are completely specified in the unit of

* To whom all correspondence should be addressed.
☎ (03311) 260-5481; fax (03311) 260-5970; e-mail armitage@agric.unp.ac.za
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measurement, reliability and priority, creating certainty in what is being traded and predictability in the reallocation process.
- Enforceable water rights that secure the net benefits flowing from the use of the water rights for the rights holder.
- Transferable water rights, ideally separate from land use, that create exposure to the opportunity to realise higher valued alternatives (Anderson, 1983; Pigram, 1993).
- Constitutional guarantee of title ownership and legal sanction of water transfers by the relevant government jurisdiction are necessary to provide for secure water rights.
- An efficient administration system to maintain the proper chain of title over the water rights (Simpson, 1992).

Establishing tradable water rights

Reforming water allocation to create tradable water rights requires that the initial assignment of water rights should be perceived as being fair. This can be achieved by basing the initial allocation on historical water use combined with some redistribution of concentrated rights holdings if necessary (Backeberg, 1995). Within individual catchments in South Africa, agreement on the initial allocation may require a sequence of preparation (water balance per catchment), negotiation (procedures to agree on an apportionment as lawful), and implementation (management by local users with some government support). Sacrifices by some users in the interest of equity are possible, but thereafter the water market should be allowed to take effect (Backeberg, 1996).

Water markets are constrained by transaction costs, which if too high can reduce the level of trading that can be profitably undertaken and negate the economic benefits from the water transfer (Hearne, 1995; Saliba, 1987). Transaction costs arise whether water is allocated through administrative control or through the market, and include:

- The cost of identifying profitable opportunities for exchange.
- The costs of negotiating or administratively deciding on the water transfer.
- The cost of monitoring third party effects and other externalities.
- The infrastructure cost of conveying the water and monitoring the transfer.
- The infrastructure and institutional cost of monitoring, mitigating, or eliminating third-party effects and externalities (Rosegrant and Schleyer, 1994).

The institutional arrangements on which a market is designed and by means of which it is regulated have a major impact on transaction costs. Excessive regulation can create high transaction costs, while inadequate regulation can impose unacceptable costs on third parties or the environment (Rosegrant and Schleyer, 1994).

Water markets can fail because of insufficient incentives and accountability due to externalities (Backeberg, 1995). Negative externalities include deterioration in water quality**,** reduction in water availability due to reduced return flows, diminished economic activity in communities from which water is sold, and a reduction in instream values such as recreation, aesthetics and environmental concerns (Colby, 1990; Howe et al., 1990). The return flow externality can be internalised by defining rights as consumptive rights, thus reducing the need for complex transfer proceedings (Martin and Brown, 1987; Griffin and Boadu, 1992). This, however, would not internalise effects such as changes in timing of use, changes in water quality, and in patterns of use (Gould, 1989). Since water-market transactions do not take place under conditions of perfect competition, this necessitates a role for public institution performance in the protection against monopoly development, third party impairment from water trades, and to resolve conflicts among water users (Rosegrant and Binswanger, 1994).

Market trading of water rights along the lower Orange River

The study area

Within the first study area, the study was conducted among irrigation farmers in the Boegoeberg and Kakamas Irrigation Schemes along the Orange River from Boegoeberg to Augrabies in the Northern Cape Province. The study area can be divided into two river reaches. The first stretches from Boegoeberg to Upington and incorporates the Boegoeberg Irrigation Scheme. The second stretches from Upington to Augrabies and incorporates the Kakamas Irrigation Scheme. The area is arid; precipitation declines from 400 mm/a to less than 200 mm/a in the West. The hottest conditions and highest evaporation rates in South Africa are experienced in this area (McKenzie et al., 1991).

Data collection and characteristics of respondents

A cross-sectional survey of 54 irrigation farmers was conducted during November 1997. The target population was identified with the assistance of the regional Department of Water Affairs and Forestry (DWAF) office, and was composed of three separate strata. The first stratum, Buyers, consists of all 11 farmers in the study area who had bought water rights. A random sample of 25 farmers (40%) who had sold water rights to other farmers, Stratum 2, represents the Sellers. Stratum 3, the Control, encompasses all 18 farmers who had river water rights but did not engage in any water trading activity. A questionnaire was completed by individual farmers during personal interviews conducted in the survey. Nine, 21 and 14 usable questionnaires were obtained from Strata 1, 2 and 3 respectively.

Eight of the nine Buyers were located in the second river reach from Upington to Augrabies, while all 21 Sellers and all but one of the Control farmers were located in the first reach from Boegoeberg to Upington. Buyers had a larger farm size mean (1 280.5 ha) than both the Sellers (132.0 ha) and Control farmers (87.5 ha). Buyers also had on average proportionately more arable land that could be developed for irrigation purposes (67%) than either the Sellers (25%) or Control farmers (24%). Differences in cropping programs and irrigation systems between the strata also exist. About 64% of Buyers' irrigated land are under table grapes, 17% under raisin and wine grapes, and 18% under horticultural crops (date, vegetables, melon and citrus). Sellers had 54% of their irrigated land under field crop production (wheat, maize, cotton, lucerne) and 44% under raisin and wine grape production. The Control farmers were similarly diversified, with 56% of their irrigated area under field crops and 36% under raisin and wine grape production. Flood irrigation systems were found on almost the entire irrigated area of Sellers (96%) and Control farmers (94%). Buyers used primarily micro systems (54%), and to some lesser degree flood systems (30%) and drip systems (16%). This information shows that Buyers may have attached greater value to water.

Transfers of "outer land" water rights along the Lower Orange River

A market for "outer land" water rights emerged along the Lower Orange River in late 1994. "Outer land" is land adjacent to but inland from the canal, coupled to a river water right. Water transactions were driven by the desire of large-scale table grape producers, with large holdings of arable "outer land" without water rights, to expand their operations. The sale price (1996 value) for "outer land" water rights ranged from R800 to R5 000/15 000 m^3·ha, with an average price of R3 378.89/15 000 m^3·ha. The overwhelming majority of water rights sold for R3 000/15 000 m^3 or R3 500/15 000 m^3. The variation in price may be the result of market information imperfection for the R5 000 transfer, while the R800 transfer may have been the result of a family transfer. An examination of land prices has revealed that undeveloped arable land coupled to a water right within the study area generally sells for R6 000 to R10 000/ha, while dry land suitable for irrigation and for which a farmer could obtain a water right generally sells for R1 000 to R2 000/ha. This information confirms that the trading value of "outer land" water rights is approximately R4 000/ha (R6 000 - R2 000). If the mid-value of undeveloped arable land with a water right is considered to be R8 000, and the mid-value of irrigable dryland is considered to be R1 500, then it can be seen that the sum of the value of irrigable dryland and the value of a water right (R1 500 + R3 400 = R4 900) is considerably lower than the value of the undeveloped arable land with a water right. From this it can be deduced that higher security and value is attached to land with a water right.

The institutional arrangements facilitating water rights trading along the Lower Orange River

Development of the water market was achieved within a centralised non-market water allocation system that was highly controlled and regulated by DWAF. Trading of water rights emerged despite a significant extent of bureaucratic regulation imparted on the water market. While some regulation of water trades is desirable within the context of a water market, much of the regulation governing transfers of "outer land" water rights serves to increase transaction costs unnecessarily. The institutional arrangements facilitating market development along the Lower Orange River are discussed below.

Initial allocations of water rights in the study area were contingent to land characteristics of individual farms. Arable land between the river and the canal, "inner land", was allocated a canal water right under the initial settlement of the irrigation scheme in 1933 and in terms of the 1956 Water Act (DWAF, 1997). Land adjacent to but inland from the canal, "outer land", was allocated a river water right for a maximum of 30 ha by the state from October 1977 (*Government Gazette*, 1977). Individual farmers had to apply to the regional DWAF to incorporate the "outer land" water right into their property. This involved a bureaucratic process in which farmers were required to obtain a cultivation certificate from an appointed soil scientist from the Department of Agriculture, serving as proof of the extent of their property's "outer land" that was irrigable; within 2 km of the river; and not higher than 60 m above the river. The application for incorporation and the soil scientist's report would be evaluated by DWAF head office in Pretoria. Following approval, a water right coupled to the land area specified by the "cultivation" certificate, up to a maximum of 30 ha, would be granted to the farmer by the regional DWAF office (DWAF, 1997). Many farmers found it uneconomic to develop their "outer land" for irrigation purposes owing to the unsuitability of this land in supporting cropping enterprises. This generated a bank of unused water rights that expedited the subsequent reallocation of water from low-potential to high-potential "outer land" through the market.

Secondly, the unit of measurement of "outer land" water rights was completely specified as a diversion right of 15 000 m^3/ha·yr. The quantity of the annual water right was set by the DWAF at the beginning of each water year according to hydrological conditions and anticipated demand. Individual farmers' river water rights were found to have a high-implied reliability since a river water quota of 15 000 m^3/ha·yr was effectively declared in each year since river water quotas were initially allocated in 1977. Only in 1993 was a restriction placed on water extraction, with a 50% reduction in water quotas for the first four months of the year due to severe drought. This was restored to its original value for the remainder of the year after favourable rains. The specification of all irrigation water rights as proportional, allowed the extent and risk associated with restrictions to be spread equally among all rights holders. Irrigation rights also enjoyed high priority, assuring irrigators of rights senior to industrial water rights, and junior only to basic human water requirements and stock-watering requirements. This created certainty among parties as to exactly what was being traded, and predictability in the outcome of the reallocation process.

Thirdly, "outer land" water rights were transferable between irrigation properties, and legally sanctioned by government from May 1993. The delegation of authority for the approval of water transfers, in accordance with a policy as determined by the Minister, was prescribed to DWAF officials in an internal memorandum at the beginning of 1993. However, before individual transfers could proceed, a number of bureaucratically determined conditions had to be satisfied. As a result of these regulations, water transfers were not simple voluntary trades between two parties, but rather negotiated transfers between the two parties and bureaucratic authorities. In the consideration of applications for the permanent transfer of water rights from one owner's land to another:

- It had to be technically possible to supply water to the property to which the scheduling was to be transferred, and all costs, if any, inherent in moving the point of supply had to be borne by the buyer.
- There had to be sufficient irrigable land on the property to which the water was being transferred.
- The regional DWAF office, Department of Agricultural Development, and local extension officers had to support the transfer from an agricultural perspective.
- The property from which water rights were being transferred could not be encumbered by the Land Bank, or no objection to the permanent transfer of the water indicated by the Bank (DWAF, 1993).

The transferability of "outer land" water rights among irrigable properties created exposure to farmers with poor "outer land" soils to realise higher valued alternatives through the transfer of these rights to table grape farmers with more fertile "outer land". However, the coupling of "outer land" water rights to land prevented any transfers of irrigation water to higher valued urban uses, eliminating the potential to generate water savings within the agricultural sector that could be reallocated to urban uses.

The controlled environment in which water rights were allocated assured that the benefits from the use of the water were secured for the right holder. Conflicts among "outer land" water-

right holders were non-existent, owing to the fact that only fractions of allocated "outer land" water rights were being exercised. From the survey sample, 72% of sample farmers believed it was not possible to withdraw more water than specified in their "outer land" water rights without any resulting penalties. However, a high percentage of farmers (40%) were unsure of what penalties would follow over-extraction, and 45% were unsure as to what method was being used to monitor their river water extraction by the DWAF. This may be due to a large number of farmers with river water rights either irrigating only a fraction of the land coupled to the water rights or not making use of the water rights at all. This substantial buffer of unused rights may mean that monitoring of river water extraction is not a critical issue to farmers. This situation may change in the future, as more river water rights are exercised, requiring more intensive monitoring of pump meters and the existence of a transparent penalty structure.

The administrative function performed by the regional DWAF office was central in the successful establishment and functioning of the regulated water market. The transfer process as specified by DWAF was clearly defined and well understood by potential market participants. The transfer process was, however, guided heavily by bureaucratic regulation. Farmers were required to prove that any land for which an application had been filed to purchase water rights, was suitable for irrigation. A potential buyer was required to obtain a cultivation certificate for the land for which he intended to buy water rights. Both buyer and seller were required to file a joint application, with the services of a lawyer at a cost to the buyer, with the regional DWAF office to have the water rights permanently transferred from the seller's property to that of the buyer's. The application was submitted to the DWAF head office in Pretoria for consideration and approval. Following approval to transfer the water, the regional DWAF office would conclude the transaction, and the transfer of the water rights would be formally registered. This supervising and recording function of DWAF was important in maintaining the correct chain of command over water rights and ensuring that transfers were concluded within three to six months. In addition DWAF performed an important role as provider of market information, matching potential sellers and buyers. On the other hand, transaction costs may have been unnecessarily high as a result of the elaborate bureaucratic conditions that had to be satisfied before transfers could proceed, and in the approval process governing voluntary transfers of water rights. Sellers faced transaction costs of R200 to R600 per transaction, stemming primarily from the cost of hiring a soil scientist to assess the "outer land" for which they were applying to incorporate an "outer land" water right, and to a lesser extent from the effort in completing and filing the transfer application. Buyers faced higher transaction costs of R2 000 to R6 000 per farm arising primarily from the legal cost involved in the application and transfer process, and to a lesser extent from the cost of a soil scientist to assess the land for which they were applying to buy water rights, and the effort in filing the application. In addition, the onus was on the buyer to bear any infrastructure costs needed in transferring the water to the future point of use. This generally involved the cost of electricity, pumps and pipes, and represented a significant investment on the part of the buyer. The high fixed transaction cost in the transfer process arising from legal fees may have ruled out small transfers. As a result the market is quite imperfect.

Finally, the specification of water rights as diversion rights, allowed for transfers within the Lower Orange River for the full quantity for the water-right allocation. Since no return flow had been calculated and implemented for water rights within the Lower Orange irrigation scheme, there was no onus on buyer or seller to determine the effects of the transfer on the other water users. This enabled transfers to be achieved through administrative procedure with no lengthy adjudication processes, to ensure there were no adverse impacts associated with each particular transfer.

Discriminant analysis between buyers and non-buyers of water rights along the Lower Orange River

Discriminant analysis was used to distinguish between those farmers who had bought water rights (Buyers) and those farmers who had either sold water rights or not engaged in any water-market trading (Non-Buyers). The dependent variable in the analysis, **Bght**, was constructed using one (1) for farmers who had bought water rights and zero (0) for farmers who had not bought water rights.

The set of discriminating variables on which the respondents are expected to differ are presented in Table 1. It was hypothesised that water rights would move from lower-valued to higher-valued uses through the market mechanism. Buyers are consequently expected to be growing table grapes (**Tblgp**), while Non-Buyers are expected to be producers of wine or raisin grapes (**Vine**). Water rights are likely to gravitate to the most effective users of water for which the estimated return (**Retrn**) per unit of water applied is expected to be the highest. In a water market both buyers and non-buyers have the incentive to adopt water-saving technology as water has an opportunity cost. Any transaction costs will drive a wedge between buyers and non-buyers of water rights, consequently forcing buyers to be more frugal users of water rights. Buyers would likely be making greater use of micro and drip-irrigation systems (**Iritec**). An institutional control variable, (**Incont**), measuring the ratio of actual irrigated area to total farm size was included in the analysis. The ratio of this control variable is influenced by the initial bureaucratic allocation of water rights to "inner" and "outer land", as well as the subsequent reallocation of water to undeveloped "outer land" through the market. No *a priori* expectation is associated with this variable. Buyers were expected to have proportionally more arable land that could be developed for irrigation purposes (**Potdev**). The availability of high-potential "outer land" is expected to be an important factor in influencing farmers' decisions regarding water trading. Buyers are hypothesised as being located in the river reach from Upington to Augrabies and using only a fraction of their available arable land (**Usear1, Usear2, and Usear3**).

The results of the discriminant analysis to determine which variables distinguish between Buyers and Non-buyers are presented in Table 2.

The most significant variable discriminating between Buyers and Non-Buyers was the estimated return per unit of water applied (**Retrn**), showing that water rights tended to move to the most effective users of water. The next most important variable was whether the farmer grew table grapes (**Tblgp**), showing that water rights transferred to the highest valued agricultural uses. These two variables had a correlation coefficient of 0.44, which was non-significant at the 10% level of significance. The third most important variable, **Potdev**, shows that Buyers have proportionally more arable land that can be developed for irrigation purposes than Non-Buyers. The location of the farmer in the river reach from Upington to Augrabies, and whether he was utilising 25 to 50% (**Usear2**) of his arable land was the next most significant variable. **Incont**, the ratio of actual irrigated land to total farm size was the fifth most significant discriminator between Buyers and Sellers. Finally, the least significant variable, **Vine**, shows that Non-Buyers tend to be wine-grape and raisin-grape farmers.

TABLE 1
DEFINITION OF VARIABLES USED TO DISCRIMINATE BETWEEN BUYERS AND NON-BUYERS OF WATER RIGHTS ALONG THE LOWER ORANGE RIVER (n=44)

Variable	Definition
Bght	=1 if respondent bought water rights, 0 otherwise.
Retrn	A proxy variable calculated as the ratio of farm gross margin from irrigation enterprises to total farm irrigation water requirement.
Potdev	Ratio of undeveloped arable land to total potential arable area.
Tblgp	=1 if respondent grows table grapes, 0 otherwise.
Iritec	=1 if respondent uses micro and/or drip irrigation, 0 otherwise
Incont	Ratio of actual irrigated area to total farm size.
Usear1	=1 if respondent is located in the river reach from Upington to Augrabies and uses 50% to 75% of his total potential arable land, 0 otherwise.
Usear2	=1 if respondent is located in the river reach from Upington to Augrabies and uses 25% to 50% of his total potential arable land, 0 otherwise.
Usear3	=1 if respondent is located in the river reach from Upington to Augrabies and uses 0% to 25% of his total potential arable land, 0 otherwise.
Vine	=1 if respondent grows wine and/or raisin grapes, 0 otherwise.

TABLE 2
ESTIMATED DISCRIMINANT FUNCTION BETWEEN BUYERS AND NON-BUYERS OF WATER RIGHTS ALONG THE LOWER ORANGE RIVER (n=44)

Explanatory variable	Standardised coefficient	F-value
Retrn	0.632	11.34*
Tblgp	0.410	5.86*
Potdev	0.409	4.58*
Usear2	0.322	3.06*
Incont	0.261	1.94*
Vine	-0.195	1.11*

* denotes statistical significance at the 1% level of probability

F-value	33.15*
Wilks' Lambda	0.157
Canonical correlation	0.92

The overall F value of 33.15 indicates that the four retained independent variables together distinguish significantly between Buyers and Non-Buyers. The Wilks' Lambda of 0.157 and canonical correlation coefficient of 0.92, indicate that the function is effective in classifying respondents correctly. Explanatory power was checked by comparing predicted with actual group membership. The discriminant function classified 100% of the cases correctly, but the classification results of 100% are upwardly biased since the same cases were used to derive the discriminate function and classify cases. The disparity in size of the two sample groups may also have biased classification in favour of the larger group.

Water allocation in the Nkwaleni Valley

The study area

The study was conducted among irrigation farmers of the Nkwaleni Irrigation Board (NIB) along the uMhlatuze River in Northern KwaZulu-Natal. The study area extends downstream from the Goedertrouw Dam to the confluence of the uMfuli and uMhlatuze Rivers. This area is semi-arid with mean annual precipitation and evaporation rates of 766 mm and 1618 mm respectively. Fertile alluvial soils derived from Beaufort and Middle Ecca are found in the Valley (KwaZulu Department of Agriculture and Forestry, 1990). Sugar and citrus are the predominant crops, with more than 30% of South Africa's grapefruit crop produced in the valley.

Data collection and characteristics of respondents

A survey of irrigation farmers was conducted during May 1998. The total population of 25 farmers comprising the NIB were surveyed by means of personal interviews. A questionnaire was completed by individual farmers during personal interviews. Twenty-two usable questionnaires were obtained from the survey. Two groups were identified from the sample data. The first, Buyers, comprised farmers who wanted to buy water rights, while the second, Non-Buyers, includes potential sellers of water rights and farmers who are neither potential buyers nor sellers.

Potential Buyers had a smaller farm size mean of 376.7 ha, as opposed to Non-Buyers with a mean of 524.4 ha. Potential Buyers also had proportionally more arable land on average (14.5%) that could be developed for irrigation purposes than Non-Buyers (7.8%). Potential Buyers' irrigated land was primarily under sugar (70%) and citrus (26%) production. Non-Buyers irrigated less sugar (56%) and more citrus (38%) on average than Buyers. Irrigation system use is similar on average between both groups. Buyers use overhead sprinklers (71%), micro (22.5%), drip (4.3%), and under-tree sprinklers (2.2%). Non-Buyers were found to use overhead sprinklers (61%), micro (22%), under-tree sprinklers (14%), and drip (1.5%).

The institutional arrangements governing water allocation in the Nkwaleni Valley

Initial allocations of water rights in the Nkwaleni Valley were also dependent on land characteristics of individual farms. "Inner land" water rights of 50 ha per farm were allocated in the initial settlement of the irrigation scheme in 1933. Each individual settlement consisted of 50 ha of "inner land", and approximately 170 ha of dry land ("outer land"). The scheduling of the total irrigable area in the Nkwaleni Valley was concluded in 1994, following the declaration by DWAF in 1977 that the Nkwaleni Irrigation District would now be a government water control area. Individual farmers were allocated a water rights permit for up to 80% of their potential irrigable land, consisting generally of both a canal and river water right. In accordance with the issue of permits for scheduled land, riparian land was allocated a water right for 20 ha plus 30% of the potential irrigable area, provided it was within 2 km of the river and not higher than 60 m above the river.

Water allocation within the NIB is highly regulated and well controlled. Farmers are required to place a water order with the water bailiff of the NIB each Monday morning, for a certain volume of canal and/or river water to be extracted from a specified pump during the following week. DWAF at Goedertrouw Dam would accordingly release the specified volume of water into the canal and

river in the following week. All pump meters are calibrated to measure electricity units used in pumping water from the source. A conversion factor is used to determine the volume of water and pro rata charge for the water extracted. Monthly monitoring of individual pump meters is undertaken by the water bailiff to ensure that ordered water and actual water use is equivalent, and that water allocations are not being exceeded. Most canal water is delivered through fixed-flow dividers that apportion water on a fixed volume throughout the year.

After rain has fallen in the valley, the canal is closed by the water bailiff and river water extractors are able to cancel their weekly water orders. This situation prevails until irrigators once again require irrigation water. Following good rains, water overflowing the Goedertrouw Dam and entering the system from downstream inlets is deemed extra water by the DWAF. This allows farmers to cancel weekly water orders and extract as much extra water as necessary. Extra water extracted from the river is not deducted from individual farmers' annual water allocations; however, it is metered and each farmer is required to pay the cost thereof. Some farmers have constructed storage dams to improve their flexibility of water use and water supply availability throughout the year. Such farmers are able to take advantage of lower cost pumping times and store this water for irrigation.

The annual water-right allocation is set by DWAF at the onset of each water year, according to hydrological conditions and expected demand for the water year. Historically, an annual water levy was charged to irrigation farmers for the full water-right allocation, regardless of whether the entire water allocation was extracted by the individual farmer. However, an agreement reached between the DWAF and NIB in 1996, gave farmers the opportunity to pay a pro rata levy for each m^3 of water used up to their maximum water allocation, for a period of six years. This policy attempts to encourage irrigators to use their water rights more efficiently, generating water savings that can be temporarily reallocated to industry. Farmers paid R135/12 600 $m^3 \cdot ha$ for their full water allocation of both canal and river water in 1997. Canal irrigators paid an additional canal maintenance fee in the region of R34/ha for the 1997 water year. These levies appear to be relatively small in comparison to development costs of arable land and potential returns from irrigation.

Water rights on the uMhlatuze River have a low implied-reliability as a result of variability in river flows. Although a water-right allocation of 12 600 m^3/ha was declared for both canal and river rights since the area had been proclaimed as a water-control area in 1977, these rights are essentially highly variable since restrictions on water extraction have frequently been enforced. Restrictions take on one of three phases. Phase 1 involves a 50% reduction in irrigation water allocations. Phase 2 results in a 70% reduction in irrigation water allocations and a 5% reduction in the downstream industrial water allocations of Empangeni and Richards Bay. The final phase (Phase 3) of restrictions for severe drought conditions is a 90% reduction in irrigation water allocations and a 10% reduction in industrial water allocations. Restrictions that have not gone further than Phase 1 have occurred in four years over the past 18 year period. Restrictions that have progressed to Phase 2 have been invoked three times over the same period, while Phase 3 restrictions have been implemented in two years. As a result, irrigation water along the uMhlatuze River exhibits both low reliability and priority.

The potential for water-market trading along the uMhlatuze River

The survey revealed that no water-market activity had occurred in the Nkwaleni Valley. No farmers purchased or rented in water rights from another farmer, nor had any sample farmers sold or rented out water rights to another party. Forty-one per cent of the sample farmers stated that they were in the situation where they needed additional water at present. If permitted to freely buy or rent water rights, 41% stated that they would like to purchase water rights at present, while only 9% stated that they would be willing to rent in water rights - and only as a second option to the purchase of water rights. The reasons why these farmers had not bought or rented in water rights in the past are presented in Table 3 below. The table shows most potential Buyers believed no one was willing to sell their water rights.

If permitted to freely purchase or rent in water rights in future, 50% of farmers stated they would be willing to purchase water rights if necessary, while 45% stated they would be willing to rent in water rights if needed. No survey farmers stated that they had any excess water for their farm. Similarly, no farmers reported that they would like to sell or rent out any water rights at the present time. Only five of all sample respondents stated that they would be willing to sell any excess water that they had for their farming operations in future. Twelve farmers, however, conceded that they would consider renting out any excess water rights that they may have in the future. A cursory examination of land prices in the Nkwaleni Valley reveals that dry land suitable to irrigation generally sells for R1 000 to R1 200/ha, while undeveloped arable land coupled to a water right generally sells for R4 000 to R5 000/ha.

Growing industrial and municipal water demands from Empangeni and Richards Bay have placed enormous pressure on water supplies in the uMhlatuze River. Industrial concerns have invested in excess of R100 m. in an emergency pumping scheme, piping water from the Tugela River to the Goedertrouw Dam. Plans are afoot by DWAF to increase this pumping scheme on a significantly larger scale. Additionally, industrial concerns have approached farmers within the NIB with the intention of purchasing a portion of their water rights for both industrial and mining uses downstream. As yet no transfers of water rights have taken place with farmers preferring to retain their water right allocations.

Survey farmers' perceptions about water trading within the Nkwaleni Valley are elicited in Table 4.

TABLE 3
REASONS PREVENTING POTENTIAL BUYERS OF WATER RIGHTS FROM BUYING

Reason	No. of farmers (n=9)	
	Purchase	Rental
Water rights purchase/rental is too expensive	1	1
Irrigation board does not allow water rights purchases/rentals	2	-
It is illegal to purchase/rent in water rights	2	-
No one is willing to sell/rent out their water rights	6	1
Water savings from a scheduled change to drip irrigation may satisfy water requirement	2	-

TABLE 4
INDIVIDUAL FARMERS' PERCEPTIONS ABOUT WATER TRADING WITHIN THE NKWALENI VALLEY, MAY 1998

Statement (n=22)	Yes	Uncertain	No
Do you believe farmers should be able to trade their water use allocations?	14	2	6
Do you believe there is sufficient demand for water in your area to facilitate the operation of a water market?	13	3	6
Do you believe a water market could function successfully in your area?	11	2	9

TABLE 5
DEFINITION OF THE VARIABLES USED TO DISCRIMINATE BETWEEN BUYER AND NON-BUYERS OF WATER RIGHTS IN THE NKWALENI VALLEY (n=22)

Variable	Definition
Bght	=1 for Buyers and 0 for Non-Buyers.
Sugr	=1 if respondent grows sugar-cane, 0 otherwise.
Citrs	=1 if respondent grows citrus, 0 otherwise.
Potdev	Ratio of undeveloped arable land to total potential arable area.
Incont	Ratio of actual irrigated area to total farm size.
Iritec	Ratio of cultivated land under drip and/or micro irrigation.
Suff	=1 if respondent does not have sufficient water to irrigate all potential arable land, 0 otherwise.

The majority of respondents believed farmers should be able to trade water rights allotments, and that sufficient demand for water exists in the Nkwaleni Valley to facilitate a water market. However, 41% of respondents believed a water market could not function successfully. From their responses it appears that this subset of respondents are not familiar with the implications of a water market. Thirty-six per cent of these respondents believed no tradable margin of water would exist as farmers required all their water in their farm operations, and would consequently not be willing to sell or rent out water rights. These respondents contended that no farmer would willingly sell water rights as this would render the land agriculturally useless. However, the respondents did not consider the compensation received for such a transfer, or the fact that the value of the land to which water is transferred would increase. The other 5% of these respondents believed a tradable water margin could not exist as this water would automatically be reallocated to industry in dry years. Twenty-three per cent of all sample respondents believed sales of irrigation water to industrial uses should not be permitted as this would take land out of production and may have negative effects on the agricultural region as a whole. Similarly, the farmers did not consider the compensation that they would receive for the sale of any water rights.

Of the 11 respondents believing market trading of water rights could take place, two perceived that most properties required certain amounts of water to develop uncultivated land. Five respondents believed that a market could develop in response to the scarcity of water and low rainfall in the area. This could be achieved through the switch to more efficient irrigation technology in response to continually increasing water charges, enabling conserved water to be sold or rented out.

Discriminant analysis of potential buyers and non-buyers of water rights in the Nkwaleni Valley

Discriminant analysis was used to differentiate between those respondents who wanted to purchase water rights (Buyers) and those who did not want to buy water rights (Non-Buyers). A dependent variable **Bght** was constructed using one (1) for farmers who wanted to buy water rights and zero (0) for farmers who did not want to buy water rights. A set of discriminating variables on which respondents are expected to differ is presented in Table 5.

Potential Buyers of water rights are expected to be those farmers who require additional water for their farm operations or to expand production on previously unscheduled land. An institutional control variable (**Incont**), measuring the ratio of actual irrigated area to total farm size was included in the analysis. No *a priori* expectation is associated with this variable as the ratio of this control variable is ultimately influenced by the historic bureaucratic allocation of water rights. Potential Buyers of water rights were hypothesised to have proportionally more arable land that could be developed for irrigation purposes than Non-Buyers (**Potdev**). Buyers were also hypothesised to be those farmers who had adopted water saving micro-irrigation or drip-irrigation systems (**Iritec**) as a response to irrigation water scarcity. Buyers were also expected to be those farmers who did not have sufficient water in terms of their rights (**Suff**), to irrigate all of their available arable land. Crop choice was also expected to be an important variable in determining whether a farmer wanted to buy water rights or not.

The most significant variable discriminating between potential Buyers and Non-Buyers was whether the farmer grew sugar-cane (**Sugr**). Potential Buyers of water rights have large holdings of sugar-cane from which favourable returns from irrigation could be attained. The second most important variable, **Incont**, shows that potential Buyers of water rights are using their total farm area less intensively than Non-Buyers. The third most significant variable, **Citrs**, shows that potential Buyers of water rights generally grow less citrus than Non-Buyers. The sign of this variable may be circumspect, but may be attributable to the recent fall in grapefruit prices. The fourth most important variable was whether the farmer had adopted water saving micro-irrigation and/or drip-irrigation systems (**Iritec**). The least most significant variable, **Potdev**, shows that potential Buyers of water rights generally have a greater proportion of their total arable area that can be developed for irrigation purposes than Non-Buyers.

The overall F value of 5.86 indicates that the five retained independent variables together distinguish significantly between Buyers and Non-Buyers. The Wilks' Lambda of 0.353 and canonical correlation coefficient of 0.81, indicate a good discriminant function but suggest that some discriminating information has not been extracted by the independent variables. The discriminant function classified 95.45% of cases correctly. Again this classification rate is biased as the same cases were used to estimate the

TABLE 6
ESTIMATED DISCRIMINANT FUNCTION BETWEEN POTENTIAL BUYERS AND NON-BUYERS OF WATER RIGHTS IN THE NKWALENI VALLEY (n=22)

Explanatory variable	Standardised coefficient	F-value
Sugr	2.295	24.49*
Incont	-2.017	14.19*
Citrs	-1.595	9.97*
Iritec	1.224	8.51*
Potdev	1.033	3.83*

* denotes statistical significance at the 1% level of probability

F-value	5.86*
Wilks' Lambda	0.353
Canonical correlation	0.810

function and classify cases. Additionally, bias resulting from the small sample size (n=22) which falls short of the acceptable sample size of 30 cases may have been introduced into the discriminant function.

Discussion and policy implications

The water market that emerged along the Lower Orange River was not fully developed since only the reallocation of unused "outer land" water rights was facilitated through the market function. Inter-sectoral trading was not permitted, nor was market transfer of canal water enacted. Although water rights and land were not used in fixed proportions, allowing a farmer to save water and irrigate a larger area or transfer the saved water through the market, no transfers of conserved water had developed in practice. A possible reason for this is that farmers prefer to retain conserved water for water supply security. No temporary water transfers had taken place, which may be explained by the high fixed costs involved in transporting the water to the "outer land" and developing this land for irrigation purposes, and the high fixed transaction cost of hiring a lawyer in the transfer process.

Discriminant analysis results highlight the efficiency improvements resulting from market allocation. The estimated return per unit of water applied was the main variable discriminating between Buyers and Non-Buyers, showing that water tended to transfer to the most effective farmers best able to utilise the water in their farm operations. Water rights also moved from potentially lower valued users, with the opportunity to cultivate only wine and raisin grapes, to table grape farmers representing the highest potential valued use of the water right. In addition, the efficiency gains in bringing fertile undeveloped arable "outer land" into production are highlighted by the results, by showing that Buyers have proportionally more arable land that can be developed for irrigation purposes.

While participation in the market proved successful in transferring "outer land" water rights, a number of institutional challenges to the *status quo* regarding water trading could strengthen the market and extend its applicability to include all categories of irrigation water rights. These include:

- Allowing farmers to develop land without the need to obtain a cultivation certificate. In this way participants in the market process will determine which land will be developed for irrigation and farmers can expand production using conserved or purchased water. Water rights would be expected to transfer to the highest valued uses generated from the more productive soils.
- Reducing the bureaucracy involved in obtaining approval of water rights transfers, by eliminating necessary sanction from the DWAF head office, will improve the ease with which market transactions occur. However, this may be tempered by providing the regional DWAF office with the authority to supervise transactions, and to prevent and resolve conflicts among users.
- Continuing the administrative function performed by the regional DWAF office in recording and monitoring water transfers. Extending this support to allow for the reallocation of canal water and any conserved water, through permanent or temporary transactions, as and when the demand arises will promote the resultant market.
- Over time, the restriction that water transfers occur only within the irrigation sector could be relaxed by separating water rights from land use to allow for inter-sectoral trading of water rights. This would allow potential sellers to sell water to higher valued municipal or industrial uses and receive effective compensation while at the same time generating the expected water savings within the irrigation sector.

Since transfers generally involved a transfer from non-use to table grape irrigation, changes in the pattern of water use in the study area due to water-market activity may create marginal impacts on lower basin water users and the environment. Agricultural users in lower basins may face increased water salinity as a result of increased upstream irrigation water use. Instream flows to sustain the environment, the reserve to meet basic human needs, and normal flow to satisfy equity objectives in South Africa must be considered. For these reasons, trading of water-use rights in the future will only take place over and above the reserve; which constitutes basic human needs, instream flow requirements, and international obligations. Procedures to identify negative external effects of a transfer and to resolve conflicts among users by the regional DWAF, along with the definition of a transparent channel for airing grievances arising from water trading activity, may become necessary as water demand rises.

In contrast to the Lower Orange River where demonstrated demand by individual farmers preceded the establishment of the water market, it seems unlikely that similar demonstrated demand in the Nkwaleni Valley for change in the institutional framework to enable trading of water rights will develop amongst irrigation farmers under current arrangements. Potential market development is shown by a significant number of farmers who want to purchase water rights at present, and a high and rapidly increasing demand for water by downstream industrial and municipal concerns in Empangeni and Richards Bay. However, this market potential appears to be constrained by the lack of any willing sellers of water rights. A number of reasons may explain this. Firstly, crops produced by potential Buyers (70% sugar-cane and 26% citrus) in the Nkwaleni Valley are not vastly more profitable than crops produced by Non-Buyers (56% sugar-cane and 38% citrus). This contrasts with farmers in the Lower Orange River where Buyers of water rights invariably produce highly profitable table grapes. Secondly, transaction costs may exceed the difference in value of water to the potential buyer and seller. Farmers may also wish to

retain surplus water for security against drought, owing to the unreliable nature of river flow in the region. Finally, farmers appear to be using all their water in their farm operations and may be unwilling to sell water rights for land they have already developed, as this would involve sacrificing the development cost of the land.

Under present conditions, farmers currently have the option of paying only for each cubic metre of water extracted up to their maximum water allocation. Any unused agricultural water is temporarily reallocated to industry downstream by DWAF. This reallocation occurs without the farmers having to spend effort permanently or temporarily alienating the unused rights, and reduces risk by ensuring that the farmer retains title to the entire water right allocation in future. While many farmers perceived this to be beneficial, farmers with unused water lose income from potential rental (or sale) transactions with industry under such a system. As a result, political resistance to the development of a water market in future may be likely from industrial users who are currently reallocated unused agricultural water without having to compensate the farmer.

A potential tradable margin of water rights may develop in future as farmers switch to more effective water saving drip and micro-technology in response to rising water levies. These levies have increased over 50% annually over the past two years. The existence of a number of private storage dams and extensive canal infrastructure in the Nkwaleni Valley would further delivery of purchased water rights, and flexibility in the allocation process. Initiating institutional change towards market trading of water rights in the Nkwaleni Valley will require that a number of issues be considered. Water rights are well defined but have low reliability, potentially driving down market prices and constraining transfers. Agricultural water sold to industry will have to be specified as having either industrial or agricultural water priority. If agricultural water sold to industry is given industrial priority, this water will be assured to industry in times of drought, reducing the total agricultural water base that can be allocated to individual farmers by DWAF. Continued monitoring of water extraction by the NIB and DWAF will be important to ensure the enforceability of water allocations, while constitutional guarantee of title to water allocations and purchased water allocations under the new Water Act will provide for secure rights. In any event, the emergence of a market will depend on how well transaction costs are minimised by the administrative function performed by the NIB and DWAF, in defining a transparent transfer process, supervising and recording trades, and resolving conflicts among members. The existing framework of NIB control provides for a highly organised water management structure that could support the development of a water market. This would be important in resolving likely third party effects resulting from market transfers along the uMhlatuze River, owing to the small and variable flow of the river, and substantial existing demand for water.

In both study areas, a water market will depend on the formal sanction of water trading under the new Water Act. Where water trading is permitted under the new Water Act, it is important that the institutional environment promote the market system. However, it can be argued that several principles underlying the new Water Act could inhibit market development. Firstly, while water-use allocations will be well defined in the unit of measurement and will be enforceable, the reliability of each use allocation will be highly variable since they will not be held in perpetuity and will not give a guaranteed assurance of supply or quality. In addition, any water use allocation may be temporarily controlled, limited or prohibited. Variability in water rights that exists under current arrangements may increase under the new Water Act from increased bureaucratic control over water allocation and assessment of applications for renewal of individual water rights. This will create substantial uncertainty over the security of water rights and may preclude any trading of water use rights. Secondly, although water use allocations may be made transferable, any transfers will essentially be limited to rentals for the duration of the temporary water use allocation, thus eliminating the potential benefits accruing from permanent water transactions. Lastly, the reality of no private control over water management and temporary water use allocations facing irrigation farmers will stifle farmer incentives to buy or sell water rights in certain instances. Farmers will not have sufficient incentive to invest in water saving irrigation technology and other production inputs if there is uncertainty about water ownership. Investments in the establishment of table grapes average R150 000/ha, and if water rights are less secure, the risk associated with such an investment will be substantially increased. Incentives to purchase water rights for arable land to be developed and equipped with costly irrigation systems will be severely distorted, as will producer incentives to change to more efficient irrigation techniques or less water-intensive crops and use the conserved water to expand production or sell to another user.

The success of market-like allocation mechanisms under the new Water Act will depend on whether water use allocations are allocated for reasonably long periods of time, and the extent to which use rights are given the certainty and definition needed for a market. This will depend on:

- The extent to which individual use rights are legally recognised
- Minimal government interference in these rights
- The willingness of legislatures to define the scope of the public interest in the water resource.

Clearly detailed definition of both current and future public interests in water supplies is unlikely from government given the current emphasis on protecting expanding public interests. As a result, public interests will in all likelihood remain ill-defined and flexible, in turn leading to lack of definition and certainty of individual use rights. In Mexico, active development of water markets has taken place despite all water being declared as public property, partly because water-use rights have been specified for up to 50 years in length on a volumetric basis separate from land rights (Easter, 1996).

Conclusion

Two separate surveys of irrigation farmers along the Lower Orange and uMhlatuze Rivers were conducted in November 1997 and May 1998 respectively. A market for river water rights had developed among irrigators along the Lower Orange River. Market development for this particular category of irrigation water rights can be attributed to the scarcity of water in this arid region and increasing demand for river water rights by table grape farmers wanting to expand production. The large number of willing sellers, and the role played by DWAF in administering market transfers, thereby reducing transaction costs and time, facilitated market development. Improving the efficiency of water market trades could be achieved by delegating authority to the regional office of DWAF to approve transfers, extending support to market transfers of canal water, and ensuring that water extraction is closely assessed as use of river water increases in future.

Discriminant analysis shows that water rights moved to farmers achieving the highest estimated return per unit of water applied, showing that water rights gravitated to the most effective users of

water. Secondly, water rights moved from potentially lower valued users with the potential to grow wine grapes and raisin grapes, to potentially higher valued users with the potential to grow table grapes. Buyers had larger amounts of undeveloped arable land, highlighting the efficiency advantage of market trades of bringing undeveloped arable land into production.

No market trading of water rights had developed along the uMhlatuze River despite the scarcity of water in the region. Forty-one per cent of survey respondents wanted to purchase water rights. However, there were no willing sellers of water rights. This may attributed to the fact that survey farmers in the Nkwaleni Valley were generally found to be using their full water-rights allocation in their farming operations, and capital investment in irrigated land may inhibit the sale of water rights from this land. Irrigators may also prefer to retain excess water for water supply security. In addition, the crops produced by potential Buyers are not significantly more profitable than crops produced by Non-Buyers. As a result, farmers with unused or underutilised water rights may have little incentive to enter into water market transactions. At present, farmers are able to pay only for water extracted up to their maximum water allocation, with any unused water reallocated to industry by the DWAF. Under such a system, farmers with unused water are unable to realise potential rental or sale income from water transfers, and resistance to a potential future water market from industry may develop.

Equity objectives in improving access to water for previously disadvantaged groups will have to be tackled by government intervention in water allocation. However, it is important that existing and potential future water markets for irrigation water are not stifled as they could have important benefits in improving the use and allocation of irrigation water. Under the new Water Act, overcoming institutional and legal barriers for market performance will require that water-use allocations be specified as perpetual or for long periods of time, as in Mexico, with an expiry date closer to 40 years, be inherently secure, and that water trading be permitted through the relevant legislatures.

References

ANDERSON TL (1983) *Water Rights: Scarce Resource Allocation, Bureaucracy and the Environment*. Pacific Inst. for Public Policy Res., San Francisco.

ANDERSON TL and LEAL DR (1989) Building coalitions for water marketing. *J. Policy Anal. Manage*. **8** (3) 432-445.

BACKEBERG GR (1995) *Towards a Market in Water Rights: A Pragmatic Institutional Economic Approach*. LAPC Water Law Legal Grouping, Johannesburg.

BACKEBERG GR (1996) Discussion of Water Law principles. Gauteng Workshop, Pretoria.

BACKEBERG GR (1997) Water institutions, markets and decentralised resource management: Prospects for innovative policy reforms in irrigated agriculture. Presidential Address, 35th Annu. Conf. of the Agric. Econ. Assoc. of S. Afr., Osner Conf. Centre, East London.

BUCHANAN JM (1986) *Liberty, Market and the State: Political Economy in the 1980's*. Wheatsheaf, Sussex.

COLBY BG (1990) Transaction costs and efficiency in western water allocation. *Am. J. of Agric. Econ*. **72** (5) 1184-1199.

CUMMINGS RG and NERCISSIANTZ V (1992) The use of water pricing as a means for enhancing water use efficiency in irrigation: Case studies in Mexico and the United States. *Natl. Resource J.* **32** 731-755.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF) (1993) Government Notice 966, Pretoria.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF) (1997) Personal communication. Upington Regional Office.

EASTER KW (1996) Market approaches to water allocation: What have we learned? Paper presented at 5th Joint Conf. on Agric., Food and the Environ., Padova, Italy. June 17-18.

GOULD GA (1989) Transfer of water rights. *Natl. Resour. J*. **29** 457-477.

GOVERNMENT GAZETTE (1977) Republic of South Africa. Lower Orange River Government Water Control Area - Determination of Maximum Extent of Land which may be Irrigated. No 2064, 7 October.

GRIFFIN RC and BOADU FO (1992) Water marketing in Texas: Opportunities for reform. *Natl. Resour. J*. **32** 265-288.

HAYAMI Y and RUTTAN VW (1985) *Agricultural Development: An International Perspective*. John Hopkins University Press, London.

HEARNE RR (1995) The Market Allocation of Natural Resources: Transactions of Water Use Rights in Chile. Ph.D. Thesis, Dept. of Agric. and Appl. Econ., Univ. of Minnesota.

HOWE CW, SCHURMEIER DR and SHAW WD (1986) Innovative approaches to water allocation: The potential for water markets. *Water Resour. Res*. **22** (4) 439-445.

HOWE CW, LAZO JK and WEBER KR (1990) The economic impacts of agricultural-to-urban water transfers on the area of origin: A case study of the Arkansas river valley in Colorado. *Am. J. Agric. Econ*. **72** (5) 1200-1204.

MARTIN WE and BROWN TC (1987) Do water market prices appropriately measure water values? *Natl. Resour. J*. **27** 617-651.

McKENZIE RS, SCHAFER NW and STOFFBERG FA (1991) Water resources of the Orange River. *Proc. 5th S. Afr. Natl. Hydrol. Symp. Stellenbosch* 6.3.1 - 6.3.10.

NIEUWOUDT WL (1990) Efficiency of land use. *Agrekon* **29**(4) 210-215.

NORTH DC (1990) *Institutions, Institutional Change and Economic Performance*. Cambridge University Press, New York.

NORTH DC (1994) Institutional Change: A Framework for Analysis. Website, http//netec.mcc.ac.uk/pub/Netec/WoPEc/wuwpeh/papers/9412/9412001.

OLSEN M (1971) *The Logic of Collective Action*. Harvard University Press.

PIGRAM JJ (1993) Property rights and water markets in Australia: An evolutionary process toward institutional reform. *Water Resour. Res.* **29** (4) 1313-1319.

PINGALI PL and ROSEGRANT MW (1995) Agricultural commercialisation and diversification. *Food Policy* **20** (3) 171-187.

POPKIN SL (1979) *The Rational Peasant: The Political Economy of Rural Society in Vietnam*. University of California Press, Berkeley.

ROSEGRANT MW and BINSWANGER HP (1994) Markets in tradable water rights: Potential for efficiency gains in developing country water resource allocation. *World Dev*. **22** (11) 1613-1625.

ROSEGRANT MW and SCHLEYER RG (1994) Reforming Water Allocation Policy through Markets in Tradable Water Rights: Lessons from Chile, Mexico, and California. Environ. and Production Technol. Div. Discussion Paper No 6, Int. Food Policy Res. Inst., Washington.

SALIBA BC (1987) Do water markets work? Market transfers and trade-offs in the southwestern states. *Water Resour. Res*. **23** (7) 1113-1122.

SIMPSON LD (1992) Conditions for Successful Water Marketing. World Bank Technical Paper No **249** 97-101.

STIGLITZ JE (1989) Rational peasants, efficient institutions, and a theory of rural organisations: Methodological remarks for development economics. In: Bardhan P (ed.) *The Economic Theory of Agrarian Institutions*. Oxford University Press, New York.