Irrigation Water Value at Small-scale Schemes: Evidence from the North West Province, South Africa

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Abstract

Insight into the value of water is essential to support policy decision making about investments in the water sector, efficient allocation of water and water pricing. However, information on irrigation water values at small-scale schemes is scarce and in general little attention is paid to the determinants of these values. In this study values are calculated for small-scale irrigation schemes in the North West Province of South Africa, using the residual imputation method. An average water value of US\$0.188/m^3, in line with expectations for vegetable crops, was found. Furthermore, the crop choice and the irrigation scheme design and institutional setting were shown to significantly influence the water value, whilst individual characteristics of farmers proved to be less important.

Introduction

Rational decision making about water management issues requires reliable estimates of the economic value of water (Ward & Michelsen, 2002; Hellegers, 2005; Hellegers & Perry, 2006; Hussain *et al.*, 2007). Knowledge of this value is necessary when, for instance, making investment decisions concerning water resources development, policy decisions on sustainable water use and water allocations, or when the socio-economic impacts of water management decisions must be determined (Hussain *et al.*, 2007). Specifically for the agricultural sector, this knowledge is important to design fair, informed and rational pricing systems, providing incentives to irrigators to use water sparingly and efficiently and allowing recovering operation and maintenance costs (Lange, 2007; Perret & Geyser, 2007).

In South Africa, small-scale irrigation is seen as an important rural development factor, creating employment opportunities, generating income and enhancing food security. Therefore, huge investments are made in the sector, rehabilitating existing schemes (Perret & Geyser, 2007). On the other hand, the growing water scarcity causes increasing pressure on farmers to allocate water more efficiently. Moreover, following the new water policy, water subsidies currently received by farmers will gradually decrease and become negative, i.e. in the near future farmers will have to pay for the water they use (DWAF, 2004). In this context, knowledge about water values can contribute to the objective of improving efficiency through better water allocation at the farm level, but is also crucial when water pricing policies that do not undermine the role of small-scale irrigation are to be designed. In addition, knowledge about irrigation water values can provide indications about the soundness of the large government investments in the sector. In an attempt to contribute significantly to this knowledge, this study applies the residual imputation approach to provide estimates of the water values at crop, farm and scheme level, in small-scale irrigation schemes of the North West Province of South Africa. Analysis of variance (ANOVA) is used to reveal significant differences in water values between crops, farms and schemes. In the following, first the methodology for calculating water values is described. The results section begins with a short historical overview of the development of small-scale irrigation in South Africa and proceeds with the presentation and discussion of the calculated water values. The main conclusions and policy implications of this study are then presented.

Methodology

Estimation of Water Value

Neoclassical economic theory predicts that, in a competitive market, the economic value of a good corresponds to its market price, which reflects individuals' willingness to pay for that good. For water, however, due to the limited role played by markets, valuation techniques must be used (Young, 1996; Agudelo, 2001).

Several methods for estimating the value of water have been developed. They can be grouped according to whether they rely on observed market behaviour and data to infer economic value (indirect techniques), or alternatively use survey methods to obtain valuation information directly from water users (direct techniques) (Agudelo, 2001). A detailed discussion of water valuation methods can be found in Young (1996) and more recently in Lange & Hassan (2007).

In general, the most scientifically accepted methods are those based on actual market behaviour and information (Hussain *et al.*, 2007). In the case of South Africa, there are currently no water markets from which values for irrigation water can be derived. Furthermore, since subsistence farmers in the study area are not paying for water, it is impossible to establish a relationship between price and demand from actual behaviour to generate demand functions. Moreover, because water is provided by the government for free, strategic biases or simply the belief among smallholders that water is a free gift (Abu-Zeid, 2001), could probably lead to erroneous estimations of water values when using direct methods such as contingent valuation (Wasike & Hanley, 1998). Therefore, following Lange (2007), the Residual Imputation Method (RIM) was used in this study. Although this method clearly has its shortcomings, which are discussed in the next section, it was considered the most suitable technique to estimate water values for the studied small irrigation schemes.

Residual Imputation Method (RIM)

The RIM determines the incremental contribution of each input in a production process. If appropriate prices can be assigned to all inputs but one, the remainder of total value of product is attributed to the remaining or residual input, which in this specific case is water (Young, 1996; Agudelo, 2001; Lange & Hassan, 2007).

Residual valuation thus assumes that if all markets are competitive, except the one for water, the total value of production (TVP) equals exactly the opportunity costs of all the inputs (Agudelo, 2001):

$$TVP = \sum_{i} VMPiQi + VMPwQw \qquad (1)$$

Where:

- *TVP* = total value of the commodity produced;
- VMP_i = value of marginal product of input *i*;
- Q_i = quantity of input *i* used in production, *w* for water.

It is assumed that the opportunity costs of non-water inputs are given by their market prices (or their estimated shadow prices). Therefore, the shadow price of water can be calculated as the difference (the residual) between the total value of output (*TVP*) and the costs of all non-water inputs to production. The residual, obtained by subtracting the non-water input costs from total annual crop revenue equals the gross margin and can be interpreted as the maximum amount the farmer could pay for water and still cover costs of production. It represents the at-site value of water:

$$GM = TVP - \sum_{i} PiQi \qquad (2)$$

Where:

- *GM* = gross margin;
- P_i = price of input *i*.

This monetary amount, divided by the total quantity of water used on the crop, determines the marginal value for water (VMP_w), corresponding to the irrigator's maximum willingness to pay per unit of water for that crop (Agudelo, 2001). Average values were used in this study as a proxy of the marginal ones.

$$VMPw = \frac{TVP - \sum_{i} PiQi}{Qw} \qquad (3)$$

The assumptions of the RIM are not overly restrictive, but care is required to assure that conditions of production under study are reasonable approximations of the conceptual model. The main issues can be divided into two types (Young, 1996; Lange & Hassan, 2007): (1) those relating to the specification of the production function and (2) those relating to the market and policy environment (i.e. the pricing of outputs and non-residual inputs). If inputs to production are omitted or underestimated (incorrect production function) or if there are inputs that are unpriced or not competitively priced, then the RIM will generate inaccurate estimates. To overcome the first problem, all relevant inputs should be included in the model. The second problem can be solved by determining shadow prices for the inputs that are not correctly priced. Because of this sensitivity to the specification of the production function and the assumptions about market and policy environment, the residual imputation method is only suitable when the residual input contributes a large fraction of the output value. However, this is the case for irrigated agriculture in water scarce regions.

Data Collection and Variables

Data were collected from small-scale irrigation schemes situated in Zeerust Municipality (North West Province, South Africa) from July to September 2005. The municipality is located in the Central District Council of North West Province and shares a border with Botswana. The surface area is 7192 km^2 with a population of 136 000 (Zeerust Local Municipality, 2004). This municipality was chosen because promotion of small-scale irrigation has been explicitly identified as a development policy for the region, while on the other hand it is part of one of the South African water catchments (Crocodile West-Marico) that is expected to suffer most from water scarcity in the future (DWAF, 2004). Questionnaires were used to collect data for the period 2004-05. In total 60 farmers were interviewed, spread over 13 small-scale irrigation schemes. The number of farmers active on the schemes studied ranged from 1 to 45, with a total of 189. Therefore, the sample covers approximately 15% of the estimated smallholder population in the study area. Extension staff of the North West Province Agricultural Department acted as interpreters. Schemes and individual farmers were selected randomly from a list provided by the Department. At each scheme the number of respondents was adapted to the number of resident farmers. The objective was to interview at least 15-20% of the farmers at each scheme.

The interviews gathered information on irrigation schemes and household characteristics, farm activities, quantities and costs of inputs used in production, quantities and value of output, quantity of water consumed and irrigation practices. Expert knowledge of the extension staff was used as a supplement to farmers' answers. This was particularly helpful for the estimation of water use and prices of inputs and outputs. Table 1 provides an overview of the use of the different inputs.

Table 1. Descriptive statistics on output produced and inputs used per farm (*n*=60)

	Unit	**Average**	**St. dev.**	**Minimum**	**Maximum**
Output	US$	423.52	1706.74	22.56	13114.88
Inputs					
Labour expenditures	US$	43.62	114.3	7.42	900.9
Expenditure on pesticides	US$	10.83	12.33	0	54.14
Expenditure on fertilizers	US$	9.63	13.69	0	72.24
Expenditure on fuel	US$	23.16	139.27	0	1082.9
Water use	m^3	1287	3299	82.9	22150
Land use	ha	0.16	0.4	0.01	2.8

Data Analysis

A first step in the analysis consisted of relating the observed reality to the history and characteristics of the South African irrigation schemes and farming practices. To facilitate the reader's appreciation of the calculated figures, some elements of the national context are briefly provided in the first part of the Results section. The second step was to determine water value at crop level using the RIM. The revenue earned by the farmers for each crop was calculated by multiplying their production by market prices. By doing so, the self-consumed part of production was valued. On the input side, costs of fertilizers, pesticides, herbicides, fuel and labour were taken into account. These were considered the relevant inputs in the production process. For fertilizers, pesticides and herbicides, the competitive market prices were used to determine costs, even when extension services provided these inputs to farmers for free. For these inputs and the output, market prices are thus considered to equal the shadow price. On the other hand, for the costs of family labour a shadow price was calculated based on discussions with farmers and extension personnel and on the scarce data on wage labour in the dataset. A value of US$1.5 per day was used. 1 Given the high unemployment in the study area (up to 40% according to PROVIDE, 2005), the minimum wage of US$5.3 per day would not be a correct reflection of the cost of family labour. This type of price corrections, as proposed by Lange & Hassan (2007), is necessary to fulfil the assumptions of the RIM. Next, the estimated water values were compared over crops using one-way ANOVA tests. The third part of the analysis was to estimate the value of water at the farm and scheme levels and to test whether significant differences could be observed among the analyzed farms and schemes.

Results and Discussion

Small-scale Irrigation in South Africa

The importance of the institutional context as a factor influencing water values is stressed by Hermans *et al.* (2006). Therefore, this section provides a brief overview of the development and the current context of small-scale irrigation in South Africa. The sector mostly originated from a food security perspective and two types of schemes can historically be distinguished: (1) former Bantustan schemes, currently accounting for 46 000 to 47 500 ha and (2) community schemes or garden schemes, representing approximately 50 000 ha (Perret, 2002). The first type of scheme dates from the 1950s and 1960s. Their objective was to provide farmers in the homelands with opportunities to produce their own food and a surplus for sale. The size of these schemes varied significantly, but the farm size per beneficiary was fixed at approximately 1.5 ha (Perret, 2002). Scheme management and operations were centralized and administered by government agencies, with the government also providing mechanization services and supplying credit and inputs. This led to a high level of dependency upon government interventions, imposed a large financial burden on the state and resulted in poorly performing schemes (Shah *et al.*, 2002).

By the end of the 1990s, when the government agencies withdrew, the income of farmers was already very poor, but without access to inputs and organizational structure to obtain credit and other services the situation became even worse. Most production units were no longer financially viable and could not enter the mainstream economy nor engage in sustainable agribusiness activities. Indeed, many farmers left production, making the burden of carrying management of the scheme on remaining farmers even heavier (Kamara *et al.*, 2002). Because of their perceived role in rural development, recently rehabilitation programmes for these schemes have been put in place. Perret & Geyser (2007) report that in Limpopo, for example, 1.08 billion Rand will be spent for rehabilitation or refurbishment of schemes between 2006 and 2010 and in Eastern Cape 100 million Rand was spend in 2006. In general, the programmes include transfer of ownership to local communities, education and training to generate awareness of good practices and the promotion of affordable technologies (IPTRID, 2000; Perret, 2002). The second types of scheme consist of the numerous community schemes or garden schemes. They are usually very small ranging from 1 and 30 ha and the area at the disposal of the farmers goes from only a few cubic metres to nearly 1 hectare (Perret, 2002). They were established by NGOs, development projects or government departments within the framework of poverty alleviation and food security. In spite of their small size, they play an important role in rural development, improving food security, income and employment opportunities. Short-term results of these initiatives were often good, but not all schemes remain successful in the long term. At some sites, maintenance and management problems caused schemes to collapse because following the withdrawal of support services, communities did not have the capacities to take over management (IPTRID, 2000). At other sites after a couple of years maintenance shifted to community users or their representatives without any problem.

The current situation of the small-scale irrigation schemes still reflects the origins and evolution as described above. Food security remains a major objective and crops and production patterns remain largely the same, together with the weak market opportunities and the poor agribusiness environment. Even so, following the changing institutional context in South Africa, farmers are now more encouraged to make some cash profit in order to be able to pay back production costs and services (Perret, 2002).

Descriptive Overview of Irrigation in the Study Area

Three different institutional settings for irrigation could be identified in the sample. (1) Schemes modelled after the former Bantustan schemes: these are the largest schemes in the sample with an average area per farmer of approximately 1.6 ha; (2) typical food gardens: these assemble more farmers on smaller areas and consequently the area per farmer is smaller, mostly well below 1 ha. Farmers are more involved in the management of the schemes, although most of them work only part-time at these schemes. Usually, they offer paid labour on commercial farms during labour peak months and work in the food gardens the rest of the year; (3) individual irrigators: encouraged by the institutional context, some farmers began irrigating on private plots of land on an individual basis. The fact that these smallholders started up their business after 2002 reveals the recent character of this phenomenon. Three farmers belonging to this category were included in the sample.

The irrigation schemes in this study are almost entirely used for vegetable crops. Figure 1 depicts the share of farmers planting different vegetables. Beetroot, spinach, onions and carrots are widely planted, being produced by 70-90% of the farmers. A different picture emerges in terms of planted area (Figure 2). Butternuts, cabbages and tomatoes appear to be the most important crops. Both figures also indicate a high degree of fragmentation, with most farmers dividing their field into several plots.

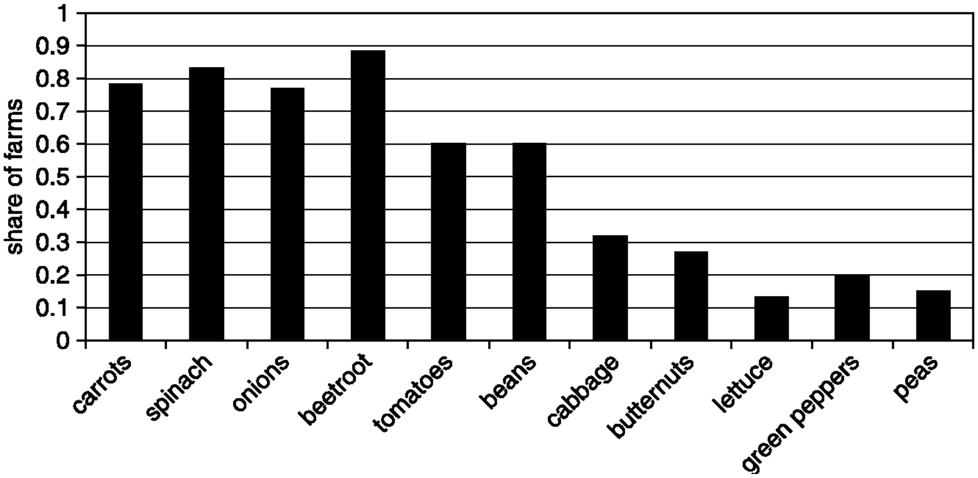
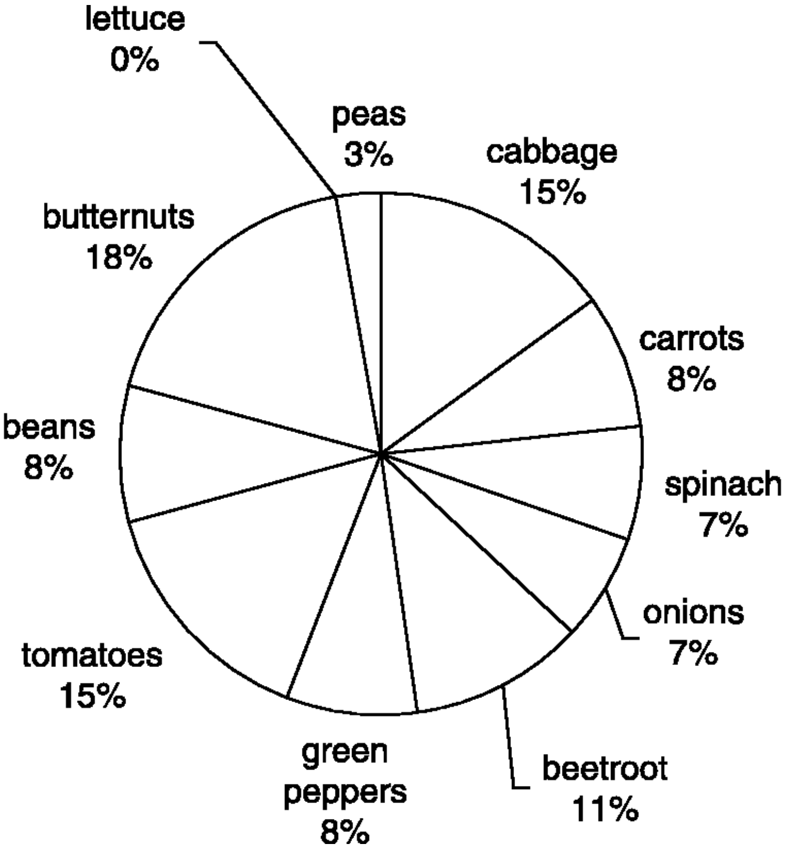


Figure 1. Distribution of crops among farmers



(*n* = 60)

Figure 2. Importance of crops in terms of planted area (% of total irrigated area occupied by each crop)

The irrigation technology used by the farmers is usually uniform within a scheme. Furrow irrigation is the most frequently used method because 40% of the studied farmers adopt it. The use of hosepipes and bucket irrigation accounts for 20% and 33% respectively. These low-cost irrigation methods are typical for the small-scale irrigation schemes. Sprinkler irrigation is not very common (used by only four farmers in the sample). A plausible explanation formulated by Brabben (2001) for the limited adoption of sprinkler irrigation is that farmers will only make the investment in modern equipment when the financial return is clear and relatively assured. Moreover, research has shown that for smallholders in South Africa, furrow irrigation is often more sustainable than equivalent irrigation using sprinklers (IPTRID, 2000). It is worthwhile noting that in this study the three farmers who own their land have all invested in sprinkler irrigation. Variation in input use and output produced is considerably large. The range in plot sizes, from less than 100 m^2 to 2.8 ha, is obviously a reason for this. In general, farmers seem to use a low input strategy. Statistics of the inputs and outputs used in the calculation of the gross margins are presented in Table 1.

Discussion of Estimated Water Values at Crop, Farm and Scheme Levels

Irrigation water values (VMP_w) are calculated per crop, per scheme and scheme type and finally per farm. Results of the RIM calculations of water value per crop are presented in Table 2. In more than a quarter (27%) of the 320 observed plots, negative gross margins (GM) where obtained, leaving no residual value to attribute to water. Surprisingly, negative GM are also frequently found for crops that are widely planted, such as beetroot, onions and spinach. On the other hand, tomatoes and cabbages seldom yield negative GM.

Table 2. Computed water values ($\$/m^3$) per plot arranged per crop (n = 320)

Crop	No. cases	No. (%) cases with negative gross margins	Water value[a] (st. dev)	Adjusted water value[b]	Range	Water values from literature for comparison
Beans	32	5 (15)	0.991 (0.941)	0.836	0.00-3.081	2.03[c]
Beetroot	52	21 (40)	0.124 (0.246)	0.074	0.00-1.26	0.99[c] /0.01-0.40[d]
Butternuts	16	7 (44)	0.042 (0.06)	0.024	0.00-0.183	0.02-0.27[d]
Cabbage	17	0 (0)	0.368 (0.417)	0.368	0.003-1.663	0.78[c]/0.07-0.44[d]
Carrots	47	13 (27)	0.111 (0.161)	0.080	0.00-0.678	0.003-0.21[d]
Green peppers	11	6 (55)	0.222 (0.504)	0.101	0.00-1.677	n.a
Lettuce	7	0 (0)	1.532 (1.075)	1.532	0.109-	n.a

[a] For the calculation of this value, only cases with positive gross margins were taken into account.

[b] Average was calculated assuming a value of 0 for the cases with a negative gross margin.

[c] Values derived from Combud crop budgets (Combud, 2002).

[d] Water values found by Ntsonto (2005), the range indicating different management styles.

[e] Water values found by Bader (2004), the range indicating different locations.

n.a.: no values found to compare.

Table 2. Computed water values (\$/m^{3}) per plot arranged per crop (n = 320)

Crop	No. cases	No. (%) cases with negative gross margins	Water value[a] (st. dev)	Adjusted water value[b]	Range	Water values from literature for comparison
					3.008	
Onions	46	17 (37)	0.154 (0.276)	0.097	0.00-1.494	n.a
Peas	8	1 (13)	0.118 (0.140)	0.103	0.00-0.417	n.a
Spinach	48	16 (33)	0.060 (0.082)	0.040	0.00-0.293	n.a
Tomatoes	36	1 (3)	0.238 (0.273)	0.231	0.00-1.281	0.27-1.22[e]
Total	320	87 (27)	0.259 (0.515)	0.188	0.00-3.081	

The meaning of these negative GM must be put into perspective. Negative margins do not necessary mean that farmers' profit was negative. GM are theoretical, as in their calculation market prices were used, while on the farm inputs are often not fully charged or even provided for free by extension services. The positive willingness to pay for irrigation water in spite of calculated negative GM, found in another study by Perret *et al.*, (2003), supports this explanation. However, the negative GM found in this study confirm the poor overall performance of small-scale irrigation. In the light of the investments made in the sector and the stated objective of cost recovery, this is a worrying situation. The study clearly supports the finding of Perret & Geyser (2007) that the capacity of farmers to pay for water is low and insufficient for the cost recovery of irrigation services. The occurrence of negative GM was also reported by Ntsonto (2005) studying smallholder schemes in South Africa and by Lange (2007) in Namibia.

In the literature, only few studies calculate water values for specific vegetable crops. In general, aggregate values are presented at farm or even at scheme level. Table 2 shows that, for the crops for which comparison is possible, average water values calculated in this study are of the same order of magnitude as those in other literature sources.[2]

For most crops the computed values are highly variable, as was the case in similar studies. For example, the range of values in Table 2 reported by Ntsonto (2005) is equally large and Frederick *et al.* (1997) give an overview of widely varying water values from different studies in the USA.

The aggregate average water value for the vegetable crops in this research is 0.259 US\$/m^3 when the cases with negative GM are not taken into account, and US\$0.188/m^3 if a value of zero is attributed to these cases. These values are comparable to results of other recent studies. In a review paper on water values, Hussain *et al.* (2007) report values up to US\$0.37/m^3 for high value crops in some African countries, concluding that for vegetable production, water values are usually higher than US\$0.2/m^3.

In this study, values per crop were shown to differ significantly using one-way ANOVA (Table 3). Knowing that values differ significantly between crops, a post hoc test (Tamhane's T2)3 was used to point out where exactly the significant differences in water values are situated. This analysis showed that significant differences in mean water values (at $p < 0.05$) exist between beans on the one hand and carrots, spinach, onions, beetroot, tomatoes, butternuts and peas on the other hand. Furthermore, the VMP_w of tomatoes also differed significantly from that of butternuts and spinach. From the perspective of improving water allocation, farmers should prefer the crops with higher water value.

Table 3. One-way ANOVA tests showing differences between irrigation water values

Factors	**Degrees of freedom (between; within groups)**	***F*-value**	**Significance**
Plot level			
Crops	(10; 309)	20.841	0.000
Irrigation schemes	(13; 306)	2.029	0.018
Scheme types[a]	(2; 317)	6.185	0.002
Farm level			
Gender	(1; 57)	0.356	0.553
Educational level[b]	(3; 55)	1.555	0.211
Fragmentation (number of crops)	(8; 50)	1.259	0.286

[a] The three different scheme types discussed in the first section of the results were introduced as factors.

[b] Educational level was split into four categories: no education, primary education, secondary education and tertiary or vocational education.

In order to explore the inter-schemes water value variability, VMP_w per irrigation scheme and scheme type were calculated and compared. Tren & Schur (2000) stated the importance of recognizing different types of schemes. They concluded that for schemes within the same region and producing the same crops, the total output and efficiency could vary tremendously due to differences in scheme design and management structure.

Similarly, Hussain *et al.* (2007) also pointed out the influence of water management factors on water values.

The ANOVA analysis revealed that using 'irrigation scheme' as a factor, the plot level VMP_w differed significantly at the 0.05% level (Table 3). To explain the differences, it is necessary to test whether they could be attributed to the various institutional settings and design principles of the schemes.

Table 4 reports the average and range of VMP_w for the three types of schemes discussed above. The values found are the same size as those reported by Hussain *et al.* (2007) for schemes producing vegetables in some other African countries. The highest VMP_w was found for food gardens (US\$0.321/m^3). However, including the cases with negative GM, the VMP_w becomes US\$0.251/m^3, which almost equals the water value for farmers irrigating on private land. An *F*-value of 6.19 confirms the significance of differences between scheme types (see Table 3). A Tamhane's T2 post hoc test showed that for the schemes modelled after the former Bantustan schemes, the VMP_w were lower than those for the food gardens and those for the irrigators on private land respectively at the 99% and 90% significance level.

Table 4. Computed water values per plot arranged per type of irrigation scheme (*n*=320)

Scheme Types	**No. plots**	**No. plots with negative gross margins (% of total)**	**Value water US\$/m^3 (st. dev)**	**Range**
Former Bantustan-like schemes	79	17 (21.5)	0.088 (0.149)	0.00-0.874
Food garden schemes	225	70 (31)	0.321 (0.593)	0.00-3.081
Individual irrigators	16	0 (0)	0.246 (0.238)	0.004-0.824

The higher values for the food gardens can be attributed to a more intensive production on the smaller plots. Other reasons for the higher values in the food gardens are a higher involvement and a lower degree of dependency on public support, leading to better management. These factors could also explain the higher water values for farmers irrigating on private land. The weak performance of the former Bantustan schemes highlights the necessity to improve their management.

Finally, irrigation water values were assessed at farm level. The cumulative distribution of these values is presented in Figure 3. VMP_w range between 0 and US$1.11/m^3, with an average of US$0.186/m^3. Eighty-five per cent of the farmers encounter a water value below US$0.4/m^3 and for eight farmers (13%) negative gross margins at farm level were obtained, indicating that at market prices these farmers would not make profit out of their farm activities. In her study on Namibia, Lange (2007) also reported that some farms appear to be operating with losses.

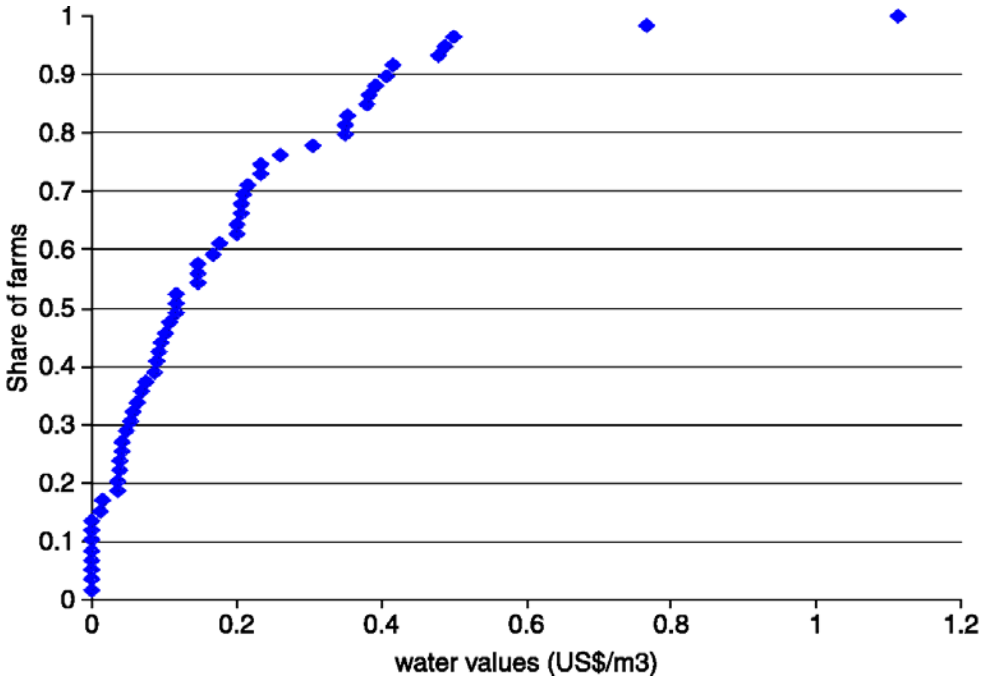


Figure 3. Cumulative distribution function of irrigation water values at farm level

No significant differences related to gender, number of crops or the educational level of the family head could be found between the water values at farm level (Table 3). The farmer's age and farm size also had no significant effect on the water value. To test whether differences in cropping pattern could possibly mask the relationship between farmers' characteristics and water values, the influence of these characteristics was also explored per crop. Again, no significant results were found, indicating that individual characteristics of farmers appear to have limited effects on the water values. Farmers' performance seemed to be related principally to scheme design, output prices and the institutional settings.

Conclusions and Policy Implications

Insight into the value of water is essential to support policy making about water pricing and the efficient allocation of water among different water users and uses in a river basin. In this study the Residual Imputation Method (RIM) was used to calculate water values in small-scale irrigation schemes in the North West Province of South Africa. The observed values of water were in the range of those found in other studies for irrigated vegetables in semi-arid areas throughout Sub-Saharan Africa (Hussain *et al.*, 2007).

The study revealed a high level of variability in irrigation water values. It was shown that the differences in water values can be mainly attributed to two factors that can be relevant for policy makers and extension services: (1) the characteristics of irrigation schemes; and (2) the type of crop grown.

With regard to the first factor, food gardens and individual irrigators proved to perform better in terms of water values than schemes derived from former Bantustans organizations. One reason for this could be the higher intensity in terms of labour and inputs, which generally leads to higher gross margins and consequently higher irrigation water values. Another reason can be identified in the lower degree of dependency upon state interventions in these schemes, which leads to a more dynamic and flexible management. Therefore, some findings of this study support the argument that more participatory scheme management leads to efficiency improvements. Moreover, they indicate that the transfer of ownership to farmers should remain a key aspect of rehabilitation plans.

However, the most important factor influencing the value of irrigation water is the crop being produced. Thus even in a case study involving only high value crops, crop choice remains the most important factor explaining differences in water value. Extension services can use this knowledge to promote more efficient allocation by creating incentives that encourage farmers to grow crops with higher water values. Other factors such as farmers' characteristics, irrigation technology or plot size proved to be less important in this case study. A possible explanation for the low importance of the latter factors might lie in the fact that the dataset was relatively homogenous for these variables. Additional research with a more heterogeneous population in terms of these factors can shed some light on this.

A high percentage of negative gross margins at plot level was found. This reveals that the sector would still have problems being viable without government support, an issue that should be taken into account when designing water pricing and allocation policies. The fact that irrigated crop yields in small-scale irrigation schemes are often weak and erratic is also problematic given the current huge public investments in smallholder irrigation in South Africa. These investments prove to be inconsistent with the liberal discourse on cost recovery and expected small-scale irrigation performance. The government officially assigns an internal rate of return of 4% to those rehabilitated schemes (Denison & Manona, 2006), and expects farmers to gradually pay water charges, which will include capital and replacement fees through a phasing-in process (Perret, 2002; Backeberg, 2006). The finding of Perret & Geyser (2007) that this is probably unattainable in the current production conditions is thus confirmed in this study.

Notes

1. The average ZAR/US$ exchange rate for the period July-September 2005 was used for conversion: 1 ZAR = 0.1504US$ (source: IMF, 2006).

2. One of the sources for comparison used are the Combud budgets. These are detailed enterprise budgets for each province in South Africa, published on a regular basis by the

Provincial Departments of Agriculture. The budgets do not contain water use, but crop irrigation requirements for the budgeted crops could be calculated with the irrigation scheduling tool SAPWAT (SAPWAT, 2003).

3. Tamhane's T2 was used since a significant Levene statistic ($p < 0.001$) indicated that equal variances could not be assumed. Tamhane's T2 is a post hoc test specially designed for situations in which population variances differ and is conservative in relation to type 1 errors (Tamhane, 1979).

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