The Cost of Meeting Equity: Opportunity Cost of Irrigation in the Fish-Sundays Scheme of South Africa

B.I. Conradie

School of Economics
University of Cape Town
Cape Town, 7701, South Africa

D.L. Hoag

Department of Agricultural and Resource Economics
Colorado State University
Fort Collins, CO 80523

Acknowledgement

The authors gratefully acknowledge financial assistance provided by the Water Research Commission of South Africa.

Contributed paper selected for presentation at the 25th International Conference of Agricultural Economists, 16-22 August 2003, Durban South Africa

Abstract:

In this paper the incremental values of water are calculated for irrigators in the Fish-Sundays Scheme of South Africa's Eastern Cape province. The socio-political pressure for redistribution of agricultural resources provided the imperative for this study. The model of the Fish-Sundays Scheme reflects a survey of 50 000ha of fodder and citrus production. It explicitly models the water demand on sixteen typical farms, for five irrigation technologies, six crops and four livestock activities. The existing allocation generates an average value of R0.0423/m^3/year, which increases to R0.0681/m^3/year if farmer-to-farmer trading is allowed given existing infrastructure. Unrestricted trade raises the average value to R0.0719/m^3/year. The marginal cost of additional water in the source basin is R0.05/m^3/year for the first 315 million m^3 and R1.27/m^3/year to extend capacity beyond that.

JEL classification: Q15, Q12,
Keywords: water value, irrigation, linear programming, South Africa, Eastern Cape

Internationally competition for water is increasing. Howe (1985) first suggested that water taken from irrigation rarely has major costs for agriculture, but despite rising dam construction costs, irrigation still dominates water use in South Africa. Apartheid's legacy of unequal resource access gives water reform especially great priority in South Africa. The National Water Act (Act 36 of 1998) and Water Services Act (Act 108 of 1997) aim to redress this by distributing water in a manner that facilitates social and economic development, emphasises access for black South Africans (and black women in particular) and recognises the need to protect rivers' ecological integrity. There is little information, however, on the opportunity cost of such water.

In the USA Taylor and Young (1995) illustrated the intensity of competition for water in Crowley County, Colorado. Calculating the direct benefits foregone by removing 50% of irrigation at $0.0177/$m^3$ while the competing marginal municipal value was $0.2200/$m^3$, they implied that water trade would raise the market-clearing water price. In California, Schmidt and Plaut (1993) predicted that unrestricted water trading would increase agricultural water prices by less than 5%. Since irrigation uses 80% of the resource and the demand elasticity for irrigation water being at least twice that of residential water, a small price increase is needed to release the water required by municipal users. Water trading data from the Northern Colorado Water Conservancy District show that scarcity increases prices over time (Cummings and Nercissiantz, 1992). Moreover, since most trades are between farmers, they refute the idea that all agricultural water values are low. Historical prices confirmed this; real water prices in 1980 being three times those in 1985. These high prices are particularly significant since the area produces mostly annual crops.

In South Africa, Backeberg (1995), Armitage et al. (1999) and Nieuwoudt (2000) argued that tradable water permits would increase commercial irrigation efficiency, allocating water to the most productive user. This paper compares the marginal value of irrigation water in the Fish-Sundays Scheme of the Eastern Cape to the cost of creating additional capacity in the system. The Fish-Sundays Scheme comprises those reaches of the Great Fish and Sundays Rivers supplied from Gariep Dam on the Orange River, but through other inter-basin transfers the Orange basin also supplies the parts of the country. The inter-basin transfer of 560 million m^3/year provides over 95% of the water in the recipient system (Basson, 1999). Competition for water is extensive. Locally irrigators compete with industrial and residential users, the environment and subsistence farmers, and through inter-basin transfers they compete with users in the industrial and mining heartland of the country in the Vaal basin. Additional capacity is primarily needed to meet growing urban demand in the Vaal basin.

The existing "no trade" scenario is compared to two levels of farmer-to-farmer trade. Results indicate that water trade between the Scheme's farmers would increase average water value by over60% and reinforce Taylor and Young's 1995result that irrigators sustain small losses when water is diverted to other uses. At an offer price equal to the cost of phase I of additional developments in the Orange basin over three quarters of the water would be released. At a price equal to the marginal cost of developing phase II farmers would sell all their water entitlements.

Methods

The model compares the costs and benefits of intra- and inter-basin water transfers. The marginal value of irrigation benefits forgone is calculated for a range of quantities. It is also known that incremental capacity can be added in two phases – phase I will generate 315 million m^3/year at R0.05/m^3/year and Phase II will produce 850 million m^3/year at R1.27/m^3/year (Basson, 1999). Although the benefits of non-agricultural uses are difficult to estimate, assumptions can be made about the quantities involved. Since these should be supplied from the cheapest source, irrigation values then provide a threshold value for alternative users.

The model of commercial irrigation consists of a suite of sixteen static linear programmes aggregated to basin level following a postal survey of all irrigation permit holders (response rate 24%). The models were populated by activity data (in table 1) collected from farmers and local agricultural experts (Conradie, 2002). Technologies reflect current practices. The models reflect 35 000ha of fodder crops in the Great Fish River basin and 15 000ha of citrus along the Lower Sundays River.

Farm size and resource mix determine the farm classes. Irrigation and stock farms both have 85ha irrigated land, but stock farm comprise 2 540ha rangeland while the irrigation farm has almost no rangeland. Dairy farms are essentially irrigation farms that keep dairy cows instead of sheep and angoras. Farm businesses are large multi-owner units with more stock and crop activities than other farms. Citrus farms are differentiated according to size, and replant rates. Small mixed (29ha) and large stable (112ha) citrus farms are barely maintaining the investment in citrus, while small expanding (50ha) and large expanding (195ha) citrus farms grow at 4%/year.

Table 1: Enterprise data by farm model

Enterprise	1999 R/ha	Modelled in farm types
Maize	(1831) – (2983)	Irrigation, stock, dairy, farm business
Lucerne	(2425) – (4990)	Irrigation, stock, dairy, farm business, small mixed citrus farms
Grass pasture	(934) – (2086)	Dairy
Dry beans	1240 – 3878	Irrigation, stock, farm business
Potatoes	5443 – 8766	Farm business, small mixed citrus
Citrus	2210 – 3368	Small mixed, small expanding, large stable, large expanding citrus farms
	1999 R/Large stock unit	
Wool sheep	901 – 1586	Irrigation, stock, farm business
Angora goats	1184 – 1398	Irrigation, stock, farm business
Ostriches	2147	Farm business
Dairy cows	4848	Dairy, small mixed citrus farms

* Exchange rate: US$1 = R10

Fodder crops were modelled to have transfer activities to dairy cows and ostriches, and wool sheep and mohair goats operated at four intensity levels. Maize production is modelled separately from maize harvesting. If ensiled, it supplies dairy and if reaped as grain it can be sold at R600/ton or fed to livestock. Lucerne hay is fed to livestock or sold at between R326/ton and R337/ton depending on quality. Potatoes and dry beans are cash crops. Four citrus varieties are modelled to reflect differences in income and input requirement. Rotational requirements and replant rates of perennial crops were specified exogenously – as for example in Louw and Van Schalkwyk (1997) – but all other fixed factors except water, are endogenous.

The water constraint is modelled in mm/ha/year using pre-1999 farm level quotas. Duplicate irrigation activities model capital-water substitution, but management-water substitution, as implemented by Gardner and Young (1988) and Booker (1990), was ignored. Data inadequacy and the scope of the project precluded the modelling of management responses to growing water scarcity for a given technology. Flood irrigation still dominates fodder production, while citrus growers have converted to micro irrigation to improve fruit quality and save labour. Since the change to micro irrigation is irreversible, other technologies are not modelled on citrus farms. Parametric changes of the water constraint generate marginal water values, total water value being the integral of the marginal water value function. Since the model has no other fixed factors, the objective function also measures total water value.

The model isolates water values using a Ricardian framework, all other inputs, including risk taking, being rewarded at a fair value. Labour is hired in at R3.97/hour in one-month blocks. Management, two classes of land and farming infrastructure are rented by the hectare assuming constant returns to scale. Risk is modelled in a MOTAD formulation, which penalises the objective function by a sum of negative deviations in historical profit (Hazell, 1971). The modeller chooses the intensity of the penalty by selecting a risk coefficient. Risk coefficients are used to calibrate models to observed enterprise mixes. The model maximises returns to water instead of returns to all fixed factors in order to find a lower bound – rather than an upper bound – to water value. The model's weakness is that a reduction in profit – arising from say a wage increase – more than proportionately affects water values, while such loss would in reality be absorbed across all factors.

Results

Water comes into the fodder-producing area on the banks of the Great Fish River between Steynsburg in the north and Cookhouse in the south. At Cookhouse 126 million m^3/year is transferred on to the Sundays River where citrus is grown south of Kirkwood. The Kirkwood supply is connected to the Nelson Mandela Municipality (formerly Port Elizabeth) where urban demand is concentrated. Current residential and industrial use is reported to be 16 million m^3/year and is projected to grow to 65 million m^3/year by 2030, of which 25.1 million m^3/year can be accommodated given existing infrastructure (Basson, 1999). According to the Scheme manager the ecological requirement, of between 63 and 69 million m^3/year, is still unappropriated in the river (Crafford, personal communication, 1999). The Scheme also serves 644ha of smallholder plots worth 8.3 million m^3/year, but this demand unlikely to grow in future. Industry and municipal users outside the basin are far more significant competitors for Fish-Sundays water than any of the equity stakeholders inside the basin. The tunnel is not a binding constraint since it is unlikely that the inter-basin transfer will be increased. Distribution in the fodder producing area is not constrained either, since the river is the delivery channel, but further supplies to the citrus area is constrained to 18 million m^3/year. The limited trade scenarios enforce the citrus constraint and the unrestricted trade scenarios disregard it.

The existing allocation of 578.2 million m^3/year generates a total water value of R24.47 million/year for commercial irrigation. Table 2 shows both water value by farm type and whether a farm is likely to be a buyer or seller. A marginal value of zero indicates that the existing water constraint is non-binding; making this class of farm a potential seller of water. If the marginal value of water is positive the farm will buy water at the margin. The existing quota and the potential change in quantity demanded are also reported. Irrigation farms in Cradock and Cookhouse/ Somerset East would be expected to sell 28.35 and 62.08 million m^3/year respectively, were trading allowed. Stock farms in Cradock would sell a further 11.69 million m^3/year. Removing all constraints, including the restriction on the inter-basin transfer, increases net water demand by 25%.

Table 2: The existing allocation of water to commercial irrigation

Farm type	Marginal Value	Average Value	Quantity Allocated	Change in demand
	1999 R/m^3/year		Million m^3/year	
Irrigation farms				
Middelburg	0.0011	0.0028	74.59	86.74
Cradock	–	0.0035	33.28	(28.35)
Cookhouse/ Somerset East	–	0.0003	70.13	(62.08)
Stock farms				
Middelburg	0.0067	0.0081	60.82	5.97
Cradock	–	0.0070	28.69	(11.69)
Cookhouse/ Somerset East	0.0014	0.0034	38.25	13.73
Dairy farms				
Middelburg	0.0427	0.0412	-	-
Cradock	0.0427	0.0427	18.36	15.57
Cookhouse/ Somerset East	0.0612	0.0378	19.13	13.55
Farm businesses				
Middelburg	0.0070	0.0076	17.01	10.51
Cradock	0.0120	0.0429	28.35	37.00
Cookhouse/ Somerset East	0.0163	0.0500	63.00	29.13
Citrus farms				
Small mixed	0.1525	0.1525	28.97	10.09
Large stable	0.0352	0.0352	33.26	13.99
Small expanding	0.2862	0.2862	36.90	11.37
Large expanding	0.3435	0.0435	31.59	9.12
Total		0.0423	578.20	154.67

Without trade the average value of irrigation water is R0.0423/m^3/year, 15% less than the cost of phase I of construction. To avoid phase I about half the inter-basin transfer would have to be kept back in the Orange River basin. The Government can do that by scaling back farmer allocations in the Fish-Sundays Scheme proportionally, even without allowing trading between farmers. Table 3 shows that a 50% reduction of the inter-basin transfer without allowing farmer-to-farmer trading will increase the average value of remaining water to R0.0797/m^3/year, since individual farmers will discontinue low value crops. Total water value falls by a mere 3% to R23.78 million/year as a result.

Table 3: Water values in 1999 Rand for three trade and two transfer levels

	100% inter-basin transfer			**50% inter-basin transfer**		
	No trade	**Citrus limit**	**Unrestr. Trade**	**No Trade**	**Citrus limit**	**Unrestr. trade**
Volume mil m^3/year	578.2	578.2	578.2	298.2	298.2	298.2
% volume – citrus	22%	22%	30%	45%	43%	59%
Value R million/year	24.47	39.36	41.58	23.78	30.20	32.56
% value – citrus	71%	64%	66%	73%	83%	84%
Average value – R/m^3	0.0423	0.0681	0.0719	0.0797	0.1013	0.1092
Marginal value –R/m^3						
Fodder		0.0014	0.0015		0.0163	0.0163
Citrus		0.0352	0.0015		0.0352	0.0163

It is not the ability to move water to citrus per se that raises the water value, but rather the ability to pick the more efficient farms within an area. For example, table 3 shows that the share of the water used in citrus remains unchanged if trade up to the citrus constraint is allowed. At this constraint small mixed, small expanding and large expanding citrus farms are buying water while large stable citrus farms are selling their current allocation. The net demand for the citrus area is less than 3 million m^3/year, but partial trade eliminates an entire class of producer and increases value dramatically. Furthermore, the share of value generated by citrus falls, implying efficiency gains among fodder producers too. However, the bottom two rows of table 3 show that the citrus constraint is binding since the canal capacity precludes the marginal value of water from equalling across the entire Scheme. Were the citrus constraint removed, large stable citrus farms would become buyers again, raising the share of water utilised by citrus farmers to 30% of available supplies. The impact of this change on value is marginal, suggesting that few low value fodder producers would remain. The second scenario in table 3 considers the effects of reducing the inter-basin transfer by half to replace phase I of further developments in the Orange basin. If trading is not permitted, a 50% cut in supply will cause average water values to rise dramatically, total value to fall marginally and water to be released mostly from fodder production. If permitted to trade up to the citrus constraint, the citrus area rearranges its production internally as before. The share of value generated by citrus now increases to 83% indicating that there are few gains from farmer-to-farmer sales among remaining fodder producers. Removing the citrus constraint draws slightly more water to citrus but creates little additional value.

Instead of just considering two levels of inter-basin transfer, Table 4 shows the quantities released from the irrigation sector at a range of offer prices, as well as the cumulative percentage water released for the Scheme as a whole. In general, fodder producers are willing to sell water at lower prices than citrus growers, and more water will be released from the irrigation sector if farmer-to-farmer sales are not allowed than if permitted. If farmers can trade among themselves, efficient irrigators will buy water from low value producers, thus keeping water in the irrigation sector. Conversely, if no trading is permitted, unused water has no value. The first 101.45 million m^3/year, or 18% of the current allocation to the Scheme, will be released by the irrigation sector at a very small positive price, but trading increases the marginal value of water to at least R0.0014/m^3. At R0.0014/m^3 intra-irrigation demand is satisfied and the irrigation sector starts to sell water to non-agricultural users in the recipient and source basins.

Table 4: Willingness to sell in million m^3 at various prices with and without trade

Price	No trade			Limited trade		
R/m^3/year	Fodder	Citrus	%	Fodder	Citrus	%
0.0000	101.45	-	18%			
0.0005	101.45	-	18%			
0.0014	133.98	-	23%	4.89	-	1%
0.0015	137.97	-	24%	41.52	-	7%
0.0017	170.18	-	29%	46.04	-	8%
0.0018	174.68	-	30%	73.47	-	13%
0.0030	202.14	-	35%	102.10	-	18%
0.0032	206.47	-	36%	102.43	-	18%
0.0045	206.79	-	36%	105.17	-	18%
0.0054	207.45	-	36%	109.09	-	19%
0.0070	252.64	-	44%	168.27	-	29%
0.0076	253.76	-	44%	168.27	-	29%
0.0080	270.11	-	47%	186.95	-	32%
0.0082	272.82	-	47%	191.92	-	33%
0.0111	277.80	-	48%	210.44	-	36%
0.0120	296.18	-	51%	245.89	-	42%
0.0163	320.25	-	55%	330.46	-	57%
0.0203	375.14	-	65%	332.18	-	57%
0.0251	377.37	-	65%	345.01	-	59%
0.0290	378.49	-	65%	346.05	-	59%
0.0352	379.52	-	66%	346.89	-	60%
0.0389	379.52	32.82	71%	356.39	20.68	65%
0.0427	385.06	32.82	72%	370.39	20.68	66%
0.0435	403.83	32.82	76%	388.75	29.81	72%
0.0437	403.83	64.33	81%	388.97	61.40	77%
0.0456	404.05	64.33	81%	390.59	61.40	78%
0.0844	424.88	64.33	85%	427.05	72.16	86%
0.1161	442.25	64.33	88%	428.57	72.16	86%
0.1818	443.30	93.21	93%	428.62	105.95	92%
0.2698	443.40	93.21	93%	428.62	105.95	92%
0.3577	443.49	129.97	99%	428.62	111.83	93%
0.4692	444.72	129.97	99%	432.43	111.83	93%
0.9347	447.09	129.97	100%	432.79	111.83	94%

The most interesting trend in table 4 is how little water is really used efficiently in irrigation in the Fish-Sundays Scheme. The bulk of the current allocation to irrigation is worth less than R0.03/m^3/year and more than three quarters of the water would be released at the construction cost of phase I (R0.05/m^3/year). Thus reducing irrigation may be a cost effective alternative to further dam construction. Furthermore, table 3 indicates that were irrigation in the Fish-Sundays Scheme scaled down by half, a core of very productive irrigation would remain, generating total values similar to those achieved under current conditions. The foregone irrigation benefits are a function of trading arrangements. The effect of a 50% cut in a trading environment would be a 20% reduction in total water value. In a non-trading environment the fall would only be 3% though from a far lower base.

Policy implications and conclusion

This paper produced several policy relevant results, the most important of which is the beneficial effect of allowing the market to allocate water to more efficient irrigators. While, improved efficiency gained through trading increases the overall benefit derived from the scarce resource, it makes it harder to argue that irrigation should release water. If farmer-to-farmer trade is not allowed, the opportunity cost of water to a given farmer is restricted to the production possibilities available to him. For the bulk of the Fish-Sundays Scheme those production possibilities are marginal fodder production that generates low water values. Freedom to sell his water permit increases the opportunity cost of a farmer's water to reflect the production possibilities faced by the best of his fellow farmers. A market creates the incentive to put water to its optimal use.

The data in table 4 does more than show the implications of reduced water transfers to the Fish-Sundays Scheme. Not only does it show the possibility of avoiding dam construction on the Orange, it also provides policy makers with an easy reference for the marginal benefits of irrigation water. These should be compared to the expected marginal benefit from any other water use, inside or outside the basin. For example, if the Eastern Cape Government wants to settle subsistence farmers on 12 000ha land that requires 150 million m^3/year, they know that they will have to pay between R0.0015 and R0.005/m^3/year depending on whether farmer-to-farmer sales are possible or not. Similarly, an allocation of 24 million m^3/year for environmental purposes would cost R0.0015/m^3/year. When the required volume of water can be bought at a cost justified by the expected benefits, the proposed reform is likely to be efficiency enhancing.

A final warning is needed to place this result in context. The framework used here supposes a national accounting stance and hides the indirect effects of irrigation in the region. The results do not extend to the value of agricultural output or the number of jobs created under the various scenarios; the indirect effects of the various water reform strategies are therefore omitted. Not being able to assess employment effects is a significant weakness in a province that is the second poorest in the country and where half of the economically active population are unemployed (Stats SA, 1999; Stats SA, 2000). In this case a national accounting stance based on direct impacts only, would argue for the release of a scarce resource from a province that desperately needs it for its own development.

References

Armitage, R.M., Nieuwoudt, W.L., Backeberg, G.R., 1999. Establishing tradable water rights: Case studies of two irrigation districts in South Africa. Water SA 25, 301-310.

Backeberg, G.R., 1995. Towards a market in water rights: A pragmatic institutional economic approach. Discussion paper, LAPC, Pretoria.

Basson, M.S., 1999. Report 32 Orange River development project replanning study. Department of Water Affairs and Forestry, Pretoria.

Booker, J.F., 1990. Economic allocation of Colorado River water: Integrating quantity, quality, and instream use values. Ph.D. dissertation, Agricultural and Resource Economics, Colorado State University.

Conradie, B.I., 2002. The value of water in the Fish-Sundays scheme of South Africa. Ph.D. dissertation, Agricultural and Resource Economics, Colorado State University.

Gardner, R.L., Young, R.A., 1988. Assessing strategies for control of irrigation-induced salinity in the upper Colorado River basin. Am. J. Agric. Econ. 70, 37-49.

Hazell, P.B.R., 1971. A linear alternative to quadratic and semivariance programming for farm planning under uncertainty. Am. J. Agric. Econ. 53, 53-62.

Howe, C.W., 1985. Economic, legal and hydrologic dimensions of potential interstate water markets. Am. J. Agric. Econ. 67, 1226-1230.

Louw, D.B., van Schalkwyk, H.D., 1997. The true value of irrigation water in the Olifants River basin: Western Cape. Agrekon 36, 551-560.

Nieuwoudt, W.L., 2000. Water market institutions in Colorado with possible lessons for South Africa. Water SA 26, 27-34.

Taylor, R.G., Young, R.A., 1995. Rural-to-urban transfers: Measuring direct foregone benefits of irrigation water under uncertain water supplies. J. Agric. Res. Econ. 20, 247-262.

Schmidt, RH and SE Plaut. 1993. Water policy in California and Israel. Fed. Res. Bank San Francisco Econ. Rev. 0, 42-55.

StatsSA, 2000. Measuring Poverty in South Africa. Government Printers, Pretoria.

StatsSA, 1999. The people of South Africa: Population Census 1996. Primary tables Eastern Cape. Report no. 03-01-20 (1996). Government Printers, Pretoria.