Step 1 : Indicates the amount of hectares earmarked for clearing by WfW.

Step 2 : Average carrying capacities as provided by agricultural extension officers and Döhne Agricultural Institute. In the case of SSU's, the ha/LSU unit ratio is divided by six, in order to get the carrying capacity per SSU, as it is assumed that one LSU equals 6 SSU's (Maphuma & Scheltema, pers. comm., 2001). This means 5.5 ha is needed to sustain one LSU, and 0.9166 ha is needed to sustain one LSU.

Step 3 : Step 1 / Step 2. This is the amount of LSU's that can be sustained on the total area earmarked for clearance. In the case of no alien infestation, this would be the amount of cattle that could be put on the natural grazing land.

Step 4 : This is the profit per LSU or SSU (value per LSU/SSU) as given in the Enterprise Budget (2001). No figures are available on the profit per cow/ sheep/ goat, but expressing profit in terms of LSU/SSU is seen as a standard.

Step 5 : Answer of Step 3 * Step 4. This provides insight into the profit if it is assumed that the total area (11400 ha) was used for beef cattle/ goat or sheep farming. This calculation assumed a zero level of infestation.

Step 6 : The average infestation level (7.5% in Albany) * Total area under WfW clearance (11400 ha). As previously noted, no carrying capacities are available for land with and without alien infestation, thus it is assumed that the carrying capacity of the land stays constant, regardless of the infestation level, with only the area available for farming/ grazing decreasing as a result of infestation. 7.5% of the 11400 ha where clearance is taking place is infested, which amounts to 860. 7 ha. Another way of seeing it, is that if all the areas infested in Albany were condensed, it would amount to 860.7 ha.

Step 7 : Step 1 (Total area under WfW clearance) - Step 6 (infested area). This is the reduced area available for farming as a result of alien infestation. Although infestation occurs only in patches, these patches can be condensed (as done in step 6) in order to calculate the reduced amount of hectares left for livestock farming.

Step 8 : Step 7 / Step 2. This is essentially the same calculation as followed in step 3. Because the amount of hectares available for livestock farming is reduced due to infestation, the amount of LSU'/SSU 's that can be sustained on the smaller area must be determined. Thus 1916 LSU's and 11497.4 SSU's can currently be sustained on the reduced farming area. Note that the same amount of goats and sheep can be sustained on the area, as both are perceived as equal to one SSU.

Step 9 : Step 8 * Step 4. The same calculation as that followed for step 5. The smaller profit for farming with livestock on a smaller area (thus having fewer animals) is calculated.

Step 10 : Step 5 – Step 9. The profit of the reduced area available for farming (with infestation) is subtracted from the profit of the total area without infestation in order to derive the net agricultural livestock benefit for each herd or flock.

Step 11 : The average of step 10. As two beef cattle enterprises are included, the average of the two needs to be calculated to determine one value for the net agricultural beef cattle livestock benefit. The same is done for the net goat and sheep livestock benefit, as farming with mixed herds (for example Angora goats and Boergoats and wool sheep (Merino's) and meat sheep (Dorpers)) occurs.

Step 12 : According to the Veterinary livestock census (1995), 9.7 % of livestock activity in the Albany region consists of cattle farming, 28.3% of goat farming and 62% of sheep farming, which together amount to a 100%.

Step 13 : The percentage of livestock farming (Step 12) * Step 11. This is done to reflect the separate monetary livestock benefits of cattle, goats and sheep in terms of the actual activity spent on it. We assume that farming in the areas cleared will be done in the same way as that currently existing (for example if sheep farming is the biggest livestock activity undertaken, as is currently the case at 62% of all livestock activity, it will also be the biggest activity in the area cleared).

Step 14 : The net agricultural livestock benefit of cattle, goats and sheep are added together. This constitutes the total net agricultural benefit derived from increased livestock activity in the Albany region.

4 PROPOSED METHODS FOR DETERMINING THE FIRE AND BIODIVERSITY NON-WATER BENEFITS

Biodiversity

The CVM was chosen for this specific study because it enables the researcher to tease out as far as possible the value of specific natural resource services in the area. It is a direct method for determining the value of a natural resource (where people state their preference), as opposed to the indirect valuing techniques (where people reveal their preference) such as the Travel Cost Method (TCM) and Hedonic Pricing Method (HPM) (Tietenberg, 2000: 38).

The HDM estimates benefits from observed market behaviour, where the change in prices or complimentary goods are used to determine the willingness to pay for a certain environmental good (Goodstein 2001: 142). All characteristics crucial to estimating the price of this good is thus included as explanatory variables. The best known example is that of a purchase of a house, where the potential buyer's WTP depends on a myriad characteristics of the house.

The TCM attempts to measure the benefits associated with recreational resources such as parks and beaches. The amount of money spent on utilising this resource (this is the so-called travel cost) will differ from person to person, and this difference in travel cost related to the differences in consumption of the good is used to derive a demand curve and hence consumer surplus for the specific environmental good (Goodstein, 2001:140).

It would be too difficult to fine-tune the TCM and HPM for the purposes of this study, as the HPM measures a composite good, in which biodiversity cannot be isolated. With the TCM, the undertaking of a trip for multiple purposes, and not just for biodiversity reasons can complicate matters. With the CVM, use- as well as non-use values can be identified, which is imperative for determining the value of biodiversity, as it is a concept which is renowned for its range of values offered (Tietenberg, 2000: 60).

A reduction in fire protection costs and less risk of damage to infrastructure as a result of wildfires

As with most of the non-water benefits, little data is available on the impact of fires on alien and indigenous vegetation and the role of the WfW project therein. In the determination of the benefit of the WfW on this topic, the impact of alien vegetation on the following should be quantified: fire regimes; fire cycles; intensity of fires; severity of fires; risk of damage to infrastructure; protective measures (fire breaks) and fire fighting costs (helicopters versus manual fire fighting) (Marais, pers. comm., 2000).

Other variables that also influence the fire hazard are the biomass involved and the level of infestation. For instance, an area 90% infested with aliens will have a substantial biomass, increasing the severity of fire in that area (Campbell, pers. comm., 2000). The physical outlay of the area also plays a role, as valleys do not burn as fast as other areas (Campbell, pers. comm., 2000). A comparison of the burnability of various areas, eg. grassland versus blackwattles, which will change the behaviour of the fire, will be investigated. An important factor is the impact of aliens (eg. Black Wattle) on Eastern Cape Thicket, which – under undisturbed conditions - does not burn. Thus aliens introduce fire management costs into these previously "burn-free" areas, and also disturb the biodiversity in these areas (Marais, pers. comm., 2001).

Two aspects need to be considered regarding the fire benefit of the WfW. Firstly, the increased cost of fire need to be investigated. This will be done by assessing the amount of money spent on fire management by authorities in the presence of aliens and without it. Secondly, the cost of soil erosion and the spread of alien seeds during fires as a direct result of alien vegetation need to be considered. Thus an expert opinion database on fire management costs will have to be developed to acquire fire management assumptions for the WfW model in the Eastern Cape (Marais, pers. comm., 2001).

5 CONCLUSTION

The clearing of alien vegetation invaders from land through the WfW programme yields a range of water and non-water benefits. The value and importance of the non-water benefits are expected to differ from site to site. In this study, a method for the calculation of an agricultural livestock benefit is advocated, and this benefit is estimated for Albany site in the Eastern Cape where substantial WfW activities are taking place. Methods for estimating two other non-water benefits, namely the reduction in fire protection costs and the conservation of biodiversity are proposed.

The net agricultural livestock benefit in Albany is estimated at R159 189, or R185 per hectare. It must be stressed that other agricultural activities such as flower harvesting have not been taken into account, which can substantially alter the outcome of a total net agricultural benefit. These other agricultural benefits should be incorporated in further studies.

Estimation of the reduction in fire protection costs and less risk of damage to infrastructure as a result of wildfires will be done by creating an expert opinion database on fire management costs. This will enable us to quantify alien vegetation's impact on fire regimes, fire cycles, intensity of fires, severity of fires, risk of damage to infrastructure, protective measures (fire breaks) and fire fighting costs.

The conservation of biodiversity and the promotion of ecosystem resilience is an important non-water benefit, especially in areas containing fynbos, as it is perceived as being one of the world's "hotspots" (Egan, pers. comm., 2001). Although methods such as the Hedonic Pricing Method or Travel Cost Method for valuing environmental goods and services were considered, the method suggested for valuing biodiversity is through conducting a contingent valuation survey in order to attain both use and non-use values.

ENDNOTES

1. Department of Economics and Economic History, P.O. Box 1600, University of Port Elizabeth, Port Elizabeth, 6000. The assistance of Stephen Hosking and Mario du Preez in drafting this paper is gratefully acknowledged, as is funding for this research from the Working for Water Programme.

2. It must be borne in mind that certain non-water benefits would be applicable to certain WfW sites, and that, for instance, the threat of fire would not be as important for some sites as for others. Thus a ranking is done to determine which benefits are the most important for the sites researched. As the three benefits discussed in this paper are deemed to be the most important for the Albany site, and because some data is available on these benefits, they were chosen. It must therefore also be stressed that this paper is work in progress.

3. The decision to use CBA as a tool for determining the viability of the WfW project was, in fact, made long before research on this paper started. Decision makers at WfW decided that this type of analysis would best suit their needs and would be the easiest to capture the costs and benefits of the project (Marais, pers. Comm., 2000). As the costs are readily available, the biggest undertaking would be the estimation of the various benefits of the programme. This paper builds on work done by Hosking and du Preez (1999).

4. We focus on the output side, thus estimating the benefit of increased livestock production due to increased grazing on cleared land.

5. More formally, it can be defined as the "sum total of all plants, animals, fungi and micro-organisms in the world, or in a particular area; all of their individual variation; and all of the interactions between them" (www.acnatsci.org/erd/ea//biodiv2.html).

6. The net agricultural benefit of WfW comprises the gain in potentially productive land. This can be used for various agricultural practices, depending on the economic objective (Palmer, pers. comm., 2001). This productive capacity can range from the increase in livestock production due to the increase in grazing land to the harvesting of flowers, honeybush tea, medicinal plants, food, sourfigs, buchu and thatch in fynbos regions (pers. comm., Marais, 2001). Interestingly, the possible income generated from commercial afforestation with alien tree species (for fuel wood, woodcarvings, furniture and other products) also needs to be assessed (Marais et al, 2000). It is expected that some areas will show higher gains in the net agricultural benefit than other areas, due to the variance in productive capacity.

7. A conversion can be done to interpret carrying capacity of SSU's in terms of LSU's. For example, as a rough estimate, in sweetveld one LSU will be equal to six SSU's (Maphuma & Scheltema, pers. comm, 2000). The Department of Agriculture has tables available for more specific and in detail conversions. This so called Meissner tables can enable a person to determine the carrying capacity of almost any animal (game and farm animals) on a piece of land, where all ratios are expressed in terms of LSU's. A LSU is defined as being a three-year-old cow (dry), weighing 400kg (Departement van Landbou, 1982:2). This will typically be a cow belonging to a small frame meat cattle herd, such as Aberdeen or Herefords, or a medium frame milk cow such as an Ayershire. The Meissner tables state that only dry milk cows be put on grazing land, due to the intensity of such farming practice (Departement van Landbou, 1982:2-4). Thus LSU or SSU is the yardstick against which all other livestock carrying capacities can be measured. The Döhne Agricultural Institute and the Agricultural Extension Officer in the area were consulted for obtaining carrying capacities in terms of SSU and LSU. The average of the range provided by them were used, and this carrying capacity is for natural veld in good condition with no heavy encroachment of bush.

However, the Department of Agriculture's Enterprise Budget (2001) and the Meissner conversion table, also from the Department of Agriculture (1982), were used for background information and cross-referencing. Although the carrying capacities between these sources sometimes differ, these differences are perceived as marginal. For standardisation purposes though, the Enterprise Budget's figures are used, as most other data pertaining to the livestock benefit (most noticeable the margin above cost, or profit per LSU or SSU) are obtained through it.

8. In a study conducted by Hirsch and Leitch (1996), which involved assessing the impact of knapweed on the economy of Montana, USA, a similar approach was followed - an acre with a patch of knapweed was considered the same as an acre totally infested with the weed (Hirsch and Leitch, 1996). This means that clearing will not increase carrying capacity as such, but will increase the area available for livestock farming.

9. The oversowing of cleared areas with grass seeds after clearing increases grass production and retard the process of re-establishment of bush, thus retaining grazing capacity for longer (Maphuma, pers. comm., 2000). However, the cost of sowing seeds to increase grazing capacity of agricultural land after initial clearing has not been taken into account, as we assumed that natural regeneration would be sufficient.

10. Margin above cost (net profit) per LSU/SSU = Total Gross income minus directly allocable costs.

It must be borne in mind that fixed costs (such as fencing) are not included in the calculation of the Enterprise Budget. These are seen as sunk costs and are not included in economic assessments (i.e. cost benefit analysis).

11. This is done for two reasons. Firstly, in the Enterprise Budget, provision is made for the purchase of one ram or bull. Secondly, it is assumed that the increased grazing land after clearing will not constitute a sufficient condition for farmers to purchase more livestock. It would also be difficult to speculate on the type of livestock bought by farmers when the grazing land available to them increases, as the future economic use of cleared land is by no means certain. A map of over/ understocking (stock numbers relating to carrying capacity) of the Eastern Cape reveals that the Albany site falls within a balanced stocked area - further strengthening our assumption that additional stock purchases, hence an increase in capital costs - is not a crucial consideration. In fact, the adjacent area to the east of the Albany site depicts severe overstocking, suggesting that increased land for grazing can be used for a better distribution of livestock (Raath, 1999).

12. The possibility of game farming is excluded. However, it has become an increasingly important scenario in the Albany region (Hahndiek & Palmer, pers. comm., 2001). Although Enterprise Budgets do exist for kudu and ostrich farming in the Grahamstown district, we felt that without data such as the livestock census in order to determine the percentage of game use in the area, no sensible benefit could be calculated. This should, however, be included in future analysis. The Grahamstown area is also seen as a perfect habitat for the endangered Oribi buck (Egan, pers. comm., 2001).

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The Pricing of Water for Conservation Projects in South Africa

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ABSTRACT

A number of water development and conservation programmes are currently being undertaken in South Africa; one of the most notable being the Working for Water Programme. It has already been subjected to economic analysis, but there are aspects of these assessments which merit more attention than has so far been given them. One of these aspects is the price of the water benefit. This paper examines this aspect from marginal cost and willingness to pay perspectives. It is shown that different approaches are appropriate for different project locations and that significantly different results are being obtained using these approaches. It is concluded that great care is needed in relating the price of water to the specifics of the various locations where the conservation project is being implemented.

1 INTRODUCTION

THERE ARE A NUMBER of substantial water development and conservation programmes currently being undertaken in South Africa; one of the most notable being the Working for Water Programme[1]. The main publicised economics rationale for this programme is that it adds to water-runoff into river systems, thereby reducing the cost of generating water in South Africa (Hosking and Du Preez, 1999). Pleasingly some of the projects in this programme have been subjected to economic analysis, e.g. Marais (1998); van Wilgen, Little, Chapman, Görgens, Willems and Marais (1997) and Hosking and Du Preez (1999). However, there still are economic aspects of these assessments which merit more attention than has so far been given them; one of which is the price of the water benefit. The outcomes of cost-benefit analyses of these projects are particularly sensitive to the price given to the water benefit.

This paper examines two options for pricing water generated by conservation projects in South Africa: marginal cost of water supply (for urban demand) and excess of marginal willingness-to-pay over marginal cost of water (for agricultural demand). Not considered in this paper are pricing perspectives for ecological demand (for the needs of river systems and estuaries) or forestry demand or the realisation of socio-political objectives (see DWAF, 1999). The Department of Water Affairs and Forestry (DWAF) set water prices in South Africa in terms of a number of criteria - relative scarcity being only one.

2 DWAF POLICY ON PRICING OF RIVER WATER

Prior to 1998 water rights in South Africa were allocated on the basis of a mix of river bank ownership, historical use and water right allocations by the DWAF. This way of allocating water rights was considered to failed to adequately take into account social needs in South Africa and in 1998 a new National Water Act was passed which revised the methods of allocation. South African water legislation was brought more into line with practice in other countries where severe water constraints are encountered, like Australia and the western half of the United States (Field, 2000:298). The Act abolished riparian water rights and replaced it with a system of government administered water rights.

In terms of this Act water rights are allocated for a 'reasonable' period rather than permanently. Users are required to register the water resources on their property with the DWAF and obtain licences in order to use it. The issuing of licences is administered by the DWAF and it is required that it be based upon the criterion of public interest. These licences are granted on a five-year cycle with a maximum duration of forty years. Provision is made for the transfer or trade of these water rights, subject to Ministerial consent (National Water Act, No 36, Section 25(2)) and Section 26(1). This consent is subject to various requirements being met; the most important being that the new use of the water entitlement is approved in the original licence issued.

The effect of the Act has not been to make historical use irrelevant (even though these are explicitly rejected). In practice historical use continues to be a key factor driving applications for water licences and their allocation (Backeberg, 2001). Although provision is indeed made for water right trading, it is felt by some authorities that this may have been undermined by the Act because limits placed on the duration of the right and the scope for transferring them (Armitage, 1999). Very apparent from the Act and other DWAF policy statements is that the need to conserve and carefully manage water resources is a cornerstone of environmental and resource policy in South Africa (DWAF, 1999).

In economic terms this means allocating water efficiently and getting prices 'right'. DWAF recognise that failing to price water efficiently can result in two kinds of misallocation of water:

an inadequate incentive to conserve water. The resultant over-use necessitates the expansion of infrastructure prematurely, tying up the country's limited capital resources when they could be better utilised for other purposes.

some water being used for low-value production instead of high-value production. In the absence of efficiency related water pricing the scope is limited for market reallocation of water supplies from low-value to high-value use.

Getting prices 'right' is interpreted at a macro level as pricing water at average cost (DWAF, 1999). It is required that sufficient revenue be generated to cover the annual cost of the management of water resources, the operation and maintenance of existing schemes, the rehabilitation of existing schemes and the development of augmentation schemes (DWAF, 1999).

3 MARGINAL COST PRICING

The most popular approach currently taken to pricing water generated through conservation projects in South Africa is that of a reference value price (see, for example, Marais 1998; van Wilgen et al. 1997; Hosking and du Preez, 1999). It refers to the marginal cost of generating water for urban demand. It is not an average cost in that it relates to the unit cost of bringing *additional* water into urban areas. The average cost is the unit cost of *all* water brought into urban areas.

The marginal cost price of river water is defined here as the cost of getting an additional cubic metre of water to a point of demand - where it is purchased by bulk buyers, mainly local authorities and agricultural associations. The costs being referred to are capital, operational and maintenance costs (Sampath, 1992). After purchase, the buyers of water add further value in the form of pumping, treatment, distribution and so on. The rationale for using these per unit costs as the price for water generated through Working for Water Programmes is that this is what additional water would otherwise cost. Examples of unit reference values that have been calculated by various researchers are shown in Table 1.

Table 1 Selected reference value price estimates of water used in South Africa

Study	**Price of water / m^3 (unit reference value)**
Van Wilgen et al. (1997) – Skuifraam development	R0.57* / R0.59+
Marais (1998) - Skuifraam scheme	R0.59
Hosking and Du Preez (1999) - Kouga / Krom River scheme	R0.89

*Unit reference value with clearing operations
+Unit reference value without clearing operations
Sources: Marais (1998); Van Wilgen et al. (1997); Hosking and Du Preez (1999).

Van Wilgen et al. (1997) based their calculations of reference value on the Skuifraam Dam development; the next one scheduled to be constructed for the Cape Town metropole. The development cost of this water supply scheme was estimated at R400 million and the operating costs at R2 million/a. Van Wilgen et al. (1997) generated two unit reference values: R0,59/m^3 on the basis that no control of alien plants took place and R0.57 on the basis that it did take place. The second value of R0.57 / m^3 was estimated by incorporating the costs of clearing alien plants and maintaining the catchment in a cleared condition, and benefits of increased water flow from an uninvaded catchment. By way of contrast with the Skuifraam Dam project, Van Wilgen (et al. 1997) estimated the cost of alien weed control in the Theewaterskloof conservation project to be R0.08 / m^3. Marais (1998) also based his estimate of the unit reference value on the Skuifraam Dam scheme.

Hosking and Du Preez (1999) also used a variant of the unit reference value approach to value water generated from an alien vegetation-clearing project; the one they assessed being in the Tsitsikamma Mountain catchment. They used a price of R0.89 / m^3 in their valuation study - the tariff charged for bulk, untreated water from state water supply schemes in the Southern Cape Coastal Drainage Region to urban and industrial users during 1993/94. Their rationale for using this as the price for water generated through the removal of alien vegetation was that no additional cost of water storage (dams) and transfer was necessary in this case. Their justification was that this infrastructure already existed and had the capacity to accommodate the extra supplies of water runoff generated in this catchment area.

The appeal to all of these authors of using marginal cost as a reference for pricing was that marginal cost is an efficient price - net social benefits are maximised (Sampath, 1992; Bate, Tren and Mooney, 1999).

The net social benefits associated with an economic activity can be represented by the following equation:

$$NB = \int_0^q P(Q)dQ - C(q) \qquad (1)$$

where P(Q) represents the demand curve for the commodity or resource Q and C (q) is the cost associated with supplying q amount of commodity Q. The maximization of net benefits requires:

$$P - \frac{\partial C}{\partial Q} = 0 \qquad (2)$$

or

$$P = \frac{\partial C}{\partial Q} = MC \qquad (3)$$

In other words, the maximisation of net social benefit requires price to be brought into equivalence with marginal cost.

However, although marginal cost pricing is efficient, the way it is applied in the above studies begs many questions (Marais, 1998; Van Wilgen et al., 1997; Hosking and Du Preez, 1999). Two aspects are problematic: (1) in all of these studies unit reference values are constant, and (2) storage projects are treated as alternatives to new water generating ones.

Data relating to the Port Elizabeth area provide evidence in support of a constant marginal cost theory (Table 2). The data is of average costs and quantities of water supplied to local authorities in the Nelson Mandela metropolitan area during the 1980s and 1990s. Distribution costs are excluded. The trend was for the average real cost of water (excluding distribution) to remain constant as quantity supplied increased during this period (see Table 3).

In the Nelson Mandela metropole the average real cost price of untreated water from 1978 to 2000 (22 years) was 152,1096 cents / m^3 with a standard deviation of 16,71929. A test for autocorrelation, the Durbin-Watson Statistic, was carried out due to the fact that the data are a time series regression. This statistic showed that autocorrelation did in fact exist. Therefore, a Cochrane-Orcutt regression was carried out to correct this problem. The results of the transformed regression are shown in Table 3. Regressing quantity of water on real bulk water prices (MC) yields a statistically insignificant slope coefficient of -0,0008624519 (see Table 3).

Table 2 Inflation adjusted water tariffs (bulk) for the years 1978 to 2000 for the Nelson Mandela metropole (Base year: 1995 = 100)

Year	Month	CPI Index (a)	Conversion factor to 1995 price levels (b)	Nominal Bulk Tariffs (c/m^3) (d)	Real Bulk tariffs (c/m^3) (d) x (b)	Quantity of water purchased million m^3 (excl. PEM)	Quantity of water purchased million m^3 (incl. PEM)
78	Jan	11,0	12,5954	15.08	189,94	8,241	N/A
79	May	12,7	10,9094	17,82	194,41	8,112	N/A
80	May	14,5	9,5551	17,82	170,27	9,968	N/A
81	Jan	16,1	8,6055	17,01	146,38	9,487	N/A
82	Oct	20,6	6,7257	18,23	122,61	18,165	N/A
82	Dec	20,8	6,6610	22,68	151,07	18,165	N/A
83	Jan	21,0	6,5976	24,74	163,22	12,192	N/A
84	June	24,6	5,6321	26,30	148,12	13,379	N/A
85	Jan	26,4	5,2481	30,04	157,65	21,07	N/A
86	Jan	31,9	4,3432	34,35	149,19	15,423	N/A
87	July	39,7	3,4899	38,41	134,05	17,313	N/A
88	Jan	42,3	3,2754	41,81	136,94	17,917	50,445

89	Jan	47,9	2,8924	49,27	142,51	17,13	43,250
90	Jan	55,2	2,5099	63,82	160,18	21,132	52,735
91	Jan	63,1	2,1957	72,18	158,49	17,591	41,062
92	Jan	73,3	1,8901	79,40	150,07	19,612	43,551
93	Jan	80,4	1,7232	87,30	150,44	22,454	50,292
94	Jan	88,4	1,5673	98,90	155,01	17,39	50,015
95	Jan	96,9	1,4298	108,60	155,28	21,341	56,565
96	Jan	103,6	1,3374	108,60	145,24	22,93	57,452
97	July	116,9	1,1852	108,60	128,71	21,279	57,189
98	July	123,8	1,1191	126,00	141,01	20,324	55,075
99	July	131,3	1,0552	140,00	147,73	16,65	52,848
00	July	138,5	1	151,00	151,00	N/A	N/A

Sources: http://www.statssa.gov.za/Economic % 20 Indicators/CPI.htm: Raymer (pers.conn 2000)

Table 3 Relationship between price of untreated water and quantity of untreated water, 1978-1999

	Intercept	**Quantity (m^3)**	**Adj - R^2**	**F-Stat**	**P-value of F-Stat**
Average cost	163,9	-0,0008624519	0,01	1,26	0,28
	(11.5)	(-1.12)			

Note: t-statistics are shown in parenthesis.

The constant slope of this regression suggests that the average cost of water remains the same as quantity of water supplied to the Nelson Mandela metropolitan area increases (Table 3). It follows that the marginal cost of water provision must have been equal to the average cost[2].

However, constant average costs do not seem likely to continue for much longer. Historically, water supply problems have been resolved through the construction of storage and conveyance facilities, but as water resources have become fully appropriated, the remaining water resources are becoming more expensive to exploit (Armitage, 1999). As could be expected many water supply experts are predicting that most of South Africa's local authorities will now encounter increasing marginal costs (DWAF, 1994).

Another curious aspect of the studies in South Africa using unit reference values is their treatment of water storage projects, like dams, as alternatives for water-generating ones, like alien vegetation-clearing ones. It is because they are treated as alternatives that dam project unit reference prices are posited as opportunity cost prices for water generated through alien vegetation-clearing projects. *A priori*, this practice is peculiar - these are complementary rather than alternative type projects.

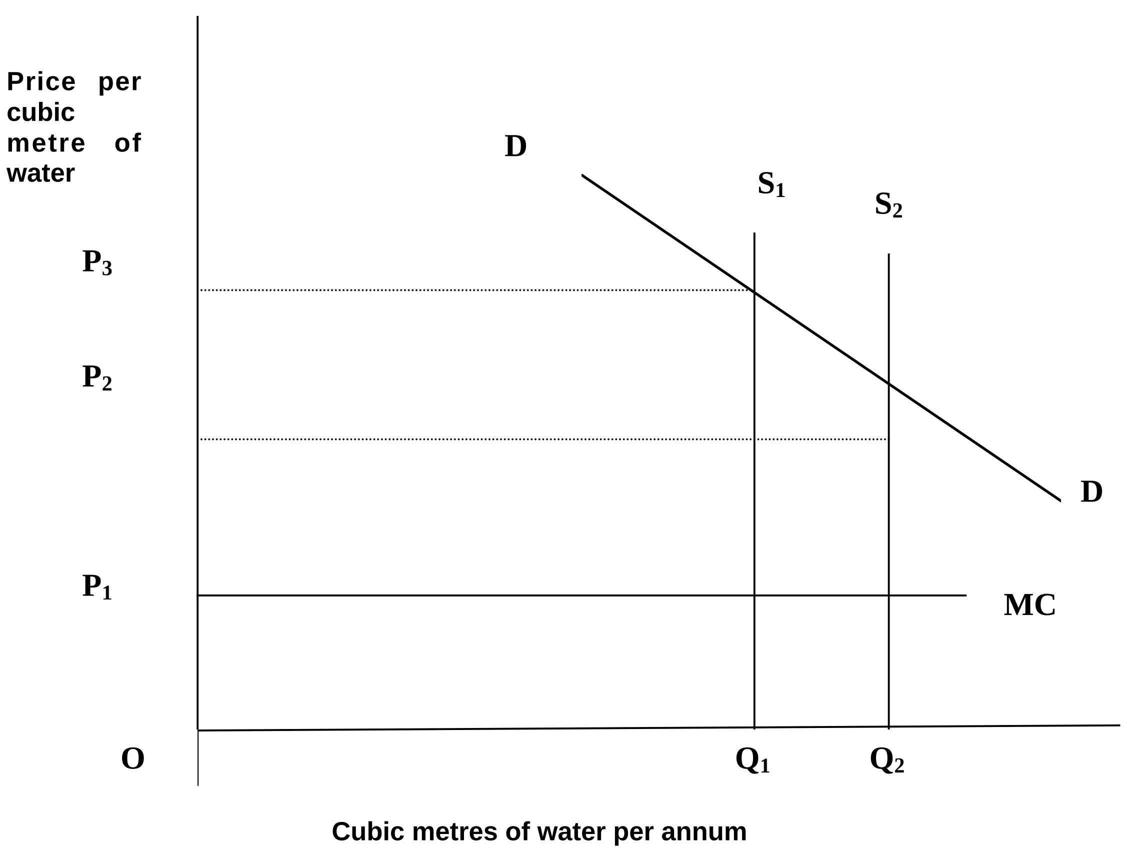
When projects are complementary, the efficiency issue is one of whether marginal costs are lower with or without alien vegetation removal. Use of a unit reference value approach to valuing water benefit is inappropriate in this case. To find a unit reference value an alternative type project should be found, one which generates additional water supply and preferably approximately the equivalent amount of it. This is not done in the above cited studies.

4 WILLINGNESS-TO-PAY APPROACH (FOR AGRICULTURAL USERS)

In cases where additional water is generated for agriculture, pricing with respect to marginal cost is unlikely to be efficient because the marginal cost referred to excludes external costs associated with water generation and abstraction – higher costs imposed on urban consumers, *inter alia*. Typically marginal cost in agriculture refers to dam storage cost and the private costs of pumping and transferring an allocation(quota) of water to farmers by pipe or canal. These costs are unlikely to change as a result of an alien vegetation-clearing programme and almost certainly do not reflect the real worth of the extra water generated for the farmer by this programme.

Farmers are prepared to pay more for this quota of water than the private marginal cost. The vegetation-clearing programme releases additional water into the river, not onto the land. To get this additional water from the river onto the land the private marginal cost referred to above must be incurred. The real marginal worth to agriculture of the additional water supply generated is therefore, the excess marginal willingness-to-pay over private marginal cost.

Figure 1 A Willingness-to-Pay approach to pricing water



In Figure 1 one demand curve, two short run supply curves (S_1 and S_2) and one long run private marginal cost (MC) curve for agricultural users are shown. The supply curve S_1 is the DWAF administered allocation of water to an agricultural area in the absence of an alien vegetation-clearing project, while the supply curve S_2 is the DWAF administered allocation of water available with an alien vegetation-clearing project. In the absence of a alien vegetation-clearing programme an farmer is prepared to pay P_3 for water (it will vary according to the prices charged for the crop produced), i.e., P_1P_3 above the marginal cost of water supplied ($0P_1$). If, as normally appears to be the case, the water supplied is not directly charged for in water right payments, the willingness-to-pay rate will exceed the marginal cost.

In this case the excess benefit to the buyer (P_1P_3x OQ_1) constitutes a benefit to land ownership and can be expected to be capitalised into land values. For this reason it has become common practice to determine the willingness-to-pay prices by reference to this capitalised portion in the land value (Backeberg, 1996). However, there are a number of problems associated with the use of this method of pricing water. First and foremost, the capitalised component of water right value is difficult to estimate because it is typically incorporated within the composite good, the farm. Secondly, this method generates prices that do not reflect social needs, for instance, those of the rural poor. Thirdly, unless demand is highly elastic, price P_1P_3 is not the value of the water benefit of an alien vegetation-clearing (Q_1Q_2). With the increase in water supply the willingness-to-pay price may drop. The appropriate price to value the water benefit of the alien vegetation-clearing programme is $[(P_2 + P_3) / 2] – P_1$.

Although the new National Water Act of 1998 abolished riparian water rights, the water entitlements generated prior to this time have largely been accommodated within the new allocative system (see Section 1 above for discussion). For this reason water pricing in South Africa by reference to capitalised land values remains relevant, even if undesirable (Backeberg, 1996). It is undesirable because the onus for improving the efficiency of water allocations falls on the farm sale market and this mechanism may be too slow and clumsy for this to be achieved. Where recognised existing water right allocation are traded directly and separately from specific farms, opportunities also have arisen to price water demand using this information (Bate et al, 1999, discussed later).

Agricultural willingness-to-pay prices for water are typically estimated from the difference between the value of land under irrigation (less the value of improvements to make the land suitable for irrigation) and under use for dry (livestock) farming (Backeberg, 1996). The approach is summarised in equations 4 and 5 below.

$$WR = \frac{r}{Q}(W_1 - M - W_2) \qquad (4)$$

$$W_1 = \frac{I}{r} \qquad (5)$$

In the above equations:

WR is the capitalised current value m^3 water right value in Rands

W_1 is the value of irrigation land per hectare,

M is the cost of improvements to irrigated land per hectare,

W_2 is the cost of 'dry' land per hectare (in best alternative use),

Q is the m^3 of water allocation (quota) per hectare,

I is the net annual income that is generated through irrigation and crop production per hectare, minus interest on operating capital and depreciation (and assuming I is received in perpetuity because the water right is granted forever), and

r is the private opportunity cost rate of money income (the discount rate).

When these equations are applied to Backeberg's (1996) data on an 87,7 ha piece of irrigated land in the Vaalharts scheme

WR = 8,4 c/m^3 (at 1995 price levels) or 12,01 c/m^3 (at 2000 price levels)[3].

Backeberg (1996) uses subjective opportunity costs and discount rates and takes no account of risk.There also have been many other water right estimates calculated for South Africa in excess of marginal cost of abstraction.

For instance, Bate et.al. (1999), using information on water right trading in the Crocodile River Catchment, Mpumalanga, found that prices paid for water rights ranged widely, with the prices paid for permanent trades being less variable than for temporary trades. They estimated that the future values of each trade discounted back to an average present value (i.e. NPV) of the permanent and temporary trades were R0.0225 and R0.0305 / m^3 of water respectively, with a discount rate of 12%. With a higher rate of discount of 16% the relevant NPVs were R0.0302 and R0.016 / m^3 respectively.

In a different study, Armitage(1999) estimated the rental value of water on the Lower Orange River. According to his calculations, based on income capitalisation, the values ranged from R104.50 to R524.50/15000m^3/a employing a 10 percent real discount rate. Using a higher real discount rate of 15 percent the values ranged from R144.50 to R774.50/15000m^3/a. In this study average rental rates for irrigation were also calculated, namely 362.39/15000m^3/a at a real discount rate of 10 percent and R531.33/15000m^3/a at 15 percent. Interestingly, average water rental values in the Lower Orange River are similar to those in the Western United States, although there are significant differences concerning the range in prices, time periods over which they are calculated, land use practices, and the discount rate used (Armitage, 1999). Values calculated for the United States ranged from R92.43/15000m^3(or \$1.52/acre/foot) in Oklahoma to R507.72/15000m^3(or \$8.35/acre/foot) in New Mexico in the Ogalla acquifer in the Western United States over the period from 1979 to 1986 (Torell, Libbin and Miller, 1990).

Trade in water rights also occurs to a limited extent in the Sundays River Valley and the Fish River area, situated in the Eastern Cape Province. According to Engelbrecht(pers comm. 2001) water rights in the Sundays River trade for on average R2000/ha (the water quota being 9000m^3/a) and for R2000/ha (the water quota being 13500m^3/a) in the Fish River area.

These and other estimates are reported in Table 4 below.

Table 4 Selected willingness-to-pay price estimates of water used in South Africa at 2000 price levels

Study	Price of water / m^3 in cents(willingness-to-pay value)	
	Capitalised value	**Rental value**
Backeberg (1996) – Vaalharts Scheme	149,79	12,01[1]
Bate et al. (1999) – Crocodile River Catchment	19,75 / 19,94	2,37[2] / 3,19[3]
	26,8 / 10,6	3,22[4] / 1,69[5]
Armitage (1999) – Lower Orange River	25,3 / 24,6	2,53[6] / 3,69[7]
Engelbrecht (2001) – Sundays River Valley	22,2	-
Fish River	14,8	-

1 Based on the average present value at a discount rate of 7,5%.
2 Based on the average present value of a permanent trade at a discount rate of 12%
3 Based on the average present value of a permanent trade at a discount rate of 16%
4 Based on the average present value of a temporary trade at a discount rate of 12%
5 Based on the average present value of a temporary trade at a discount rate of 16%
6 Based on the average present value at a discount rate of 10%.
7 Based on the average present value of the discount rate of 15%

5 INCORPORATING RATIONAL EXPECTATIONS

There are many factors which influence the price of water and they change over time - both on the supply and the demand sides (Michelsen, Booker and Person, 2000). Ideally, these factors need to be taken into account. This method entails estimating water prices on the basis of expectations of demand and supply over time. It generates a series of different prices for different periods, rather than one.

The main problem with respect to this approach is that the pricing of water becomes subject to speculative forecasting for which the information requirements are great but the margins of error are virtually unknown. Michelson et.al (2000) found that a large number of factors influenced the value of water rights (in the United States) over time. These included economic growth, population growth, the prime interest rate farmers, debt-to-asset ratio, price expectations, market share holdings of water rights and changes in the water supply for the region. The information problem is compounded further by substantial variations that exist in water market situations between and within regions.

Michelson et al. (2000) observe that water-right prices vary widely between different regions because of differences in the utilisation of water resources and institutional constraints. Price variations within a given region are mainly due to heterogeneity of the product. Water rights are heterogeneous with respect to water right priority and supply reliability and transfer impediments (Michelson et al., 2000).

Even when water rights are homogeneous in character (the same characteristics in terms of their size, priority and source, and transfer impediments) they also are often subject to large price variation over time (Michelson et al., 2000). These variations are usually due to differences in the net returns to irrigated crop production and make water rights a speculative or risky asset to trade in.

6 CONCLUSION

In pricing the water generated through a conservation project it is important to determine which measure is most likely to reflect an efficient price and identify for whom the water has been generated. A marginal cost measure is probably efficient if the water is being saved for a local urban authority. However, if the marginal cost concept is unlikely to reflect external costs, willingness-to-pay is probably the efficient choice of measure for price. This situation appears typically applicable when the water is generated for agriculture.

Ideally, prices also should be adjusted to take into account expected changes in demand and supply and differences between and within regions. Both marginal cost and willingness-to-pay approaches have their deficiencies, but are consistent with DWAF's (1999) new water pricing strategy that water should be priced in order to promote the efficient allocation and beneficial use of water (see Section 56(2) (c) of the national Water Act, 1998). Their pricing strategy provides for administrative as well as market-related measures to achieve this goal.

Currently the main method used to value the benefit of the water saved through conservation projects is the marginal cost approach. The average of selected estimates cited in this paper was 56 c/m^3 (at 1995 price levels or 77 c/m^3 at 2000 price levels) in the Western Cape. These estimates are based on the costs of water storing rather than water- generating projects. In cases where a willingness-to-pay approach is appropriate the average of selected estimates cited in this paper was 7,30 c /m^3 (at 2000 price levels).

Given the significant differences in prices generated from different areas and different methods it is clearly very important in water project investment analyses that great care be taken in relating the price of water to the specifics of the various locations where the conservation projects are being implemented.

ENDNOTES

The government budgeted R241 million for the Working for Water Programme during the year 1999/2000. The project has cleared about 238 823 ha of invasive alien plants and created about 21 000 jobs during the year (Mvoko, 23 August, 2000: 10).

The fact that average costs tend to be constant over time for this case suggests that marginal costs and average costs are equivalent. In these types of cases pricing by reference to marginal and average costing of water amounts to the same thing.

Follow – up studies of this work are currently being carried out by the Water Research Commission but the results have yet to be released.

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The Role of Virtual Water in Food Security in Southern Africa

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CONTENTS

CHAPTERS 1 AND 2 AND APPENDIX NOT PUBLISHED IN PROCEEDINGS. THEY ARE AVAILABLE BY CONTACTING ANTON EARLE.

Tables & Figures

ABSTRACT

The goal of this study is to analyse the interaction between water, food and trade. Botswana, Namibia, South Africa and Zimbabwe all have arid climates and are increasingly water stressed. Therefore, water and trade form an integral part of the food security of the region. The theory of Social Adaptive Capacity will be used to explain how countries respond to natural physical resource scarcity. The hypothesis is that a country with well-developed social resources can overcome physical resource scarcity and continue developing in a sustainable manner. In terms of the international grain trade this means that countries with higher levels of social resources will be able to import grain, which provides the bulk of the per capita calorie intake in the region. Each tonne of grain imported represents over a tonne of water saved locally. This water, used in the manufacture of grain, is called virtual water. The water saved can assist a country to achieve the goals of water demand management. Additionally, money that would have been spent on costly water transfer and storage schemes can be used more efficiently by investing in industial and service oriented projects. The level of reliance of each of the four countries on virtual water is assessed and compared to the state of food security in the country. It is found that there is a marked correlation between a country's reliance on virtual water and the level of food security in the country.

Key terms:
Virtual water, water demand management, Social Adaptive Capacity, international factor trade, food security, allocative efficiency, productive efficiency, levels of agricultural assistance, soil water, development aid, sustainable livelihoods.

Abbreviations used in the study

ABARE	Australian Bureau of Agricultural Resource Economics
ACP	African Caribbean and Pacific (countries)
AGRIC	Department of Agriculture (South Africa)
AoA	Agreement on Agriculture
DWAF	Department of Water Affairs and Forestry (South Africa)
EU	European Union
FAO	Food and Agriculture Organisation of the United Nations
GDP	Gross Domestic Product
GIEWS	Global Information and Early Warning System
GTEM	General Trade and Environment Model
HDI	Human Development Index
H-O	Heckscher Ohlin (model)
OECD	Organisation for Economic Cooperation and Development
SAC	Social Adaptive Capacity
SADC	Southern African Development Community
UNDP	United Nations Development Programme
WDM	Water Demand management
WTO	World Trade Organisation

1 INTRODUCTION: VIRTUAL WATER OR REAL DROUGHT?

i. Goal of the Study

The goal of this study is to analyse the interaction between water, food and trade at a theoretical, as well as a practical level. This will be done by gauging the level of reliance on virtual water imports and the effect on food security in southern Africa.

Section **ii** will give an introduction to the debates surrounding food security. Section **iii**, on page three provides some background to the concept of virtual water. The specific objectives of this study are presented on page 6, in Section **iv**. These objectives will contribute toward achieving the overall goal of this study. This introductory chapter will end with Section **v**, which gives the regional context and associated policy issues of the countries in the study.

ii. Food Security

"Food security exists when all people, at all times,
have physical and economic access to sufficient,
safe and nutritious food to meet their dietary needs
and food preferences for an active and healthy life."
\- 1996 World Food Summit

The individual is at the centre of the food security debate. As Amartya Sen (1981) pointed out, the emphasis should not be on the production or supply of food, but on the individual's access or entitlement to it. A country does not achieve food security, households and individuals do. Definitions of food security have moved from objective to subjective, reflecting a shift away from concerns about the number of calories consumed by a

person. Issues such as cultural acceptability and food quality, as defined by individuals, have gained prominence.
For the past century world food production has been outstripping population growth, resulting in a long-term trend of declining food prices in real terms (ABARE, 2000). Yet, despite this increase in food production there are still 800 million people in the world considered food insecure. Many of these people live in Sub-Saharan Africa, with over 46 per cent living below the international poverty line of US$1 per day (Devereux & Maxwell, 2001). The greatest single cause of famine in Africa is not drought, nor plagues, but war. Correspondingly the focus in development assistance has moved away from an emphasis on food self sufficiency to promoting sustainable livelihood strategies for the rural, as well as the urban poor. In effect, creating an enabling environment for household food security.

Agriculture is central to any food security policy, accounting for the production of all food grown on land. Self evident as this may be, it is important to remember that there is a finite amount of land and, more importantly, water available which is suitable for the production of food. The issue is deciding where to produce this food.

Food self-sufficiency, achieved by meeting all food needs through domestic supplies, used to be a national agricultural objective in many countries. It had the effect of keeping foreign exchange in the country, where it could then be used to import products, which could not be locally produced. A measure of control over producer prices, resulting from less exposure to the vagaries of international market prices, was kept. In the South African case there were the political factors of the 1970’s and 1980’s, which saw food self-sufficiency becoming part of a goal of national self-sufficiency.

Yet, in the 1990’s nearly 80 percent of all malnourished children lived in developing countries, which produced food surpluses (FAO, 2000). Increasingly the trend is away from food self-sufficiency and towards partial reliance on food imports. This provides a measure of protection against droughts, an important factor in southern African agriculture. There is also the potential of releasing for other uses substantial amounts of water, used in the production of food crops.

Aside from the water savings from a reduction in agriculture, the other factor, which has an effect on food self-sufficiency policies, is international terms of trade. Trade barriers, in the form of import taxes and quotas, and agricultural subsidies have a direct effect on the world prices of agricultural commodities. These world market prices must form an integral part of any food security policy.

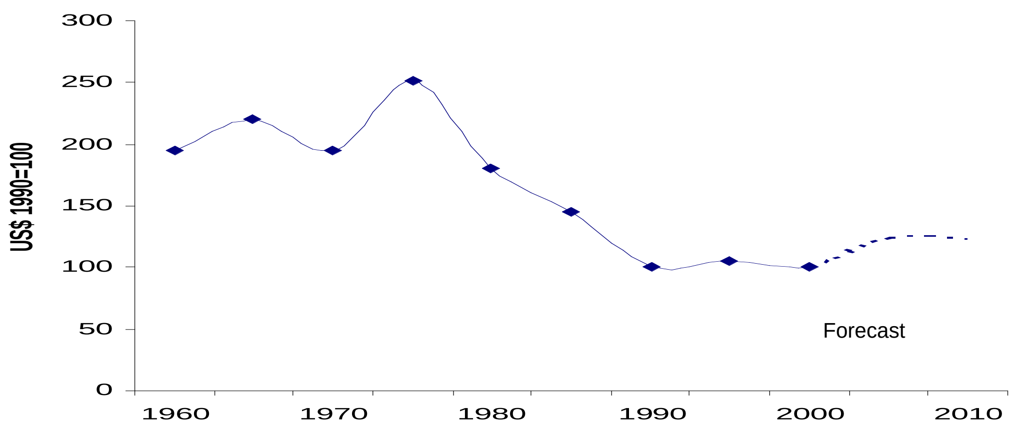
iii. The concept of virtual water

In the arid regions of the world water is the limiting factor in agriculture, with a direct bearing on what can and what cannot survive in a particular region. During the growth cycle of a plant water is applied to the field, whether by rainfall or by irrigation. Some of this is absorbed by the root system of the plant, while the remainder finds its way into rivers, percolates into the soil or evaporates. At harvest most of the water consumed by the plant has been lost to the atmosphere through the process of evapo-transpiration. A small portion of the water is locked inside the structure of the plant. Once the plant has been processed into an agricultural commodity, such as wheat, it contains very little moisture. Yet, the quantity of water involved in its production is large. In arid regions a tonne of wheat requires 1300 tonnes of water (Krieth, 1991). The concept of virtual water serves as a metaphor for the complex interaction between water, food and trade.

It has been calculated that the flow of virtual water into the Middle East region, in the form of grain imports is equivalent to the annual flow of the Nile (Allan, 1996). This has been a major factor in averting conflict over water in the region, as local water resources have, since the early 1970’s been insufficient for the production of local food needs.

Importing food into arid regions not only mitigates physical water scarcity, but also provides economic benefits. Since the Second World War there has been a strong downward trend in food prices (Merret, 1997). World grain prices in 1999 were no more than half of their real value in 1961 (Figure 1), with no indication of a long-term reversal to this trend (Berkoff, 2001).

Figure 1 World grain prices

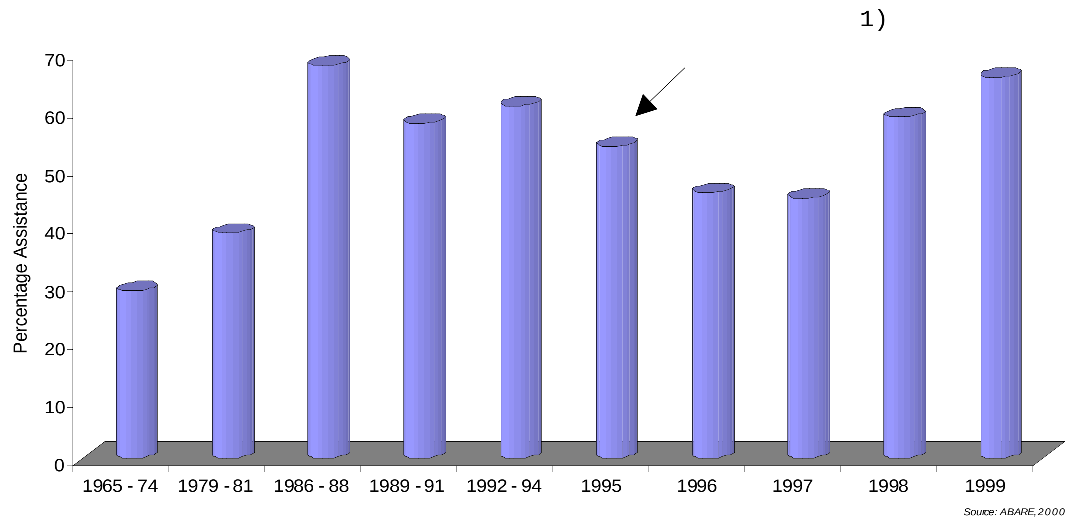


Source: (World Bank, 2000)

There are two main reasons for these low grain prices. First, crop productivity has increased. New and hybrid species have been created which respond well to large amounts of fertilisers commonly used in commercial farming. So effective have these productivity increases been that world food output has risen by more than 25 percent per capita from 1961 to 1998 (FAO, 2000).

Secondly, agricultural sectors of the large food exporting countries receive subsidies. These are in the form of restrictions or taxes on imports, direct payments or subsidised inputs to farmers and export subsidies. The 1995 Agreement on Agriculture of the World Trade Organisation (WTO) was supposed to lead to a decrease in the level of support given to farmers in the North. This has not been the case (Figure 2) as the nominal rate of assistance has increased in the OECD countries and is fast approaching the high levels of the mid 1980's (ABARE, 2000).

Figure 2 Rates of agricultural assistance – OECD countries



Source: ABARE (2000).

With world food prices at such a low level, imports form an important part of any food security policy in southern Africa.

Two thirds of annual grain exported on international markets comes from the countries of North America and the European Union (World Bank, 2000). These areas have temperate climates, well suited to large-scale rainfed agriculture. The water used in growing this grain was not diverted from another source. Assuming that the natural vegetation of these areas would have consumed a similar amount of rainwater as the grains grown there, the opportunity cost of this water is, in effect, zero. Rainfed agriculture accounts for sixty percent of the world food supply (FAO, 1998).

Arid developing countries are at a double disadvantage when attempting to compete in the international grain market. First, they do not have the resources to compete against the agricultural subsidies provided to farmers in the North. This means that their cost of production will always be greater than the international market prices.

Second, their climatic conditions are not conducive to the large-scale production of temperate-zone crops, such as wheat. They will have to mobilise large volumes of water for irrigation, often at great economic, social and environmental cost. Large parts of South Africa are well suited to rainfed farming; a third of South Africa's wheat is grown in the western Cape without irrigation and the majority of maize is grown on rainfed land (AGRIC, 2001) These areas can potentially produce grains efficiently, if they can keep costs below world market prices. In many circumstances irrigation schemes are efficient, using relatively little water and adding value to it, such as viticulture and various other horticultural products. Zimbabwe is in a similar situation, with large parts of the country also suitable for rainfed farming. Whereas, most of Botswana & Namibia's crop farming potential would involve irrigation, as less than half a percent of both countries areas receive more than 500 mm per year (FAO, 1995).

iv. Objective of the study

The goal of this study is to analyse the interaction between water, food and trade at a theoretical, as well as a practical level. This interaction has profound effects on both development aid as well as sustainable livelihood strategies. The theory of Social Adaptive Capacity will be applied in the context of virtual water as an aid to food security in southern Africa.

v. Regional Trends

- *First Objective: is virtual water a policy decision, or is it a reaction to drought?*

The study will investigate whether the four countries are adopting a long-term trend of relying increasingly on virtual water. In times of drought the need to import food is forced upon countries, but this does not imply a consistent reliance on virtual water. Data on agricultural trade and production over the past forty years will be used to identify trends in food provision. Changes in the composition of food trade and production, such as from cereals to cash crops, will also give an indication of the reliance on virtual water

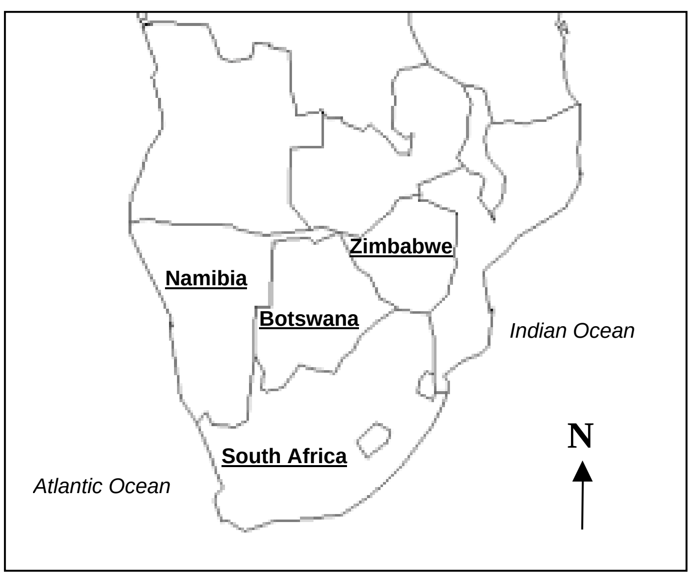
- *Second Objective: what trends in food security are observable?*

Once it is determined how the food is supplied the study will investigate the effect on food security within the country. Data on calories per capita will be looked at to give an indication of long-term trends. The depth, as well as the extent, of hunger will be determined. The level of food security will be viewed in context of the result of the first objective. Any correlation between the adoption of a virtual water policy and the level of food security within the country should become visible. According to the theory of Social Adaptive Capacity, a country can overcome a shortage of first order resources if its second order resources are sufficiently evolved. Therefore, countries with the highest level of second order resources are expected to be able to adopt the concept of virtual water.

Background to the study-region

This study will focus on Botswana, Namibia, South Africa and Zimbabwe. In a study by Turton (1998) these four states were grouped together as a "central belt of scarcity" (Map 1).

Map 1 Southern Africa



This region has relatively limited water resources. In relation to other countries in southern

Africa, these four countries have the most developed economies, making current and future competition for water great. They also have the largest number of technological and economic options available.

The Governments of the countries in the study region have all committed themselves to implementing policies of water demand management. In South Africa the only right to water granted is to the reserve, comprised of a minimum amount of free water for each person and for the environment. Apart from this no other group or individual receives an automatic right to water, even if the water is on their property. There has been a move toward charging a market-related price for water, as water has been recognised as a scarce and strategic resource, which has to be used sustainably. Zimbabwe has also moved away from automatic rights to water. There, an order of priority of use has been developed. Primary water, for domestic purposes & non-commercial farming are at the top of the list, with the environment, urban sectors, industry & finally agriculture following.

The rural populations of both Namibia and Botswana are net consumers of food (SADC, 2000). The provision of water for domestic purposes has received priority. Although there is not a formal policy of water demand management in either country, Namibia has recognised the need to maximise returns to water and Botswana has focussed on the provision of domestic water and sanitation.

There is potential for a number of interbasin transfer schemes within and between countries. Botswana could, potentially, tap water from the Zambezi or the Okovango rivers, but this has environmental and political problems. Both Namibia and Zimbabwe have made tentative plans towards the large-scale use of the Zambezi, but the main hurdle to overcome is the distance this water will have to be transported to bring it to where it is needed.

Most of the available water resources within South Africa's borders have been used (Turton, 1998). The Lesotho Highlands Water Project is predicted to be able to supply the needs of Gauteng until about 2020, with current water use growth increases. The next available source of water will be from the Zambezi, 1200 km away. Such a project would prove to be expensive, both from an economic as well as from an environmental point of view. It would also leave South Africa vulnerable to interruptions in the supply of this water. This is an important factor as other riparians also have plans to use the water from the Zambezi. It is preferable for a country to be water self sufficient rather than food self sufficient, as food is much easier to transport internationally than water.

Water Demand Management (WDM) has as its focus the efficient use of existing water supplies, in preference to the development of new ones. For any WDM policy to be successful there must exist the economic capacity and the political will within the society. If water is to be allocated to more efficient uses the capacity must exist in the economy to add greater value to a unit of water than what agriculture can. The ability of a society to adapt to natural resource scarcity has been called *social adaptive capacity* by Turton & Ohlsson (1999). A scarcity of first order (or natural) resources leads to absolute scarcity only if there is also a scarcity of second order (or social) resources (Turton, 2000). Scarce water resources in a country, in combination with socio-economic resource abundance leads to *structurally induced relative water abundance* such as in Israel (Turton & Ohlsson, 1999). In such a situation virtual water acts as a bridge in achieving the goals of WDM.

2 CONCLUSION

The goal of this study is to provide a greater understanding of the complex interaction between water, food and trade. This was done by looking at the level of reliance on virtual water by the countries in the region. The theory of Social Adaptive Capacity predicts a movement away from a reliance purely on first order resources. As development progresses the social resources become increasingly important, especially once there is a shortage of the physical resources.

The study showed that Botswana and South Africa rely the most on virtual water imports. This is as predicted by the theory of Social Adaptive Capacity (SAC), as they have higher levels of social resources. Although Botswana has a slightly lower HDI value than Namibia, its GDP is higher, therefore it can import more. As their water resources have become increasingly limited they have started using water where it will receive maximum returns. The success of their policy is borne out by the fact that they are also the two countries which are most food secure.

As the SAC theory predicts, the country with the lowest levels of social resources, Zimbabwe, is least able to find alternatives as physical scarcity threatens. Reliance on virtual water remains low and it is the only country in the study that is a net exporter of grains. Despite this, it is also the least food secure. It would appear that for the four countries studied there is a positive correlation between levels of SAC, reliance on virtual water and the state of food security.

On an international level the import of grains by arid developing countries is likely to continue. It seems unlikely that agricultural assistance levels and trade barriers will be reduced in the near future. If they were reduced the results would also appear to be mixed for the four countries, with some even showing an improvement in terms of trade. Virtual water imports are likely to remain a rational choice for the countries in the study.

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