A NET BACK VALUATION OF IRRIGATION WATER IN THE HARDAP REGION IN NAMIBIA

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Abstract

Namibia is currently in the process of phasing out water subsidies in its government-sponsored irrigation schemes. However, the financial effects on the affected farmers are frequently unclear, and so are the economic effects on society as a whole. The net back method provides a framework for estimating rough values of irrigation water in situations such as those in Namibian agriculture, where farmers face a number of constraints which are difficult to model explicitly due to the dearth of reliable data.

We apply the net back method to estimate the value of irrigation water used for different crop alternatives in the Hardap region in southern Namibia. We find that all the crop alternatives, which farmers in the region currently choose between, will remain financially viable after the increases in user charges which are envisaged in the near future. However, substantial shifts in agricultural production will become necessary once the long term cost recovery policies are in place in the water sector. We also extend the net back framework in order to study potential effects of further increases in water user charges, which may become necessary in future as the water demand from other water users increases.

1. INTRODUCTION

In Namibia, as in many other countries in southern Africa, water use has grown rapidly over the past 25 years, and there is concern that potential water sources are running short. Consequently, water management policy is becoming a critical component of Namibia's development strategy. Until recently the government has mainly emphasised the importance of increased supply of water, but with the realisation of water as a finite resource, the focus is now on the demand side of water management. This means that different demand-side policies, for example water pricing and investments in advanced technologies, are used in order to achieve a decreased demand for water. As

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the competition for water will intensify further in the future, it is essential to examine the current situation of water use and the influence of different policies on water demand. The design of sustainable development policies requires an understanding of the full social value of water (Lange, 1998).

The most water intensive sector in Namibia is agriculture, where irrigated crop production uses twice as much water as livestock agriculture. Irrigation water has been heavily subsidised historically, and those farmers who are supplied through government irrigation schemes do not pay the full financial cost of supplying water. However, the government is planning to raise the user charges for irrigation water in the near future, with the goal of full cost recovery. The problem is that currently farmers are mainly growing low-value crops under inefficient irrigation systems, and therefore may not be able to bear the full cost of water. A change of the production into more high-value crops and more efficient irrigation methods may be necessary if the farmers are to be able to pay the new, higher user charges.

Obviously, it is necessary to have some idea of how changes in water user charges will affect crop patterns and, hence, water demand. However, as in many African countries, there are a number of constraints affecting farmers' decisions – limited access to capital markets, information costs for establishing new middleman relationships in order to market new crops, and so on – and it is frequently difficult to find the economic data which would be needed if one were to include these constraints in sophisticated modelling frameworks. Empirical studies of water needs in Namibian agriculture have therefore often used the net back technique, a version of the residual imputation approach which relaxes some of the more restrictive assumptions in that method but which can still provide rough estimates of the values of irrigation water in different potential uses (Lindgren, 1999; Brunnström & Strömberg, 2000; Lange *et al*, 2001).

This study applies the net back technique to study crop patterns and the value of irrigation water in the Hardap region in southern Namibia. However, we extend the technique slightly in order to estimate an upper bound for the demand for irrigation water at different water user charges. A detailed prediction of the exact amount of water which will be demanded at different user charges is not possible to make, using the information provided by the net back method, but an upper bound for water demand at different user charges is nonetheless useful for planning, for instance, investments in water supply facilities. This slight modification of the net back method can thereby, hopefully, provide a useful planning tool.

2. THEORY

The residual imputation method is one of the most frequently used approaches for determining shadow prices for irrigation water. The method measures the value of an input used to produce intermediate goods. If appropriate prices are assigned by market forces to all inputs but one, the remainder of total product is imputed to the remaining or residual input. By subtracting all costs of production but one from the total value of output, the approach approximates the value of the marginal product of a productive input, such as water. The remaining, or residual, value is assigned to the non priced input (Young, 1996).

Two conditions need to be fulfilled to derive the residual function. First, the competitive equilibrium requires that the prices of the inputs are equated to returns at the margin. It is assumed that profit maximising producers add productive inputs until the value of marginal products are equal to the opportunity costs of inputs; however, where credit markets are not functioning well, or where retraining in order to grow new crops is not readily available, the opportunity costs of physical and human capital may not correspond closely to the market prices (if any) for these inputs.

The second requirement is that the total value of production can be divided into shares so that each factor, except the unpriced one, is paid according to its marginal productivity, and that thereby the total value of the production is completely exhausted; this will only be the case if constant returns to scale apply (Debertin, 1986). The residual imputation method is highly sensitive to these restrictive assumptions and, if they are not fully met, will produce misleading shadow prices for water.

The residual method has been used in a survey at the Stampriet Aquifer in Namibia to estimate the value of water for an average farm (Lindgren, 1999). However, a subsequent study in the same area (Lange *et al*, 2001) found results which indicated that the assumption of constant returns to scale did not hold. Moreover, given that very little retraining is available for active farmers in Namibia, wishing to change to new production alternatives, and given that interest rates on loans to farming are high and variable – where loans are available at all – the assumptions of clearing markets in physical and human capital do not necessarily hold and are, in any case, difficult to model.

The net back method (Bate & Dubourg, 1997) is closely reminiscent of residual imputation, but relaxes the restrictive assumptions in the residual imputation method. The net back method has been used to study water use in Namibian agriculture (Brunnström & Strömberg, 2000; Lange *et al*, 2001) as well as in South African agriculture (Tren, 1997). If we consider a farm abstracting water in a region where water is a scarce resource, and cannot be supplied costlessly, a simple net back model of the water use for growing a specific crop can be written as $N = (P * Q) - C$, where P represents the price of the crop, Q is the quantity produced of that crop and C represents the total non-water costs of producing the quantity Q. This model is applied for each crop separately.

The net back for a given crop reflects the farmer's maximum ability to pay for water (MATP), and is represented by N in the equation above. This value of MATP is the maximum amount a farmer could possibly pay for the water used to grow a crop, with the crop still remaining financially viable. While the residual imputation method assumes that the shadow price calculated in this fashion provides a correct marginal valuation of the water used, the net back approach acknowledges that the correct marginal value – and hence the willingness to pay – for the last unit of water may be lower than the MATP, for instance because of omission or underestimation of the shadow price of some production factor.

In our study we have calculated the farmers' MATP/m^3 for irrigation water when growing different crop alternatives under different irrigation techniques. These values can then be compared to the current tariff for irrigation water and also to the total cost for water supply (water, maintenance, all capital costs and flood damage), to see what user charge the farmers would be able to pay, while still remaining profitable.

The demand for water is affected by which crops are grown and by what irrigation method the farmers use. Therefore the demand for irrigation water can be decreased if the farmers choose to change the production from a low-value alternative that gives a low MATP/m^3 to a higher-value alternative with a higher MATP/m^3. An outer bound for the demand curve for water can be determined by assuming that farmers will change their production alternative if a higher user charge makes their current alternative unprofitable. The change in production can be attained through a raise in the user charge for irrigation water.

The demand curve thus estimated only shows the farmers' *maximum* ability to pay and thereby the *maximum* total demand for water, based on current production patterns in the region, and cannot predict the farmers' real behaviour and reactions to a raised user charge for water. Farmers may change crop patterns before a crop becomes unprofitable, or may switch to other production alternatives than the ones currently grown. Consequently, the demand for water at a specific user charge may be less than what is indicated by our calculations; the relationship between actual demand and estimated demand is illustrated schematically in Figure 1, where the horizontal shifts in the estimated demand curve occur at those water user charges where some crop alternative becomes unprofitable and has to be replaced by some other crop alternative. Actual demand at a specific user charge is thus likely to be less than the demand estimated through our method. Nonetheless, for planning purposes it is of considerable interest to be able to predict the maximum demand for irrigation water at different user charges, even if actual demand falls short of this predicted amount.

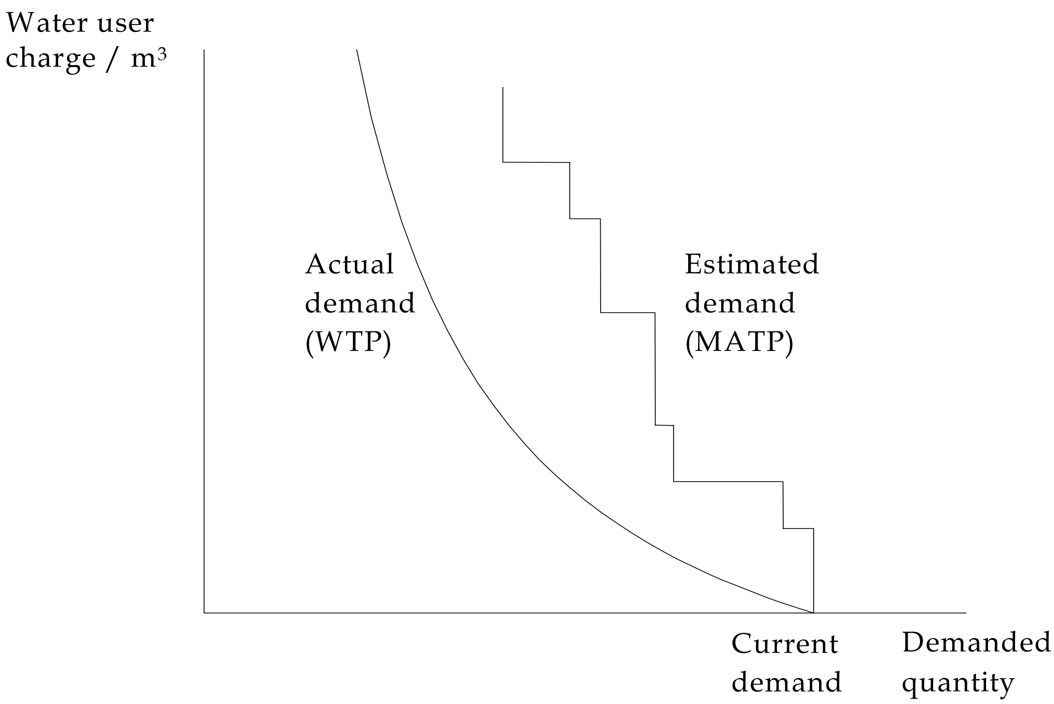

Figure 1: The approximate relationship between the actual demand for water and that predicted by the extended net back method

3. HARDAP

The Hardap dam is the largest state water dam in Namibia and is situated in the Fish River catchment approximately 250 km south of the capital, Windhoek. The Hardap dam was completed in 1962, and was built to provide an assured water supply for the town of Mariental and the Hardap irrigation scheme. The main reasons for the dam's location are the suitable topography in this area for the construction of a dam and the good soil for a large scale irrigation scheme. The Fish River catchment area flowing into the dam covers an area of 13 600 km^2 and stretches from the Hakos Mountains in the north-west, to just north of Maltahöhe in the south-west. The storage capacity of the dam was calculated in 1992 to 294 593 000 m^3. The dam generally reaches its full capacity during February, but depending on rainfall this can be delayed until as late as mid April. Rainfall data have been recorded in this part of the country from the year 1913, and the yearly average rainfall of the catchment varies from 180 mm in the northwest to 209 mm in the southeast. The vegetation type in the area is typical for the dry expanses of the southern parts of the country, namely dwarf shrub savannah vegetation.

In the years 1963 – 1964, shortly after the Hardap dam was completed, the irrigation scheme was established. Water is bought from the water parastatal, Namwater, by the Ministry of Agriculture, Water and Rural Development (MAWRD), which in turn distributes the water to the farmers in the scheme; there are currently 32 commercial farmers benefiting from the scheme. The irrigated area also includes the Hardap Research Station, which consists of governmental experimental farms with an area of 135,40 ha, and a 20 ha plot farmed by the Mariental prison. Apart from the irrigation scheme, Namwater also supplies water from the dam to the local population and to a tourist camp located in the Hardap dam National Park (Muduva & Williams, 2001).

Wheat, maize, and cotton are annual crops, which means that they are replanted each year. As some of the crops have their growing season in the winter period, and others during the summer, it is possible to combine two crops on the same land area during a year. The growing season for wheat in this area lasts from May or June until December, while for maize and cotton the season lasts approximately from December or January until June. Lucerne and grapes are so called permanent crops, i.e. their lifecycles stretch over periods of several years – lucerne has to be replanted every five years while grapes are replanted approximately every 25 years. Wheat and maize are grown in combination on approximately 1000 ha, wheat and cotton in combination on about 100 ha, lucerne on 800 ha, and grapes on 250 ha.

Most of the irrigation at the Hardap scheme is gravity fed surface irrigation, mainly flood irrigation. Other irrigation systems are used only on a small scale; the main alternative method is micro or drip irrigation, which is used for grape production. The irrigation techniques have varying degrees of efficiency, which are shown in Table 1.

Table 1: Irrigation system efficiency

Irrigation System	Efficiency %
Surface systems (flood)	50
Sprinkler	70
Centre Pivot	80
Micro	85
Drip	85

Source: Siegfried Engels, personal communication.

Combining these figures with the different crops' annual net water requirements gives the gross water requirements listed in Table 2.

Table 2: Net and gross water requirements for different crops and irrigation systems

	Wheat	Maize	Cotton	Lucerne	Grapes
Net water req.					
m^3/ha/annum	5974	12415	8000	22716	15100
Gross water req.					
m^3/ha/annum					
Flood	11948	24829	16000	45432	25167
Sprinkler	8534	17735	11429	32451	21571
Centre pivot	7468	15518	10000	28395	18875
Micro/drip	7028	14605	9412	26725	17765

Sources: Siegfried Engels and Francois Wahl, personal communication, and calculations based on Table 1.

In Hardap, water for irrigation is distributed through a system of lined canals, but also through buried pipelines, to 114 individual offtakes on the east and west banks of the Fish River. Farms are grouped close together on both sides of the river so as to make the water distribution more effective. The water consumption at the scheme depends on the growing seasons and the stages of the growth of the crops. Consumption is measured by water meters at each individual offtake. As the old meters do not function properly, it is important to be aware of the fact that it is very difficult to get reliable figures for the actual water consumption; both our calculations, and the billing from MAWRD, are therefore based on estimates of water use rather than on the actual figures. Improved water meters are currently being tested by Namwater (Muduva & Williams, 2001).

In 1993, the average subsidy to users of government water supply in Namibia was 71% of total costs. Commercial crop farmers were the most heavily subsidised, on average paying only about 4% of total costs (Lange, 1998). The farmers in Hardap pay N$ 0,02147/m^3 of water to MAWRD's Mariental office[2], whereas Namwater charges MAWRD N$ 0,03/m^3. In the near future the water tariffs charged to farmers will increase to N$ 0,03/m^3 so that the actual cost of water from Namwater is covered. This will still not cover MAWRD's costs for the scheme which, including water, maintenance, all capital works (new pipelines, reed spraying, etc.) and flood damage, are estimated to be approximately N$ 0,109/m^3 (Engels, personal communication). The user charge for water will increase further over time, in order to compensate for these costs. In future, as water demand from other sectors and regions increases, Namwater may increase water user charges further and MAWRD will then, presumably, have to pass these increased costs on to the farmers. The exact increases in user charges are of course difficult to predict, but this nonetheless means that it is necessary to have an idea of how further increases are likely to affect farmers in the scheme.

4. DATA

A survey was carried out among some of the farmers in the Hardap region with help from people at the MAWRD and at the Ministry of Environment and Tourism – Directorate of Environmental Affairs (DEA). The questionnaire dealt with questions about the land use on the farm, irrigation technology, and incomes and costs connected to each crop grown. In many cases, farmers did not know the exact figures for their incomes and costs but were able to provide estimates. This was combined with information from Arnold Klein, manager of the Hardap co-operation, from Francois Wahl, who had made a survey in the region a few years earlier, as well as from Siegfried Engels, engineer at the MAWRD and stationed at the Hardap scheme. All figures were recalculated into real values with the year 2000 as base year.

The farmers had some difficulties separating the capital costs between their different crops. Therefore, the capital cost for each crop alternative grown at the farm was calculated with concern to the percentage share of the total ha under irrigation. However, refrigeration was only used for growing grapes and the capital costs for refrigeration could therefore be entirely allocated to

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2 *Namibia is part of the CMA zone and 1 N$ = 1 ZAR.*

this crop. All capital costs, as well as revenue from multi-year crops, were recalculated into annualised values using a discount rate of 8%.

Centre pivot irrigation has relatively low investment costs compared to the other irrigation techniques. However, this irrigation method has high operating costs, and no local data on these costs were available. Including only the low investment costs, but not the high operating costs, would have made this technique seem more attractive than it really is. We therefore used estimates of operating costs for centre pivot irrigation for similar farms in South Africa (Meiring & Oosthuizen, 1991), with the cost estimates recalculated into current prices.

In order to compare financial and economic results for the different crop alternatives, shadow prices were applied (Barnes, 1994). The social costs for unskilled labour were valued at 35% of their financial value, reflecting the high unemployment in Namibia. All tax-inclusive prices were adjusted downwards by a flat 11% rate except fuel costs, where taxes are assumed to internalise externalities and hence reflect the fuel's social costs. Concerning subsidies, no adjustments were necessary in our calculations as water is the only input in agriculture that is still subsidised. A foreign exchange premium of 12% was used to calculate the economic values of tradable goods.

When the values of MATP/m^3 had been calculated for each crop grown, these values were used to estimate a demand curve for irrigation water. As this curve is intended to show which production alternatives the farmers have, the financial values for MATP/m^3 were used. The fact that some of the crops can be grown on the same land at different seasons of the year, like for example wheat and maize, means that these crops together can be seen as one production alternative. Due to this an MATP/m^3 is calculated for these two crops jointly, in order to get a value based on a one year period. The same reasoning also applies for the alternative of growing wheat and cotton. The relevant alternatives for the construction of the demand curve are; lucerne, wheat plus maize, and wheat plus cotton, grown under flood irrigation, and grapes grown under flood, sprinkler, centre pivot and micro/drip irrigation.

5. RESULTS

The survey information on incomes and costs for the different crops grown was used to calculate the MATP/m^3 for each crop alternative under each irrigation technology. In the tables, micro and drip irrigation are placed in the same column because the equal investment costs and efficiency rates for these irrigation systems mean that the MATP/m^3 are the same.

The least valuable crop, lucerne, has a financial MATP/m³ of N$ 0,103 under flood irrigation (Table 3). This implies that lucerne will still be financially viable after the user charge for irrigation water is raised to N$ 0,03/m³, the raise currently envisaged. However, if the full supply cost for the irrigation scheme were taken into account, so that the user charge were raised to N$ 0,109/m³, lucerne would no longer be financially viable with any of the available irrigation methods and would thus be replaced by other crops.

Table 3: Financial and economic values for Lucerne

AVERAGE FINANCIAL VALUES				
Irrigation methods	**Flood**	**Sprinkler**	**Centre pivot**	**Micro/drip**
Gross income (N$/ha)	12276	12276	12276	12276
Variable costs (N$/ha)	5469	5469	7803	5469
Gross margin (N$/ha)	6807	6807	4474	6807
Fixed and capital costs (N$/ha)	2149	3846	3186	4318
MATP (N$/ha)	**4659**	**2961**	**1287**	**2490**
Water requirements (m³/ha)	45432	32451	28395	26725
Gross income (N$/m³)	0,270	0,378	0,432	0,459
Gross margin (N$/m³)	0,150	0,210	0,158	0,255
MATP (N$/m³)	**0,103**	**0,091**	**0,045**	**0,093**
AVERAGE ECONOMIC VALUES				
Irrigation methods	**Flood**	**Sprinkler**	**Centre pivot**	**Micro/drip**
Gross income (N$/ha)	12237	12237	12237	12237
Variable costs (N$/ha)	4976	4976	7305	4976
Gross margin (N$/ha)	7261	7261	4932	7261
Fixed and capital costs (N$/ha)	2139	3831	3173	4301
MATP (N$/ha)	**5123**	**3431**	**1759**	**2961**
Water requirements (m³/ha)	45432	32451	28395	26725
Gross income (N$/m³)	0,269	0,377	0,431	0,458
Gross margin (N$/m³)	0,160	0,224	0,174	0,272
MATP (N$/m³)	**0,113**	**0,106**	**0,062**	**0,111**

The economic value of lucerne production is calculated as N$ 0,113 per m³. The slightly higher economic value is largely due to the social cost of the employed unskilled labour being lower than the financial cost for this labour. It deserves to be noted that the economic value of the lucerne production per m³ is actually higher than the full supply cost for the water, and that even though lucerne production would no longer be financially viable under full cost recovery, it might still be economically justified as being preferable to having no production at all. However, as shown below, all other crop alternatives have higher economic values per m³ than lucerne does, so a shift to other production is desirable from an economic viewpoint as well.

Maize is a typical low-value crop and is grown by a majority of the farmers at the Hardap scheme. The crop is relatively water intensive. Due to this, the combination of wheat and maize, grown under flood irrigation, is only slightly more profitable than lucerne in terms of N$ per m³ of water (Table 4). The financial MATP/m³ for this crop alternative is slightly less than the full supply cost, so that this alternative would also become unprofitable if MAWRD were to raise user charges in order to recover its provision costs. Lucerne and the combination of wheat and maize are currently the two dominant production alternatives in the area, so the implementation of full cost recovery pricing will lead to important shifts in production in the long term.

Table 4: Financial and economic values for wheat and maize

AVERAGE FINANCIAL VALUES				
Irrigation methods	**Flood**	**Sprinkler**	**Centre pivot**	**Micro/drip**
Gross income from wheat (N$/ha)	7913	7913	7913	7913
Gross income from maize (N$/ha)	7587	7587	7587	7587
Gross income (N$/ha)	15500	15500	15500	15500
Variable costs (N$/ha)	8428	8428	10317	8428
Gross margin (N$/ha)	7073	7073	5184	7073
Fixed and capital costs (N$/ha)	3126	4824	4163	5295
MATP (N$/ha)	**3947**	**2249**	**1020**	**1778**
Water requirements (m³/ha)	36777	26269	22986	21634
Gross income (N$/m³)	0,421	0,590	0,674	0,716
Gross margin (N$/m³)	0,192	0,269	0,226	0,327
MATP (N$/m³)	**0,107**	**0,086**	**0,044**	**0,082**
AVERAGE ECONOMIC VALUES				
Irrigation methods	**Flood**	**Sprinkler**	**Centre pivot**	**Micro/drip**
Gross income from wheat (N$/ha)	7888	7888	7888	7888
Gross income from maize (N$/ha)	7563	7563	7563	7563
Gross income (N$/ha)	15451	15451	15451	15451
Variable costs (N$/ha)	8199	8199	10084	8199
Gross margin (N$/ha)	7252	7252	5366	7252
Fixed and capital costs (N$/ha)	2926	4618	3960	5088
MATP (N$/ha)	**4326**	**2633**	**1406**	**2163**
Water requirements (m³/ha)	36777	26269	22986	21634
Gross income (N$/m³)	0,420	0,588	0,672	0,714
Gross margin (N$/m³)	0,197	0,276	0,233	0,335
MATP (N$/m³)	**0,118**	**0,100**	**0,061**	**0,100**

In the same fashion as for lucerne, the economic value per m³ of producing wheat and maize is slightly higher than the financial value because the opportunity cost of farm labour is less than the financial cost. Therefore, just as for lucerne, using water to grow wheat and maize is socially preferable to not utilising the water at all. Again, however, there are production alternatives which are economically preferable to growing wheat and maize.

Cotton is sometimes grown on the same land as wheat, instead of maize, during the other half of the year, and uses less water per hectare than maize does. Cotton prices are more volatile than maize prices, but the average price is higher. The combination of wheat and cotton, grown under flood irrigation, therefore has a higher MATP per m^3 (Table 5). This alternative would remain financially viable even if MAWRD were to raise its user charges to the cost recovery level. Cotton is a more labour intensive crop than lucerne, wheat or maize, so that the economic value per m^3 for this crop alternative is substantially higher than the financial value. The water savings and low opportunity cost of labour, taken together, mean that it would be economically (though not financially) attractive to switch from flood irrigation to micro or drip irrigation for this crop alternative.

Table 5: Financial and economic values for wheat and cotton

AVERAGE FINANCIAL VALUES				
Irrigation methods	**Flood**	**Sprinkler**	**Centre pivot**	**Micro/drip**
Gross income from wheat (N$/ha)	7913	7913	7913	7913
Gross income from cotton (N$/ha)	9828	9828	9828	9828
Gross income (N$/ha)	17741	17741	17741	17741
Variable costs (N$/ha)	10279	10279	11714	10279
Gross margin (N$/ha)	7462	7462	6027	7462
Fixed and capital costs (N$/ha)	3198	4895	4235	5367
MATP (N$/ha)	**4265**	**2567**	**1792**	**2095**
Water requirements (m^3/ha)	27948	19963	17468	16440
Gross income (N$/$m^3$)	0,635	0,889	1,016	1,079
Gross margin (N$/$m^3$)	0,267	0,374	0,345	0,454
MATP (N$/$m^3$)	**0,153**	**0,129**	**0,103**	**0,127**
AVERAGE ECONOMIC VALUES				
Irrigation methods	**Flood**	**Sprinkler**	**Centre pivot**	**Micro/drip**
Gross income from wheat (N$/ha)	7888	7888	7888	7888
Gross income from cotton (N$/ha)	9797	9797	9797	9797
Gross income (N$/ha)	17684	17684	17684	17684
Variable costs (N$/ha)	8806	8806	10239	8806
Gross margin (N$/ha)	8878	8878	7445	8878
Fixed and capital costs (N$/ha)	3180	4872	4214	5342
MATP (N$/ha)	**5698**	**4006**	**3231**	**3536**
Water requirements (m^3/ha)	27948	19963	17468	16440
Gross income (N$/$m^3$)	0,633	0,886	1,012	1,076

Gross margin (N$/m³)	0,318	0,445	0,426	0,540
MATP (N$/m³)	**0,204**	**0,201**	**0,185**	**0,215**

Grapes are a high-value crop and far more profitable, both financially and economically, than the low-value crops discussed earlier. In recent years, some of the farmers in the area have realised this fact and started to grow grapes. However, due to the high investment costs and the loss of income during the first three years of the lifecycle, it is not yet a very common crop in the area. The water requirements for grapes are low compared to other crops grown in the area, and as grapes are a high-value crop the water requirements can be further decreased by profitable investments in more technically advanced irrigation systems.

The annualised financial values for MATP/m³ are considerably higher for grapes than for any of the other production alternatives (Table 6). This is due to the high export prices for grapes, which in the long run outweigh the relatively high investment costs and the first three years' loss of income. It can be seen that investments in more technically advanced irrigation methods give a higher MATP/m³ than the low-technology method of flood irrigation. Micro or drip irrigation, which have the highest investment costs but are also the most water efficient methods, give the highest MATP/m³ of N$ 1,318.

Table 6: Financial and economic values for grapes

AVERAGE FINANCIAL VALUES				
Irrigation methods	**Flood**	**Sprinkler**	**Centre pivot**	**Micro/drip**
Gross income (N$/ha)	74856	74856	74856	74856
Variable costs (N$/ha)	36452	36452	38003	36452
Gross margin (N$/ha)	38404	38404	36853	38404
Fixed and capital costs (N$/ha)	12821	14518	13858	14990
MATP (N$/ha)	**25584**	**23886**	**22995**	**23415**
Water requirements (m³/ha)	25167	21571	18875	17765
Gross income (N$/m³)	2,974	3,470	3,966	4,214
Gross margin (N$/m³)	1,526	1,780	1,952	2,162
MATP (N$/m³)	**1,017**	**1,107**	**1,218**	**1,318**
AVERAGE ECONOMIC VALUES				
Irrigation methods	**Flood**	**Sprinkler**	**Centre pivot**	**Micro/drip**
Gross income (N$/ha)	74616	74616	74616	74616
Variable costs (N$/ha)	27418	27418	28966	27418
Gross margin (N$/ha)	47199	47199	45650	47199
Fixed and capital costs (N$/ha)	12786	14478	13820	14948
MATP (N$/ha)	**34413**	**32721**	**31831**	**32251**
Water requirements (m³/ha)	25167	21571	18875	17765

Gross income (N$/m³)	2,965	3,459	3,953	4,200
Gross margin (N$/m³)	1,875	2,188	2,419	2,657
MATP (N$/m³)	**1,367**	**1,517**	**1,686**	**1,815**

There is a substantial difference between the financial and economic values for MATP/m³. As for cotton, this is due to the unskilled labour intensive production. Because of this, it is even more economically profitable to grow grapes from society's point of view than it is for the individual farmer.

In Figure 2, the great differences in MATP/m³ between grapes and the other alternatives can be seen clearly. The economic values are consistently higher than the financial values, and substantially higher for wheat and cotton and for grapes.

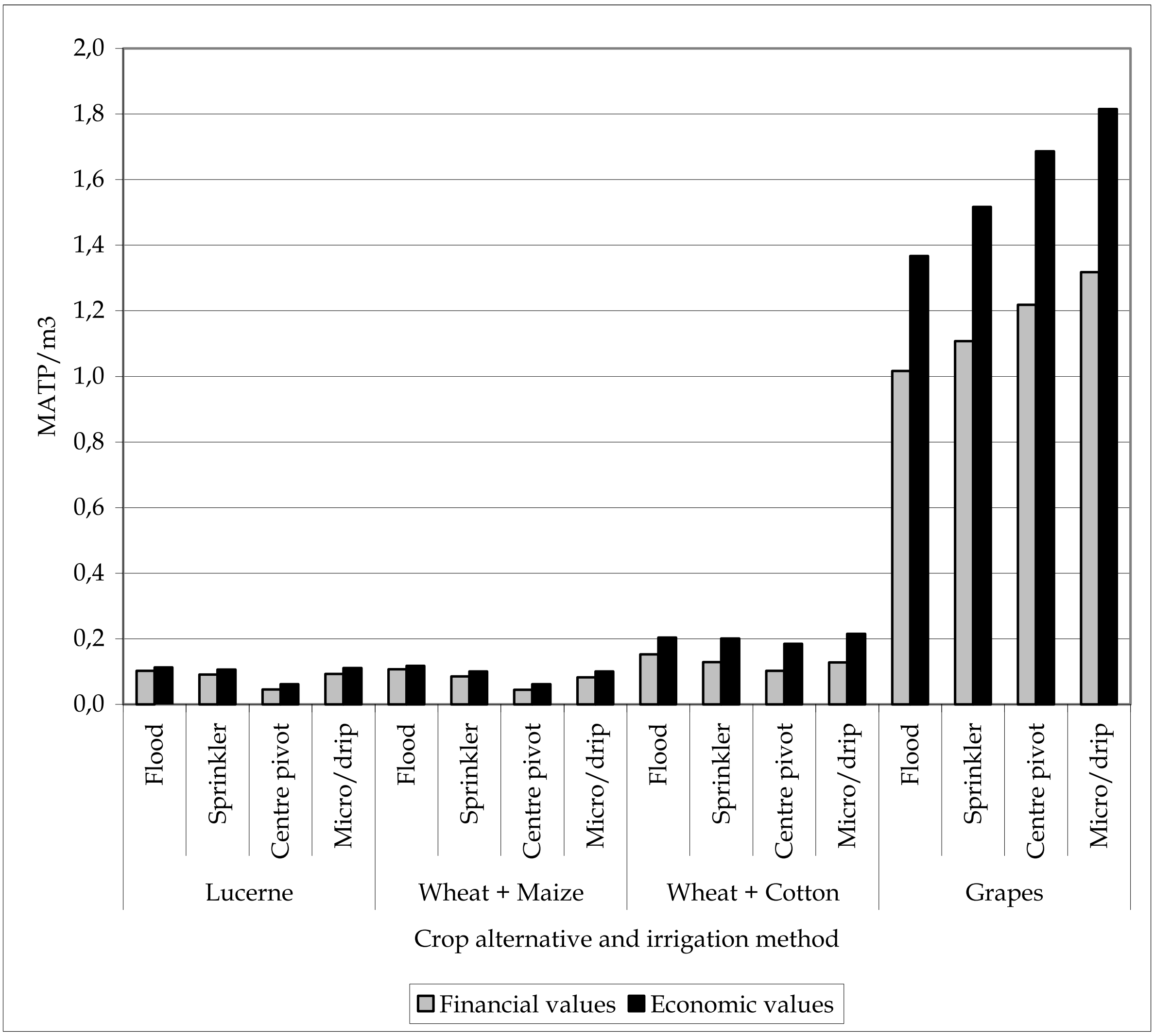

Figure 2: MATP/m³ for different crop and irrigation alternatives

As discussed previously, the financial values per m^3 of water for different crop alternatives can be used to determine an outer bound for the demand for water at different user charges. This estimated demand curve for irrigation water is shown in Figure 3.

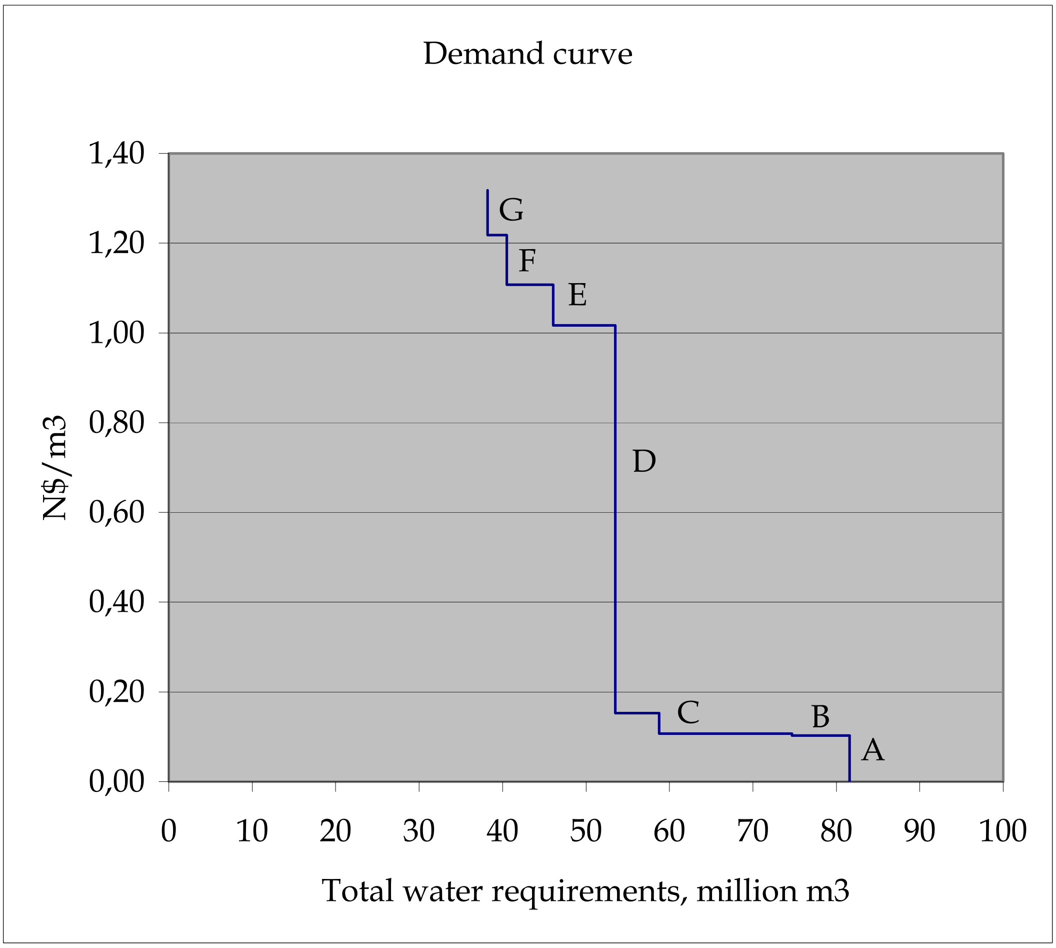

Figure 3: Maximum water demand at different user charge levels

The vertical intervals on the demand curve represent the present crop alternatives grown under current irrigation techniques (A); present crop alternatives grown under current irrigation techniques, but with lucerne replaced by wheat and maize (B); present crop alternatives grown under current irrigation techniques, but with lucerne and the combination of wheat and maize replaced by the combination of wheat and cotton (C); lucerne, wheat, maize and cotton replaced by grapes grown under flood irrigation (D); all flood irrigated crops replaced by grapes grown under sprinkler irrigation (E); all flood irrigated crops replaced by grapes grown under centre pivot irrigation (F); and, finally, grapes grown under micro or drip irrigation everywhere (G).

It is possible that once improved water meters are in place, and once the first round of user charge raises have been carried out, farmers will become more conscious of their water use and start switching to less water intensive production. However, our demand curve shows that this may not necessarily happen. All the current crop alternatives will still be financially viable after the user charge has been raised to N$ 0,03/m^3, so farmers will not be forced to change their production. Total water use may therefore remain at the current levels. However, if MAWRD raises its water user charge to N$ 0,109/m^3, the level needed for full recovery of its supply costs, lucerne and maize will cease being financially viable and water demand will decrease by (at least) a quarter. If farmers switch to grapes, rather than combined wheat and cotton production, water demand will decrease even further. Once production has shifted to grapes (which would have to take place if the user charge were raised over N$ 0,153) farms can bear substantially higher user charges for their irrigation water without having to change their production again. If farmers were to switch to grapes grown under micro or drip irrigation, water use would be reduced by over half and user charges could potentially be raised to over N$ 1,3.

As already mentioned, it is important to bear in mind that our demand curve only shows the upper limit of water consumption at different user charge levels. This means that the real demand for water at a specific user charge level cannot be predicted, as this will in the end depend on farmers' behaviour and reactions to a raised user charge. A raise in the user charge for water may cause a change into a more water efficient production alternative and thereby a greater decrease in the water requirements than is shown in our demand curve.

6. CONCLUSIONS

The envisaged short-term increase in user charges for irrigation water in the Hardap area, from N$ 0,02147/m^3 to N$ 0,03/m^3, will not necessarily have any effect at all on farming. All the crops currently grown in the area will remain financially viable after this increase. However, it is thought-provoking that neither of the two production alternatives which are currently favoured by most farmers, lucerne and combined production of wheat and maize, would remain profitable if farmers were charged user charges sufficiently high to recover the supply costs of water. Since the long-term intention is to raise user charges to at least this level, it appears that agricultural production in the area is likely to change substantially.

This raises important issues. Some farmers in the region have started growing grapes, a crop which uses considerably less water per hectare, and it is highly desirable that more farmers switch to this crop; grape production would increase farm profitability, reduce water use, and create new employment for unskilled labour. Many of the farmers in the area are aware of the benefits from changing their production, but are concerned about the investment costs and high initial losses. They do not have easy access to credit for investing in new production, especially not if they will have to manage without revenue during the first three year period. Moreover, some farmers are concerned because grapes are perceived as being more difficult to grow than lucerne or maize.

Obviously, if water user charges are raised to the point where none of the current low-value crops remain financially viable, the current farmers will either change their production or be replaced by other farmers who do. However, it is likely that this would be a highly disruptive process. If the government were to provide state-guaranteed loans and/or training for those farmers who wish to start growing grapes, a substantial decrease in water use could probably be achieved rapidly and with considerably less disruption. Such a policy could be justified by the high potential for employment generation. The unskilled farm labour used in grape production will in all likelihood be unemployed otherwise, which means that in the long term grape production is even more profitable for society as a whole than for the individual farmer.

Our paper extends the net back methodology slightly in order to estimate the maximum demand for irrigation water at different user charges. As pointed out elsewhere in the paper, agricultural water demand at a given user charge may be lower than what our demand curve suggests. Nonetheless, this method can still provide useful information. Policy makers in the water sector in Namibia and elsewhere are frequently in a situation where, unlike previous investments, future investments or reinvestments in water supply schemes are expected to be paid for by the beneficiaries of these schemes, through increased user charges. However, if these higher user charges will lead to drastic decreases in water demand – as seems likely in Hardap, and probably in many other irrigation schemes – this should be taken into account before the decisions on investments or reinvestments are made. Being able to predict what the maximum demand for water will be, at a given user charge, can thus help policy makers to avoid investing in supply schemes that nobody will want to pay for.

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