Article

Jaap Arntzen

Economic Instruments for Sustainable Resource Management: The Case of Botswana's Water Resources

The performance of economic instruments in resource management in developing countries is inadequately known. This paper contributes to filling this gap with a case study from Botswana's water-supply sector. It was found that economic instruments contribute towards better resource management, especially in terms of fund raising for the construction of new water-works, but that their impact on the actual resource use is less certain and that their performance can be significantly improved. The low per capita water consumption figure cannot be solely attributed to the high water price. The economic structure, poverty and inadequate access to water in remote areas also explain the low figure. It was found that the scope of economic instruments is limited because of the large nonmarket" water sector, the ambiguity about property rights and low incomes. Economic instruments should be part of an instrument package, which includes regulations and consultation. Consultations were effective during the last drought period.

INTRODUCTION

Since the mid-1980s, there has been a worldwide surge in the use of economic instruments to improve natural-resource management. To a large extent, this reflected the dissatisfaction with environmental legislation, which often proved ineffective, and an increasing appreciation of the role of economic instruments to serve the environment. Regarding the water sector, the World Bank (1) argues that economic criteria are often subordinate to political and social criteria, and water is often underpriced. Developed countries have so far gained most experience with environmental-economic instruments. This paper aims to contribute to the knowledge of the functioning of environment-economic instruments in developing countries by analyzing their application in the water sector in Botswana.

Since the early 1980s, the government of Botswana has used resource pricing as a method to ease mounting water scarcity. Water pricing is claimed to be successful in curbing per capita demand (in 1990, 93 L person^{-1} day^{-1}; 2). This paper has the following objectives:

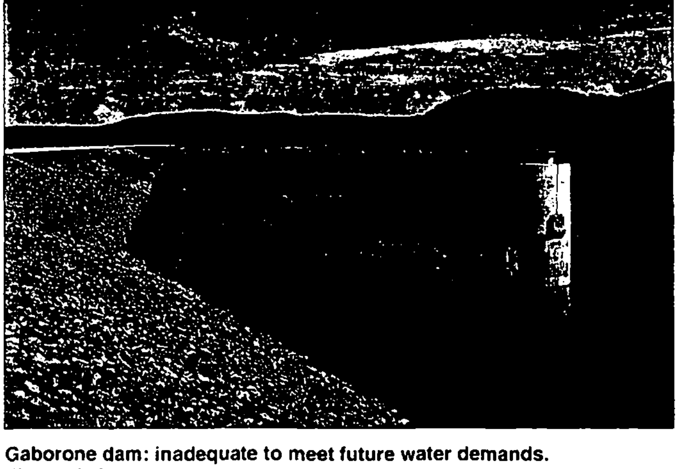
i. to assess the impact of economic instruments on water consumption;
ii. to identify factors which influence the performance of economic instruments;
iii. to explore the role of other instruments in promoting efficient water use.

Within the context of environmental policies, economic instruments are used to raise funds for environmental expenditures and/or to influence resource-consumption patterns; price elasticities determine to what extent consumption actually changes. In the OECDcountries, the fund-raising purpose of economic instruments has been most important (3). Economic instruments are more likely to impact resource behavior if the price increase is substantial; small increases only have a limited impact. In order to optimally influence resource consumption, a fairly sophisticated pricing system is needed, which takes into account different price elasticities and attitudes of resource-use groups. A number of special features of developing countries may influence the functioning of environmental-economic instruments (4, 5). These include:

- The existence of a significant nonmarket economy which reduces the scope of market-conform instruments.
- Low incomes and a bias towards immediate survival. Poverty in itself is an incentive to make limited and efficient use of natural resources. But obviously, the social consequences of economic instruments need to be given thorough attention.
- Resource property rights may be unclear. This begs the question as to who is responsible for resource management, and who generates the necessary funds.
- The prevalence of a culture of consultation. This may offer comparative benefits for noneconomic instruments such as persuasion and consultation.
- The limited expertise and implementation capacity of governments, particularly regarding environmental economic instruments.

BOSTWANA'S DEVELOPMENT AND WATER RESOURCES

In Botswana, water is a scarce commodity. The sustainable groundwater potential is unknown but certainly limited. Surface water is very scarce with the exception of the Okavango and the



Gaborone dam: inadequate to meet future water demands. Photo: J. Arntzen.

Chobe systems, which together account for 95% of the surface water (Fig. 1). These resources, however, are shared with neighboring countries, and their use is subject to international negotiations. Botswana has made substantial progress in meeting people's basic needs of watering. Potable water is now provided to most settlements, benefitting families and commercial activities. The proportion of people with access to safe drinking water has increased from 56% in 1981 to 77% in 1991 (6). But the remaining task is very difficult: how to improve the water supply for the scattered people on the lands and in remote areas?

There are three commonly perceived water concerns. Together with land, water is the key development resource. Water shortage could restrict human well-being and the commercial sector. In the National Water Master Plan (7), it was concluded that until the year 2020 no water shortages need to exist. Shortages are likely to occur in southeastern Botswana unless new water supplies are constructed and interconnected. Beyond 2020, it may be needed to source the Okavango and/or Zambezi systems.

Second, the present ratio of ground-surface water consumption (2:1) cannot be sustained. Locally, groundwater mining is occurring, probably leading to a decline in future water yields. Therefore, government intends to make more use of renewable surface water resources, in line with the principles of sustainable development.

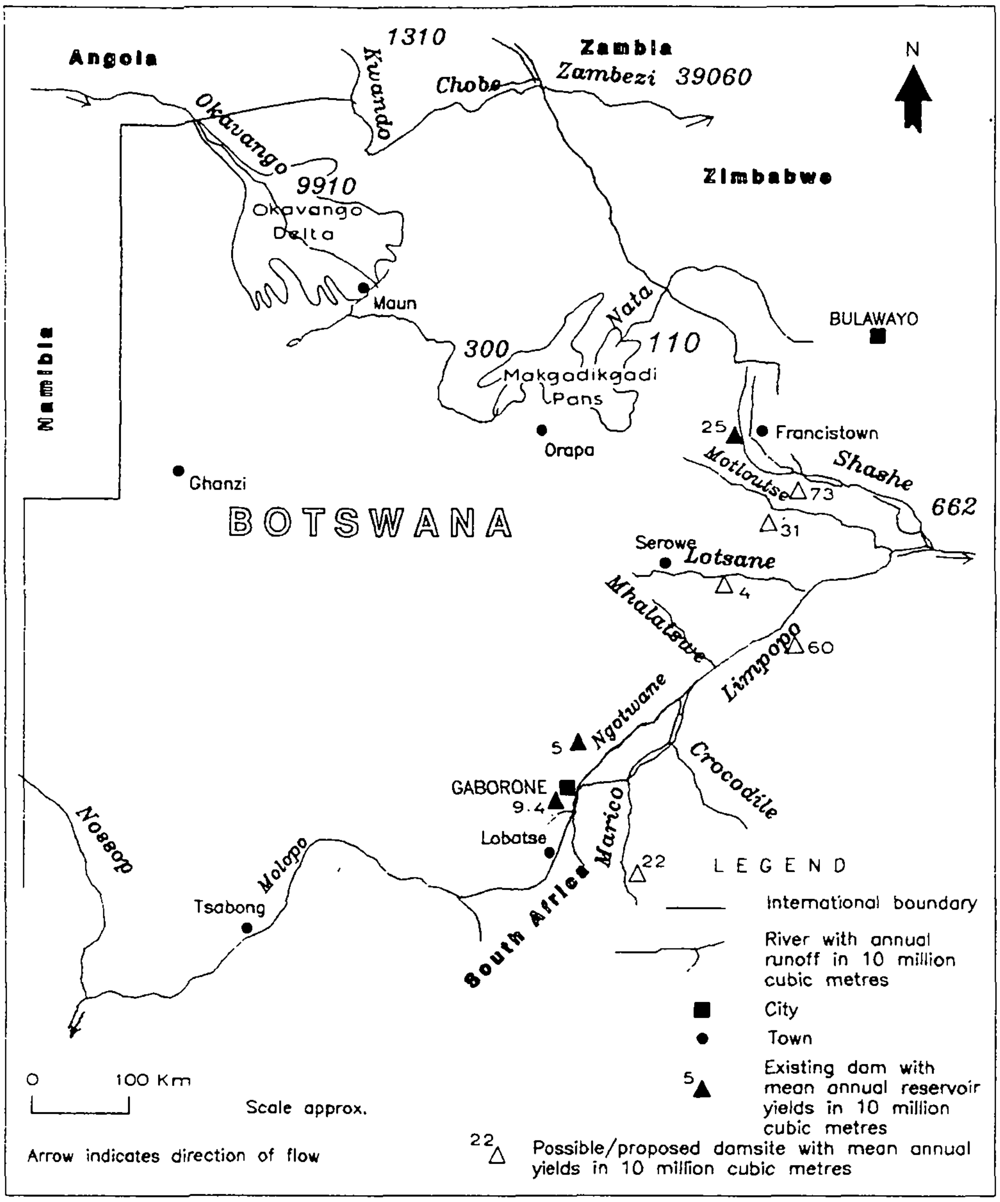


Figure 1. Botswana and its major water resources (7).

Third, water pollution is increasing, and threatens the water quality. Traditional surface water sources—vital for people outside villages—are often of poor quality. But recently, nitrate pollution of groundwater and increased salinity have posed additional problems. The water quality of some boreholes around large settlements is poor, forcing the closure of some of the boreholes (8).

Resource consumption must be understood within its physical and socioeconomic context. The most important physical features are the low mean annual rainfall and a high variability (rainfall averages range from less than 250 to 650 mm); evapotranspiration potential of around 2000 mm, restricting the water availability from the mostly shallow dams; limited spare groundwater potential, some of which is saline. More opportunities exist for new surface-water sources, but they are located in the north. The major socioeconomic features include rapid population growth and concentration (3.5% annual growth for the period 1981–1991); rapid economic growth over the last two decades: a doubling of the real per capita income, which reached USD 2790 in 1992 (13); an increase in living conditions and welfare despite the skewed income distribution (around 60% of the rural population and 30% of the urban population cannot meet their basic needs; 9); the absence of many large water consumers (only 1200 ha are under irrigation and the manufacturing sector only contributes some 5% of Gross Domestic Product); and, an increasing spatial imbalance between water demand and supply.

The water sector has changed dramatically since the 1970s. Water supply has rapidly increased and now covers settlements throughout the country, but the demand has increased even faster due to the rapidly growing population and economy and improved living standards. In future, water consumption is expected to continue its rapid growth, but moreover, there will be significant changes in the consumption structure. These changes have been summarized in Figure 2. The urban and industrial consumption is expected to grow fastest with a shrinking share for the livestock sector. The bulk of the increase will occur in urban/semiurban areas, mostly in southeastern Botswana.

Clearly, water planning should strike a balance between economic, social and ecological objectives and criteria. In particular, a compromise must be reached between the goals of economic growth, resource-use efficiency, social justice, and sustainable water management (1). Water planning must be simultaneously directed towards supply and demand. But water planning is as yet mainly supply-oriented. The government has embarked on an large-scale investment program to build new dams and to link water sources through the north-south water carrier (10, 11). Much less attention is being paid to other strategies such as increasing user efficiency, water harvesting and water recycling. This supply bias is reflected in the two goals for the water sector (12). (i) To meet the basic needs of the population through the provision of an accessible, safe, reliable and affordable water supply; (ii) To meet water requirements of industrial, agricultural commercial and institutional users to boost economic growth. Water demand is based on potentially conflicting principles of equity, affordability and efficiency. No reference is made to curbing demand nor to the key role of water in controlling land and other resource use.

As in other countries (1), government institutions dominate the water sector. Responsibilities for water supply are divided among central government (Department of Water Affairs or DWA and the Ministry of Agriculture), local government (District Councils) and the parastatal Water Utility Corporation (WUC).

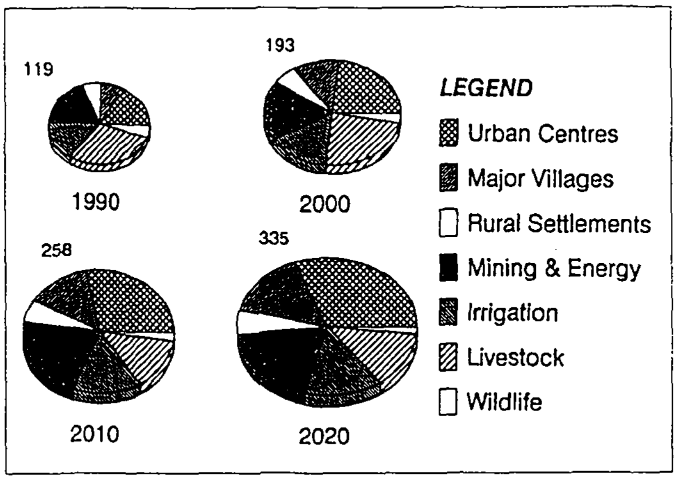


Figure 2. Changes in water consumption (period 1990–2020; million m³) (7).

THE WATER "MARKET"

About half of the present water consumption is channelled through a "market"; the other half remains outside the market's sphere. Perhaps, the market and nonmarket sector could be more appropriately labelled the formal and informal water sector. Water in the formal sector is distributed through DWA, WUC or the District Councils, and is spatially confined to urban areas and villages. The water supply covers households and industries and services, with the exception of some mines. The formal water sector will gain importance because of the forecasted changes in the demand structure (Fig. 2). The informal water sector, where the producer and consumer are often the same, prevails in rural areas outside villages. Examples include water consumption by the livestock and wildlife sector, domestic use outside villages and water consumption by some mines.

Property rights are not necessarily conducive to efficient resource use. Government "owns" all water resources on behalf of its citizens, and controls its use. In the formal sector, WUC, DWA or District Councils have been given water-user rights with some degree of government control (e.g. prices). But in the informal sector, water-user rights are exercised by boreholes owners, etc. without any water-user restrictions or stipulations for users charges.

Water Demand

Water consumption has rapidly increased as a result of population growth, higher incomes and economic growth. Where water supply is inadequate as happens in some rapidly growing settlements, there is a suppressed water demand. The demand for water can be classified according to *purpose*:

i. household demand for basic needs (e.g. washing, food preparation);
ii. household demand for nonbasic needs (e.g. garden, swimming pool);
iii. commercial demand (industry, government etc.).

The price elasticity of demand is probably close to zero for the basic needs, low for commercial activities (unless alternatives are available) and higher for nonbasic household use. No reliable elasticity estimates exist. Therefore, the precise slope of the demand curves remains unknown (Fig. 3). Households may have a curve similar to D_1 with a higher elasticity for nonbasic demand. The curve, however, is different for households for whom their employers pay the water bill (e.g. common in parts of the private sector); in this case, the price elasticity will be low (e.g. D_2). The water demand curve of commercial activities depends on the production structure and may vary greatly among enterprises. In the majority of cases, the demand curve will intersect the supply curve in the highest price band (e.g. D_3).

Water demand can also be classified according to *location*. Here, the major distinction is between scattered, mostly informal, and concentrated, mostly formal, resource use. Water consumption by cattle, wildlife and population on the lands is scattered. Villages, mines and urban areas are large demand "points".

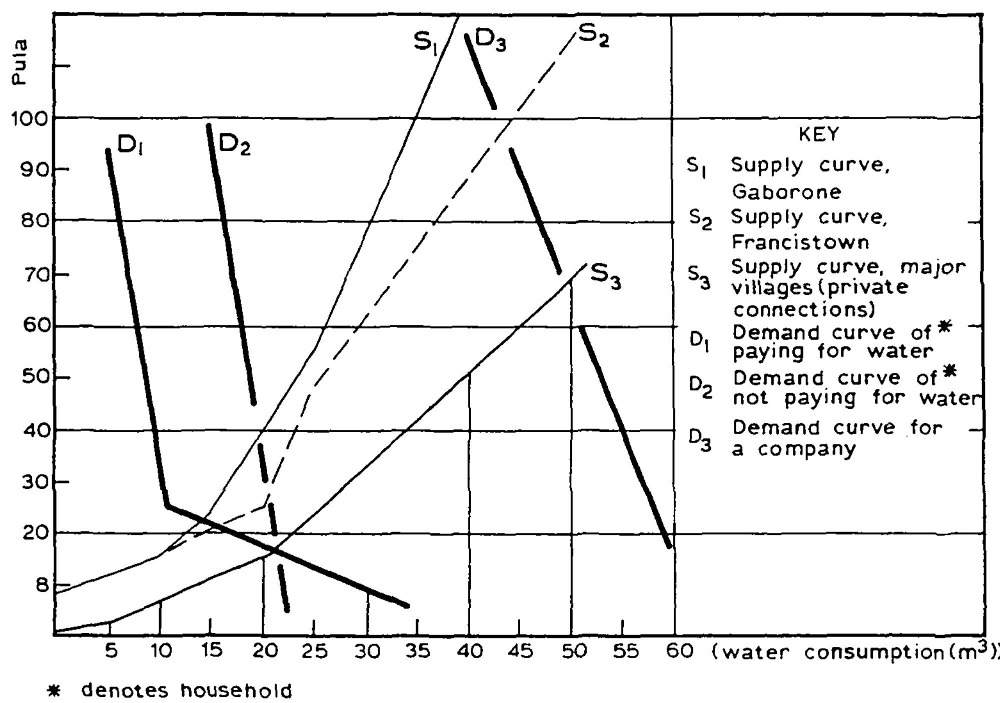


Figure 3. Supply curves and possible curves for water consumption by households and companies.

Scattered use—usually with lower risk of water depletion—is still substantial (36% in 1990), but its share of total consumption is predicted to decline to 27% and 16% in the years 2000 and 2020, respectively (7).

Only scanty information exists regarding the impact of income on water consumption. In the National Water Master Plan, the income elasticity of water consumption was estimated to be 0.46: a 1% income increase in real terms would lead to a 0.46% increase in the water consumption (7). This appears very low, and further research should generate more reliable estimates. Per capita water consumption strongly reflects living conditions. For example, in major villages, per capita water consumption ranges from 7–26 L day^{-1} for standpipes to 85–201 L day^{-1} for house connection. Similarly, in urban areas, water consumption in low income urban areas ranges from 28–65 L day^{-1} to 346–382 L day^{-1} in high income areas (7). These differences in water consumption—around a factor 10—suggest that the income elasticity may be higher than the above estimate. However, one must realize that the income disparities are also great. In 1985, the lowest 20% of the income earners got 3.6% of the income, whilst the top 10% received 42.9% (13).

Wells in dry rivers provide people and livestock with "free" water. Photo: J. Arntzen.

Water Supply

Highly variable climatic conditions cause a great inter-annual variation in water supply, both in surface water and recharge of groundwater. At present, the main "market" problem is a spatial mismatch of demand and supply. Possibilities for new water sources include:

- a few remaining possibilities for use of aquifers (most are already used);
- more large dam sites in the north (10);
- largely untapped potential for rainwater harvesting (16);
- re-use of water and purification of effluent. It is estimated that re-use may reduce the capital's water consumption by 20% saving at least Pula 33 million (1 Pula = USD 0.4079);
- purchases from neighboring countries. Such opportunities are limited because most countries in the region face similar or even more severe water constraints. However, it may be an efficient solution in border regions;
- reduction of water-supply systems losses. Current losses are high and costly;
- international agreements to share the use of the Okavango and Chobe rivers. The available sources are huge in comparison to other surface-water sources.

WUC (urban), DWA (large villages) and District Councils (other settlements) monopolize water supply. Consumers can access water through standpipes and through yard or house connections. For small-scale piped water-supply systems in rural areas, per capita water-supply costs are generally inversely related to village size (local hydrogeological conditions are also an important cost factor). Generally, the water source is local groundwater, reducing the investment and transport costs. For large urban systems, local groundwater sources do not suffice, and expensive dams and pipelines have to be constructed. In this case, per capita water costs decline with increasing population size.

Water supply is still problematic in the informal sector. In remote areas, people use less than 10 L day^{-1} and consumers have to secure their own supply. The level of consumption fluctuates, based on the accessibility of water sources, the physical efforts to collect water, and people's financial means. In practice, people use a number of different waterpoints through the year based on criteria such as reliability (which source holds water), convenience (distance from the homestead) and affordability (costs). This fallback strategy is well documented for the livestock sector (15), but people probably apply the same strategy for domestic water use. People rely on poor quality surface water or purchase water from boreholes. The latter is more expensive and is usually confined to year-around domestic consumption and dry-season livestock watering. As the population density in remote areas is below 1 person km^{-2}, the costs of piped water are prohibitive. For this category of users, local ground and surface water sources probably offer more efficient solutions (e.g. wells, livestock boreholes, pans, haffirs). This includes rainwater harvesting techniques and groundwater utilization with low external inputs (e.g. hand pumps).

WATER PRICES AND SUBSIDIES

In Table 1, the different pricing principles are shown. The existence of different principles can be attributed to the co-existence of the market and non-market sector, the multiple institu-

Table 1. Resource pricing principles.

Consumer categories	Market/ nonmarket sector	Water sources	Water supplier
urban consumption	market	ground- surface water	WUC supplies
major rural villages	market	mostly ground water	DWA
other rural villages	market	ground-water	District Councils
livestock sector	non-market	70% ground-water; 30% surface water	Land Boards allocate groundwater sources; livestock owners supply
mining sector	market + non-market	ground- + surface water	WUC + companies
wildlife sector	non-market	mostly surface water	DWNP supplies some boreholes + dams

tions involved in water supply and foremost a trade-off between economic, social and environmental criteria. For the formal water sector, unit consumer prices are set by WUC and DWA subject to government endorsement. Generally, government provides substantial subsidies to the water sector, thus lowering water prices. In urban areas, consumers will soon have to pay the full supply costs. Table 1 further reveals substantial variation in incentives for water conservation. Progressive water prices in the formal sector encourage efficient water use, but there is no such incentive in the informal sector.

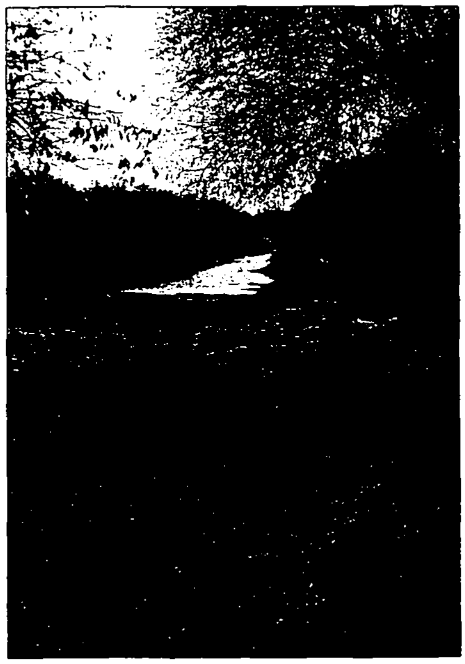
The equation for the market price of water is:

production costs + transport costs - subsidies

In Table 2, the trend in urban-water prices is shown. Gaborone has the highest water prices in the country due to the high production and transport costs. A price comparison between Gaborone and large rural villages is presented in Table 3.

The consumer pricing system in the formal sector has three distinct features. First, water charges are progressive with increasing use. This is achieved by the distinction of users bands with increasing unit charges for successive use bands. The resulting supply curves are presented in Figure 3 (S_1 Gaborone; S_2 Francistown; S_3 large villages). The price system offers households an extra incentive to use water efficiently. This incentive is unattainable for most companies because they have limited scope for a reduction in total water consumption. Second, prices reflect the policy principle that water for basic needs should be accessible to everybody. It is assumed that all water provided through rural standpipes serves the basic needs of the poor; in urban areas, a low monthly flat rate is charged in areas with standpipes. For private connections, water charges have been consistently low for up to 10 m^3 in urban areas and 5 m^3 in rural areas. As Table 2 shows, there has been an apparent change in what constitutes basic needs for private urban connections (cf. 11–15 m^3 prices over the period 1984–1993). Third, there are important spatial price variations. The charges are lowest where water is relatively abundant, i.e. in the north. The price system thus offers an incentive for large water users to move to the north. But few companies have used this advantage, apparently because it has been outweighed by other cost disadvantages. There are substantial variations in rural water-supply costs, mostly due to varying production costs. Transport costs in rural areas are generally lower than in urban areas. The variations in rural supply costs are not reflected in the water price which is uniform for all major villages. Comparing urban and rural prices, the former are two to three times the latter. In addition, rural prices are less progressive than the urban ones (Table 3 and Fig. 3).

Dams in rivers locally prolong the surface water supply.
Photo: J. Arntzen.



Pricing principles	Details
full cost recovery	progressive rates with increasing use: rates lower in the north
standpipes free; recovery of recurrent costs; charges for yard/ house connection	progressive rates, but less progressive than in urban areas
standpipes free; charges for yard/ house connections	
owner bears full costs	regressive; no charges related to amound used
full cost recovery (WUC)	WUC supply + own supply
water costs incurred by DWNP	regressive

Table 2. Trend in unit water prices in Gaborone (constant prices 1990; USD cents m^{-3} $month^{-1}$) (16).

Water consumption band	1981/82 Price	1984/85 Price	1985/86 Price	1990 Price	1993 Price
first 10 m^3 $month^{-1}$	21	24	24	22	22
next 5 m^3 $month^{-1}$	32	58	75	22	65
next 10 m^3 $month^{-1}$	32	58	75	88	84
next 5 m^3 $month^{-1}$	32	58	75	88	84
next 10 m^3 $month^{-1}$	42	81	102	88	115
next 10 m^3 $month^{-1}$	42	81	102	119	115
use over 50 + m^3 $month^{-1}$	37	106	139	119	115

Conversion rate: 1 Pula = USD 0.4079 (1993).

Table 3. Water prices in Gaborone and large rural villages (November 1993; USD cents m^{-3} $month^{-1}$) (16 and pers. comm. DWA).

Water consumption band	Gaborone	Large villages
first 5 m^3	35	18
next 5 m^3	35	37
next 5 m^3	102	37
next 5 m^3	131	37
next 5 m^3	131	73
next 5 m^3	179	73
next 5 m^3	179	73
over 40 m^3	179	163*

* only applies to two semi-urban villages. Conversion rate: 1 Pula = USD 0.4079.

As the non-marketed water sector is left to the private sector and it is government policy not to subsidize this sector, "informal" consumer prices are close—or even equal—to the real production costs. The latter costs depend on the type of water source, the physical conditions and the type of use. The few available data show substantial cost and price differences (Table 4). The unit water price for domestic consumption appears high, whilst the water price for livestock is low. The water price per cow tends to be regressive as borehole groups charge members flat rates irrespective of the herd size (18, 19). This practice discourages efficient water use and even encourages overstocking because of the economies of scale. Unintentionally, district councils sometimes subsidize livestock owners through council operated boreholes. For example, in Kgatleng charges at council boreholes in the mid-1980s would have to double to meet the recurrent costs, and should increase six times to recover the investment costs (17).

Table 4. Some water supply costs and prices in the informal sector (in USD cents) (14–20).

Type of use	Costs per animal	Water costs m^{-3}
Livestock $month^{-1}$	borehole rates USD cents 12 to 33 $month^{-1}$ cow^{-1} (1992)	USD cents 9 to 24 m^{-3}
	USD cents 20 $month^{-1}$ cow^{-1} (1987)	USD cents 9 m^{-3} $month^{-1}$
	USD cents 8 $month^{-1}$ cow^{-1} at council boreholes (1982)	USA cents 9 m^{-3} $month^{-1}$
	Estimated watering costs by (1980):	
	– haffir	USD cents 22 m^{-3}
	– private borehole	USD cents 135 m^{-3}
	– open well	USD cents 63 m^{-3}
Household	USD 1.70–2.20 (200 litres)$^{-1}$ government provision by bowser	USD 8.16– 10.20 m^{-3} up to USD 20.40 m^{-3}
	rainwater harvesting	over USD 2.04 to 4.08 m^{-3}

1 Pula = USD 0.4079 (1993).

Table 5. Estimated annual water supply expenditures (million USD) and government subsidies (6).

Expenditures	1990–1999	2000–2009	2010–2019
Urban centres	28.2	21.3	34.3
Major villages	22.1	16.5	14.2
Rural villages	20.3	17.6	20.6
Percentage of subsidies	49.3%	39.8%	29.2%
Total expenditures	70.7	55.4	65.1

1 Pula = USD 0.4079.

Conventional piped water-supply systems have long been subsidized by government. Because of the rocketing supply costs and the economic recession, government intends to cut and better target water subsidies (Table 5). Government subsidies for major water supplies are scheduled to decrease from 76% of the sector's expenditures in 1990 to 40% in 2000 (7). In absolute terms, the subsidies are expected to decrease by 50% by 2020. The remaining subsidies should be targeted to the poorest, and to rainwater harvesting and water-saving technologies, which have high social benefits but are only sparingly applied because of the high private costs. Despite the decrease in subsidies, the water sector will on the short run usurp a growing part of the nation's development budget (7.3% in 1991; 20.9% in 1996).

ENVIRONMENTAL IMPACTS OF WATER PRICES AND SUBSIDIES

To explore the environmental impacts of water prices and subsidies, we need to examine the question to what extent the present price incorporates environmental considerations and what the environmental impacts of recent price changes have been. Prices and subsidies are treated here simultaneously. Subsidies lead to lower water prices for households and companies, and *vice versa*, the reduction of subsidies will lead to higher prices.

The Price Level

In the market sector, present consumer prices do not cover the production costs. Prices in real terms are expected to rise because of lower subsidies and escalating production costs. The average LRMC (Long Run Marginal Costs), based on future production and transport costs, in Gaborone and Francistown has been estimated at USD 1.94 m^{-3} and USD 0.62 m^{-3}, respectively (21). For Gaborone, this implies that the water price in real terms will have to double. The level of the LRMC depends on the *location*, the *discount rate* and the *forecasted demand*. The further away the water sources are, the higher are the supply costs. That is why the water supply costs to southeastern Botswana are three times the supply costs in the northeast. Assuming that the sector's investments have been agreed upon, lower water consumption would imply higher per unit water costs in order to recover the investments. Finally, the LRMC increases with increasing discount rates because the revenues lag behind the costs.

One method of incorporating environmental aspects in resource prices is the marginal opportunity costs (MOC). The MOC equals the above LRMC *plus* the external costs of water extraction and the foregone benefits of future users (22). Internalizing external impacts would imply that the water sector would be charged for two impacts. First, the direct environmental changes caused by the physical construction of waterworks. This includes mitigation measures and compensation for negative downstream effects of dams. Second, indirect environmental changes because of water extraction and diversion. These may be substantial. For example, waterworks may lead to a drop in the groundwater table, altering the local ecosystem and its productive potential. However, the water sector would be compensated for adverse impacts inflicted by other sectors such as reservoirs siltation, water pollution and increased evaporation due to global warming. The MOC further includes foregone benefits. These are presently limited, but may become substantial when; in the long run, the Okavango or Zambezi systems would be tapped. The difference between the LRMC and the MOC can only be properly estimated through in-depth research of the externalities and the foregone benefits.

Another way of properly valuing the resource is using the concept of total economic value (TEV). The resource price equals the change in TEV. In addition to the present use value, the indirect users' values and nonuse values should be estimated

(Table 7). At the moment, the price only reflects the direct-use value. Changes in indirect-use values of surface and groundwater source should be incorporated. At present, the most important value changes probably comprise—poorly documented—groundwater-table changes and changes in surface-water sources. (e.g. dams, rivers). Future changes could even become more important when the Okavango and/or Zambezi sources would be used. The MOC and TEV methods reveal a third motive, in addition to increased production costs and lower subsidies, for a price increase, i.e. to incorporate environmental externalities and foregone resource benefits.

Table 6. Long-run marginal supply costs (m^{-3}) for various discount rates and demand scenarios by region (in USD) (7).

Area	Demand scenario	Discount rate 6%	Discount rate 8%	Discount rate 10%
Southeast	high	1.15	1.37	1.62
	medium	1.31	0.56	1.99
	low	1.77	2.30	2.99
Northeast	high	0.51	0.58	0.65
	medium	0.58	0.68	0.79
	low	0.65	0.88	1.04

1 Pula = 0.4079 USD (1993)

Table 7. The total economic value of water.

Value Components	Value subcomponents	Examples
Use value	direct use	food, health, livestock, wildlife, industry, government households
	indirect use	indirect impacts on ecosystems and human beings
Nonuse values	option value	future direct and indirect use such as biodiversity, conservation of habitat
etc.		
	existence value, based on, e.g. moral grounds	conservation of habitats and species

Environmental Impact of Price Changes

In this section, the impacts of the expected price increase are examined. We distinguish certain and possible impacts. The only certain impact of higher prices is increased government—and parastatal—revenues. The generated funds will be used for the construction of new waterworks. In addition, water charges probably curtail the expected demand increase but, as pointed out earlier, there are insufficient data to substantiate this impact. Higher prices may reduce demand for piped water in various ways:

- Discouragement of excessive water consuming activities. For example, it is argued that irrigation is uneconomic unless subsidized water is made available (7, 23).
- Suppression of nonessential household demand. The installation of water-saving appliances and rainwater tanks becomes more attractive.
- Reduction of water losses. The relatively high system losses in large villages (25%) and urban areas (20%) become extra costly. A loss reduction to 15% would represent an annual savings of approximately USD 2.5 mill. or around 6% of the current water expenditures.
- Increased viability of nonconventional water source such as water tanks and sewage water.

There are reasons to believe that price changes may have reduced water consumption, but to a limited extent. First, lower consumer prices in the north have generally failed to attract enterprises because the water costs only constitute a small segment of their production costs. Second, the significant nonmarket water consumption is not covered. Though its importance will decline in future, separate incentives are needed to promote efficient use in this sector; at the moment, there are none. The price incentive also fails to work when employers foot household water bills. This practice should be discouraged, for example, by taxing this benefit. Third, unlike households companies lack extra incentives to curb water consumptions. Tax relief or subsidies for water-saving technologies should be considered to enhance their resource-use efficiency. Fourth, currently the resource consumers receive confused signals because of the co-existence of subsidies and price increases. The reduction of subsidies would necessitate a more substantial price increase, and this may enhance the impact on resource use. Relatively small price increases are known to have little impact on resource-consumption patterns (3).

The above notwithstanding, it must be emphasized that resource-use changes can only be properly assessed when price elasticity of demand data are known. The effectiveness of price and subsidy instruments is limited when the elasticity is low. In that event, noneconomic instruments must be used to bring about the desired changes.

Given the paucity of empirical data, we cannot conclude that economic instruments are primarily responsible for the relatively low per capita water consumption. On the contrary, government subsidies have probably led to extra demand and a low water-use efficiency. It is likely that supply restrictions in villages and remote areas, poverty (countrywide) and the small size of the manufacturing and irrigation sectors are equally important in explaining the low per capita water consumption.

THE IMPACT OF OTHER ENVIRONMENTAL INSTRUMENTS ON A SUSTAINABLE WATER SUPPLY

Water consumption may be influenced by *legislative* and *consultative* instruments. Groundwater may only be used after approval of the Land Board or the Water Apportionment Board. The former institution controls the allocation of boreholes for the livestock sector; the latter deals with applications from industries, mines, etc. The Land Boards—one in each district—do not consider the water supply in their borehole allocation decisions, which are normally based on rangeland conditions; boreholes are allocated provided they are 8 km apart in order to prevent excessive grazing (24). Moreover, Land Boards do not restrict the amount of water extraction. This is in contrast to the Water Apportionment Board, which stipulates the maximum amount and conditions of water consumption through the Water Act. Effective control is, however, very difficult. In brief, legislative instruments have a firm grip on groundwater sources, but do not sufficiently control the level of water consumption.

The most effective instrument has been a consultative one, i.e. education and persuasion. During the severe drought of the 1980s, the water supply of southeastern Botswana was threatened. An educational campaign to inform the public about the need to restrict water consumption proved very effective in reducing water consumption. Its impact continued beyond the drought; because, although the water consumption resumed growth after the drought, there has never been a "catching-up" effect. There has been a lasting decline in water consumption.

Supply restriction, e.g. increased physical efforts, form another instrument which may reduce water consumption. The greater the physical impact required, the lower—and probably more efficient—the water consumption is. Obviously, such an instrument must be used with great care in order to make sure that the basic needs are met. But it should be recognized that the improved access to water has led to spillage too.

CONCLUDING REMARKS

Growing water scarcity inevitably leads to higher water-supply costs and increasing environmental problems. Botswana's future water supply can only be secured by simultaneous demand and supply management (cf. the Maghreb; 25). Increased surface-water consumption is positive because it is a renewable resource and relieves the pressure on groundwater. In addition, greater efforts must be made to restrict water demand. To achieve this, a good set of instruments is required. Economic instruments may improve resource-use efficiency and at the same time raise revenues to finance the required investments in the water sector. Since the 1980s, water pricing has been deliberately used to this effect. Present water prices are based on the production costs, the transport costs and subsidies. There are three arguments in favor of a price increase: (i) government cannot afford large-scale subsidies; production and transport costs are increasing; (ii) environmental externalities; and (iii) foregone benefits should be included in the price.

Recent price increases have been successful in increasing government revenues, but their impact on water-use efficiency has probably been limited; in the absence of prices elasticity data only tentative conclusions can be drawn. It is probable that the price increase has curbed luxury household demands, e.g. lawns and swimming pools. The impact on commercial activities is largely unknown, although the private sector frequently complains about the high water costs. It is too easy to credit water pricing for the low per capita water consumption. Equally important factors are low incomes, water-supply restrictions and the small size of the manufacturing and irrigation sectors. Further research is needed to assess the importance of each factor.

As expected, the effectiveness of economic instruments is restricted by certain characteristics of developing countries. First, the existence of a large informal, "nonmarket" water sector—presently accounting for almost half of the consumption—restricts the scope of economic instruments. Sectors such as livestock, wildlife and parts of the mining sector, are least affected by economic instruments. These sectors are not subsidized but in most cases, the water prices are regressive, hence encouraging large consumption and inefficiencies. Second, the widespread poverty necessitates the provision of free or cheap water to meet people's basic needs. But, this may lead to wasteful resource use around standpipes in villages. Third, the limited implementation and monitoring capacity explains the absence of essential data such as price and income elasticities of demand. Fourth, ambiguities in property rights in the informal sector have discouraged efficient water consumption.

The effectiveness of economic instruments can be significantly improved. Most important, subsidies should be restricted and redirected to the basic needs, particularly of the poorest, and to water-saving appliances and technologies only. This would lead to a price increase and better chances of a significant impact on resource-consumption patterns. To further strengthen the pricing instrument, the practice where employers foot household water bills should be discouraged, for example by taxation. In addition, the progression in rural water prices should be the same as that in urban areas; unless research shows that the price elasticities depend on the location too. Particularly in rural areas near towns, water rates should progress similarly to that of towns. It will be more difficult to extend economic instruments to the nonmarket water sector. To increase users efficiency in this sector, a charge could be introduced in proportion to the amount of water consumed. Finally, the creation of a water market could be considered to curb demand (26), and to delay huge investments in the water sector. This would first require additional research to examine the demand impact and the social consequences.

The case study showed the positive role of consultative instruments and the limitations of regulatory instruments. Consultation and an awareness-raising campaign succeeded in substantially reducing water consumption during the 1981-1987 drought. Regulatory instruments proved useful with regard to water-rights allocation, but very limited in influencing the level of water consumption. We may therefore conclude that a balance package of economic, regulatory and consultative instruments offers the best perspectives for a sustained water supply in Botswana.

References and Notes

1. Feder, G. and le Moigne, G. 1994. Managing water in a sustainable manner. *Finance and Development, June 1994, pp. 24–27.*
2. Khupe, B.B. 1994. Integrated Water Resource Management in Botswana. In: *Integrated Water Resources Management Workshop 1994: Proceedings*. Gieske, A. and Gould, J. (eds). Gaborone, Botswana, pp. 1–10.
3. Opschoor, J.B. and Vos, H. 1989. *Economic Instruments for Environmental Protection*. OECD, Paris.
4. OECD, 1993. *Economic Instruments for Environmental Management in Developing Countries*. Paris.
5. O'Connor, D. and Turnham, D. 1992. Managing the environment in developing countries. *OECD Development Centre Policy Brief No.2*, Paris.
6. Ministry of Finance and Development Planning. 1993. Population and development. Country report for the UN-Conference on Population and Development. Cairo, Egypt.
7. SMEC Ltd. 1991. *The Botswana National Water Master Plan (vls 1–12)*. Prepared for the Department of Water Affairs, Gaborone.
8. Lagerstedt, E. 1992. *Nitrate Contamination in the Groundwater and Nitrogen Circulation in an Area of South-East Botswana*. Dep. of Physical Geography, Stockholm University, Sweden.
9. Central Statistical Office. 1989. *The Poverty Datum Line*. Ministry of Finance and Development Planning, Gaborone.
10. Global warming may have a substantial impact on surface water sources because of their shallow nature. However, such impacts have not been incorporated in the National Water Master Plan.
11. Gieske, A. and Gould, J. (eds). 1994. *Integrated Water Resources Management Workshop 1994: Proceedings*. University of Botswana/ RIIC, Botswana.
12. Government of Botswana. 1991. *The Seventh National Development Plan (1991–1997)*. Government Printer, Gaborone.
13. World Bank. 1994. *World Development Report 1994*. Oxford University Press, New York.
14. Gould, J. 1991. *Rainwater Catchment Systems Development in Botswana*. Report to Botswana Technology Centre, Gaborone.
15. Bailey, C. 1982. *Cattle Husbandry in the Communal Areas of Eastern Botswana*. Unpubl. Ph.D Thesis, Cornell University, USA.
16. Water Utilities Corporation. 1994. *Annual Reports*. Gaborone, Botswana.
17. Motsomi, A.M. 1983. An analysis of the use of council boreholes for livestock in Kgatleng. *NIR-Research Notes No. 13*. University of Botswana.
18. Peters, P. 1983. *Cattlemen, Borehole Syndicates and Privatisation in the Kgatleng District of Botswana*. Unpubl. Ph.D Thesis, Boston University, USA.
19. Arntzen, J.W. 1989. *Environmental Pressure and Adaptation in Rural Botswana*. Unpubl. PhD Thesis, Free University, Amsterdam, The Netherlands.
20. Fortmann, L. and Roe, E. 1981. *Water Use in Eastern Botswana: Policy Guide and Summary of the Water Points Survey*. Ministry of Agriculture, Gaborone, Botswana.
21. This is based on a 8% discount rate and the medium demand scenario. The LRMC is very sensitive to the discount rate and the demand forecast.
22. Perrings, C., Opschoor, J., Arntzen, J., Gilbert, A. and Pearce, D. 1987. *Economics and Sustainable Development*. Technical report prepared for the NCS, Gaborone.
23. Krook, J. 1994. An Overview of Water Resources Development in Botswana. In: *Integrated Water Resources management Workshop 1994: Proceedings*: Gieske, A. and Gould, J. (eds). Gaborone, Botswana, pp. 27–38.
24. This rule is not sufficient to prevent land degradation because there is no limit to the number of cattle per borehole. As a result, most boreholes have many more cattle than the range may sustain.
25. Ayub, M.A. and Kuffner, U. 1994. Water Management in the Maghreb Region. *Finance and Development, June 1994, pp. 28–29.*
26. Simpson, L.D. 1994. Are water "markets" a viable option? *Finance and Development, June 1994, pp. 30–32.*

27. This article is based on a presentation at the Integrated Water Resource Management Workshop in Kanye, Botswana. The author wishes to thank John Gould and the Ambio reviewers for comments on an earlier version of the article. The author is also indebted to Mr. P. Koruutwe for the drawing of Figs 1 and 2.

28. The Botswana currency is 1 Pula. In May 1994 1 USD is Pula 0.39; in 1993 1 Pula was 0.4079 USD. The Pula has progressively depreciated against the USD during the 1980s. In 1982, 1 Pula was valued at 0.9425 USD.

29. First submitted 3 August 1994. Accepted for publication after revision 15 March 1995.

Jaap Arntzen, PhD is a lecturer at the Department of Environmental Science, University of Botswana. As an environmental economist, he has been involved in research on rangelands, desertification, population and environment, and environmental policy analysis and instruments.
His address: University of Botswana, Private Bag 0022, Gaborone, Botswana.