Economic value and pricing of water in agriculture

Kasnakoglu H.

in

Dupuy B. (ed.).
Aspects économiques de la gestion de l'eau dans le bassin méditerranéen

Bari : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 31

1997
pages 137-145

Economic value and pricing of water in agriculture

Haluk Kasnakoglu
Middle East Technical University
Department of Economics
Ankara, Turkey

Erol H. Çakmak
Býlkent University
Department of Economics
Ankara, Turkey

SUMMARY - The subject of this paper is to suggest a methodology to evaluate the economic value of water which can be used as a basis for water pricing. The methodology involves the use of agricultural sector models incorporating water as a scarce input. The economic value of water for different land types, regions and crops are estimated from the shadow prices of water and irrigated land constraints. After a theoretical discussion, the paper will also present the results of such a model applied to the South-eastern Anatolia Project (GAP) Region in Turkey, which is one of the world's largest irrigation and integrated regional development projects. Changes and differences in land values as a result of irrigation will be presented towards the estimation of the economic value of water.

Key words: Value of water, sector models, water pricing, shadow prices, GAP

RESUME *- Cet article suggère une méthodologie d'évaluation de la valeur économique de l'eau qui peut être une référence au prix de l'eau. Les modèles sectoriels agricole sont à la base de la méthodologie qui considère l'eau comme une ressource rare. La valeur économique de l'eau pour différent types de terre, régions et cultures sont estimés par le prix ombre des contraintes de l'eau et de la terre irriguée. Suite à une discussion théorique, l'article présente les résultats d'un modèle sectoriel appliqué au projet Sud-est Anatolien (GAP), qui, par ailleurs, est un des plus grands projets intégrés d'irrigation dans le monde. Les changements et les différences de la valeur de la terre dus à l'irrigation seront présentés en fonction de l'estimation de la valeur économique de l'eau.*

Mots-clés: *Valeur de l'eau, Modèle Sectoriel, Prix de l'eau, Prix de référence, GAP*

INTRODUCTION

Water is a scarce economic asset. Its use is limited by physical, economic and spatial conditions. When used under controlled circumstances it has very significant effects on yields and thus revenues from agriculture. While water is one of the most valuable inputs of production, it is one of the most subsidized inputs in many countries. Water from irrigation projects is usually offered to the users at a price, at most sufficient to cover operating costs and in some instances to partially cover the investment costs. Either way the basis for the water charge is cost-based. There is usually no charge for natural water (i.e. rain or underground water capitalised in the quality of soil and crop production environment).

Underpricing of water leads on the one hand to the inefficient use of water, on the other hand results in income transfers from non-irrigated to irrigated areas and thus increases the inequalities in income distribution. Furthermore, there is usually no cost or penalty for polluting the water through waste and fertilizers or chemicals, nor is there a penalty for environmental damages due to the misuse of this valuable resource. All these result eventually in the inefficient allocation of water as well as other scarce resources.

An alternative to the cost based pricing of water is the economic value based pricing of water. This requires the knowledge of the value of water which would differ by crop, region and quality of water and appears to be a more complicated scheme than cost pricing. On the other hand, to the extend realized, this approach leads to a more equitable distribution of the costs and more efficient use of the scarce resources including water itself.

The correct cost and benefit calculations of irrigation is not only important to decide on the investment but also important in distributing the costs of the investment to prospective users.

The purpose of the this report is to suggest a methodology to evaluate the economic value of water which can be used as a basis for water pricing. The methodology involves the use of agricultural sector models incorporating water and or irrigated land as scarce inputs. The economic value of water for different land types, regions and crops are estimated from the shadow prices estimated for water and irrigated land constraints.

After a theoretical discussion, the paper will also present the results of such a model applied to the South-eastern Anatolia Project Region in Turkey, which is one of the world's largest irrigation and integrated regional development projects. Changes and differences in land values as a result of irrigation will be presented towards the estimation of the economic value of water.

THE WATER DEBATE

Should water be treated as an "economic good" and allocated via market institutions, or is water somehow "different", therefore making a market allocation sub-optimal, or inefficient? This basic issue must be resolved, in order to achieve the optimal allocation for both the surface and ground water (Brajer and Martin, 1990).

Kislev (1994), like many others, argues that efficiency of resource allocation in the water economy can be markedly improved by greater reliance on price mechanism. He claims that the efficiency gain is much larger and deeper than commonly assumed, by pointing out the implications of subsidized water pricing: (i) creation of rents and development of rent seeking, which result in pressures to increase supply from existing sources and to invest in the creation of additional sources, thus resulting in the over-utilization and deterioration of the main aquifers; (ii) cost recovery is not assured, and funds for new investment are not generated, thus reliance on state budget and politics increases; (iii) limited monitoring of state institutions providing the service at subsidized prices; (iv) water price viewed as a mean to improving income distribution, not as an allocation device and (v) consumers paying a higher price than producers.

Whittington *et al.*,(1990), point out also that the progress in improving the quality and quantity of water used by people in rural areas of the developing world has been unsatisfactory, which results in: (i) incorrect use and non-proper maintenance of existing supplies and (ii) slow extension of improved service to unserved population They argue that if rural water projects are to be both sustainable and replicable, an improved planning methodology is required that includes a procedure for eliciting information on the value placed on different levels of service, and tariffs must be designed so that at least operation and maintenance costs (and preferably capital costs) can be recovered. A key concept in such an improved planning methodology is that of "willingness to pay." If people are willing to pay for the full costs of a particular service, then it is a clear indication that the service is valued (and therefore will most likely be used and maintained) and that it will be possible to generate the funds required to sustain and even replicate the project.

Anderson and Leal (1991) observe that artificially low prices for federal water promote waste at a time when water supplies are coming under increasing stress from industrial, municipal, and environmental demands. and point out that free market environmental principles have become in the 80's a coalescing theme among environmentalists and fiscal conservatives who oppose water projects that are both uneconomical and environmentally destructive. They suggest that water marketing can: (i) encourage efficient use; (ii) discourage detrimental environmental effect; (iii) reduce the drain on governmental budgets and (iv) release the creative power of individuals in marketplace, enabling water users to bring to bear specific knowledge to respond to growing scarcities. They note however, water marketing depends on well-specified (clearly defined, enforceable, and transferable) water rights which unfortunately are absent in the legal and institutional infrastructure of most countries.

On the other side, many others, argue for the treatment of water as a "social good" rather than an "economic good" and point out that because water is critical to human survival, and because reliance on market forces alone would not bring about socially optimal solutions, public authorities in most countries have assumed vast responsibilities for the overall management of water resources. They nevertheless accept that the performance record of publicly-owned and managed water services system is unsatisfactory and declining in many developing countries as well as in the industrialized economies. It is granted that at the macro level, the way water resources are managed results in major misallocations as well as quality deterioration and in many cases current practices and policies are not sustainable. Therefore the need for countries to consider alternative ways of using more private incentives to improve water management is not questioned (Easter and Feder, 1994).

Brajer and Martin (1990) point to the "community value" of water as opposed to its "commodity value". They argue that the public (social) definition of benefits may differ from those of an individual appropriator. Estimating the total benefits derived from water use involves consideration not only of direct benefits to water users, but also return flows and related secondary benefits. They correctly warn that many figures obtained on direct benefits neglect to allow for value generated from return flows, and subsequent reuse. They argue that when calculating secondary benefits, it is important to recognize that there exist backward and forward economic linkages. Direct water users are related to other sectors of their local, regional, and even national economies. As their activities contract or expand, so can the activities (and incomes) of those they supply or from whom they buy. Therefore, they argue that water is not just a commodity, but rather is "a necessary prerequisite for development and maintenance of the economy and social structure which make a society possible" Such a reasoning implies that a value placed on water-related secondary benefits using strict economic criteria may be incomplete and water cannot be treated simply as a market commodity, subject to typical supply and demand analysis, and to calculations of economic efficiency. Rather it must be treated in terms of social and economic welfare.

Roumasset (1994) also emphasizes the need for improving the efficiency and sustainability of water provision and use in the light of water scarcity, heightened awareness of water pollution and widespread dissatisfaction with deficit finance. To design efficient systems of water delivery and finance he recommends a theoretical approach at three levels, in an attempt to reconcile the two extremes outlined above. At the first level he examines the "first-best" optimization models which abstract from considerations of transaction costs and political economy. The efficiency here involves equating marginal costs of provision to marginal benefits (net of pollution costs) of use. At the second level "second-best" models which explicitly incorporate organizational and administrative difficulties deriving from the costs of information and enforcement are considered. Here, the most promising approach to achieving spatial efficiency at moderate decision making costs according to Roumasset (1994) involves using a mix of both top-down and bottom-up approaches.

Bottom-up decision making allows those best placed to know marginal value products, i.e., the farmers, to articulate water demands, but the communication costs of locating a market-clearing price are severe. Top-down decision making saves on communication costs but is likely to be inferior in terms of spatial efficiency. At the third level "third-best" models are considered to allow for strategic win-lose behaviour by coalitions of agents that seek rents for their membership at the expense of the general population. The problem of public finance is specified as to minimize rent-seeking and hence the equitable distribution of total benefits between direct and indirect beneficiaries.

APPROACHES TO WATER PRICING

The theoretical framework proposed by Roumasset (1994), suggest that the first-best optimality principle can constitute a useful benchmark and a point of departure for optimality at lower levels. The first-best optimum on the other hand requires the knowledge of marginal benefits and marginal costs of water. The marginal costs of water, which include costs of supply as well as externality costs are beyond the scope of this paper. Quantification of the marginal benefits of water use is the subject of the following discussion in the paper.

Estimation of the benefits of water use in agriculture have been attempted in general by estimating the yield increases and evaluating them at market prices. Such an approximation disregards the complex nature of interdependencies and interactions in the input and output markets of agricultural production activities.

Another approach has been to estimate the "willingness to pay" by the users of water to approximate the value of water. Most attempts to incorporate willingness to pay considerations into project design have, however, been ad hoc, in large part because of the absence of validated, field tested methodologies for assessing it. Two basic theoretical approaches are attempted for making reliable estimates of households' willingness to pay. The first, "indirect" approach, uses data on observed water use behaviour (such as quantities used, travel times to collection points, perception of water quality) to assess the response of consumers to different characteristics of an additional or improved water system. Among several modelling approaches possible here, one can name, varying parameter demand, hedonic property value, and hedonic travel cost models. The second, "direct" approach which is called the "contingent valuation method." is simply to ask an individual how much he or she would be willing to pay for the additional or improved water service (Whittington *et al.*, 1990).

In this paper we attempt to show how agricultural sector models can be employed to assess the value of water in its agricultural use. This approach we believe will not only provide consistent and more reliable estimates of the marginal benefits of water use, but can also more easily amend itself to the second and third-best optimum solutions.

The partial equilibrium mathematical optimization models of the agricultural sector of the following general form can be employed for this purpose:

$\text{Max } W = CS + PS$

s.t. $AX < B$

where,

W = Social Welfare

CS = Consumer Surplus

PS = Producer Surplus

A = Technology and Balance Matrix = $[A_1, A_2, A_3]'$

A_1= Irrigated Land Use Vectors

A_2= Water Use Vectors

A_3= Other Resource Use and Balance Vectors

B = Resource Availability Vector = $[B_1, B_2, B_3]'$

B_1= Irrigated Land Availability Vector

B_2= Water Availability Vector

B_3= Other Resource Availabilities and Balances Vector.

X = Vector of Production Activities

The shadow prices of the irrigated land constraints and water constraints can than be employed to estimate the marginal values of the water for different regions, periods, land types and crops depending on the detail incorporated into the formulation. As the dual of this problem will be W = [S]'[B] where [S] is the vector of shadow prices, the marginal value of irrigation can also be decomposed into consumer and producer surpluses to distribute the benefits between the two major groups of beneficiaries. The model can also be employed to simulate the marginal benefits under different irrigation investment and policy environments.

WATER RESOURCES, INSTITUTIONS AND PRICING IN TURKEY

Water Resources and South-eastern Anatolia Project (GAP)

Turkey is classified as a relatively water-abundant country with an average of 3,900 m^3/person/year availability of potential water resources. The potential cannot be fully developed, and the availability is not evenly distributed in time and space. Usable potential is 1,830 m^3/person/year, and 30% of this potential was consumed in 1993. The share of the agricultural sector in total consumption is around 75%. Lack of well-defined property rights, and centralized supply management hinder the efficient use of already developed water resources.

Sectorial distribution of water consumption shows the characteristics of a developing nation. The share of irrigation in total consumption is around 75% and is expected to remain almost constant until the year 2000 (the share of domestic consumption is 15% and industrial use is 10%). Furthermore, it might go up as high as 80% upon the completion of the GAP project. Per capita domestic water consumption is less than 100 m^3/year, which is quite low by European standards.

Rainfed agriculture covers 75% of the total arable lands in Turkey. The water basin studies indicated that 8.5 million hectares of land are "economically" irrigable of which 48% is already irrigated. Surface irrigation methods (such as furrow, basin, border or flooding) are used in 95% of the total irrigated area. The remaining area is irrigated with sprinklers. The average irrigation efficiency is around 41%, with a wide variation between 10% and 70% in 1990. The low irrigation efficiencies are caused by improper matching of supply and demands during the season, inaccurately executed water management programs, insufficient density of tertiary/quaternary canal system, poor field conditions (non-uniform slopes, poor levelling) and the reluctance of the farmers to irrigate at night (Çakmak, 1994).

Euphrates-Tigris scheme, referred to as the South-eastern Anatolia Project (GAP) is one of the largest integrated irrigation and regional development projects in the world. It consists of 80 dams, 66 hydroelectric power plants, and 68 irrigation systems bringing water to 1.6 million hectares of land. This would represent about 46 percent of all potential generating capacity and 53 percent of all potential hydroelectric production and 25 percent of all the irrigable land in Turkey with 1.6 million new hectares. The GAP is planned to be completed by 2010. The full cost of the project is estimated to be $32 billion (Çakmak, 1994 and Kolars, 1986).

One can summarize the significance of the project with the following quote from Kolars (1986): "What may be occurring is the end of the era of oil imperialism in the Middle East and the beginning of new and unavoidably necessary cooperation...There are two sets of resource rich nations in the Middle East: those with oil and scant water and those with abundant water and little oil. There may well come a time in the near future when shipments of these precious fluids will move in both directions."

Institutional Structure

Water Rights and Ownership: All natural resources, except some privately owned small springs, are vested in the state in the Turkish Constitution. However, the property rights in water resources are not well defined in the legislation, especially for surface water. The surface water is considered to be a public good and everyone is entitled to use it subject to the rights of the prior users. Prior authorization is required for non-consumptive use of water such as hydropower production, fishing, and thermal waters. The use of ground waters is more clearly defined. Ground water is the sole property of the state and State Hydraulic Works (DSI) is the only legal authority responsible for investigation, use and allocation of ground waters. Prior authorization is required to use all ground water from DSI. The permits by DSI are neither tradable nor transferable. DSI is responsible to provide water to cities with more than 100,000 population. General Directorate for Rural Services (KHGM)) provides water to villages. The municipalities do the rest with financing from the Bank of Provinces.

Institutions: DSI and KHGM are the critical institutions for the development of water resources. DSI controls almost all water resources in Turkey. Its duties include, to plan, design and construct works for irrigation, drainage, flood protection, water supply, and treatment, hydroelectric schemes, water and soil related investigations, river basin development plans. KHGM's responsibilities include, to complete on-farm canals of the DSI irrigation schemes, to develop the water resources up to 500 liters/second for irrigation purposes, field levelling, and to supply drinking water to villages. The General Directorate of the Bank of Provinces is responsible for the development of municipal infrastructural projects, including the construction and/or financing of drinking water and sewerage projects (Çakmak, 1994).

Water Pricing

Pricing and cost recovery policies vary among sectors. There is almost no volumetric system in irrigation, whereas volumetric charges are common in domestic and industrial use. The farmers are not charged any fees based on the resource value of the water they use for irrigation. The pay an annual area based fee for DSI operated irrigation schemes. It has two components. The first component, which is the significant portion of the fee, is intended to recover the costs of operation and maintenance (O&M) expenses incurred by DSI in the previous year without any inflation adjustments (inflation in the last 10 years around 80%). Furthermore, the government has the right to adjust the fees, and they are usually set lower than the rate proposed by DSI. For instance, in 1993, the O&M fees per hectare of wheat were $12 for gravity irrigation and $33 for pump irrigation, same fees for cotton were $34 and $80, respectively. The second component of the water charge is intended to recover the capital cost of a project. First of all, DSI is not allowed to charge any capital recovery for 10 years after project completion. Furthermore, the project's net present value at the completion date is amortized over a period not exceeding 50 years. Again no inflation adjustment is allowed.

The charges vary by region, and they ranged from $0.3 to $0.7 per hectare in 1993. Despite these favourable terms the collection rate of these fees was less than 50% since 1985. In 1992 only %33 of the fees was collected. KHGM transfers all ground water projects, and since 1992 all small scale surface water projects, to irrigation cooperatives free of charge. The irrigation cooperatives are responsible for the O&M costs and pay back the capital cost of pumps on very advantageous terms.

As it is the case for all input subsidies in agriculture, water pricing sends wrong signals to the farmers and encourages the over-use of water resources. By the year 2010, per capita water availability in Turkey will be slightly less than 2,500 m^3/year. Conflicts in sectorial allocation of water will certainly arise. The burden of adjustment will ultimately fall on the agricultural sector as the major consumptive user. The environmental problems related to water resources have reached quite dangerous levels in Turkey. 72% of the cultivated area is affected by water-borne erosion. 1.5 million hectares of soil contains concentration of sodium or other salts high enough to have significant impact on yields (Çakmak,1994).

TURKISH AGRICULTURAL SECTOR MODEL (TURGAP)

In this section we briefly describe the agricultural sector model for Turkey whose results we will employ in the next section to analyze the marginal value of water.

TURGAP is constructed to simulate and analyse the developments in the agricultural sector of the GAP region and the rest of Turkey between the next two decades covering the various stages of development of the irrigation project.

TURGAP is a partial equilibrium model of the agricultural sector of Turkey. It is a non-linear programming model with quadratic objective function which maximizes the sum of consumer and producer welfare.

TURGAP has a nested structure. Turkey is interacted with a World Trade Model (WTM) in its foreign trade. The GAP region is nested in Turkey and the individual irrigation projects are nested in the GAP region. All components interact with each other through input and output flows and the model is solved simultaneously.

The model simulates the variables such as crop pattern, production, domestic and international trade, human and livestock consumption, producer prices, factor prices, factor use endogenously at the irrigation project, GAP region and Turkey levels. The model works with price responsive domestic demand functions and foreign demand functions generated by the WTM. The supply functions are determined in the model endogenously by the non-linear cost structures of individual crop activities.

TURGAP treats, field crop, perennial crop and livestock activities simultaneously. There are 83 products in the model. 37 of these are field crops, 20 are perennial crops, 20 are livestock products and 6 are feed crops. 8 agro-climatic zones are specified for non-GAP regions and 732 sub-regions are specified for the GAP region representing different sub-regions, dry and irrigation project areas, weather conditions and land capability classes.

In the model labour, machinery and water inputs are specified monthly (10 day periods during peak months) for the GAP region and quarterly for the rest of Turkey. Two types of fertilizers, namely nitrogen and phosphate are employed as inputs, in addition to seeds and feed for livestock where variable feed rations are specified consisting of crop by-products, concentrates, grains, fodder and oil cakes.

TURGAP has approximately 4500 variables and 1250 equations and can be operated on a personal computer (Henrichsmeyer, *et. al.*, 1992).

THE MODEL RESULTS

In this section we present selected results on shadow values of land projected by the TURGAP model in the GAP region. In the GAP region there are 14 irrigation project which are expected to be completed by the year 2010. 7 of these irrigation projects are in the northern part and 7 are in the southern part. There is also one other irrigated region in the Southeastern region which is outside the GAP project. Table 1 presents the projected land indices for these 15 irrigated regions as well as 4 dry regions in the GAP area in 2010. The first 7 irrigated sub-regions presented in Table 1 are in the north and the following 7 sub-regions are in the south. The shadow price indices for dry and irrigated land by 3 land classes are presented in Table 2.

Table 1 - *Land Value Indices in the GAP Region for Year 2010 by Irrigation Project Regions (Irrigated Land Value = 100)*

Regions	Land Value Index
Irrigated	**100**
Siverek-Hilvan	92
Adýyaman-Kahta	72
Adýyaman-Göksu-Araban	71
Dicle	110
Garzan	76
Batman	110
Batman-Silvan	76
Urfa-Harran	113
Mardin-Ceylanpýnarý	121
Bozova	100
Suruç-Baziki	116
Gaziantep	95
Nusaybin-Cizre-Ýdil	88
Silopi	126
Non-Project Regions	95
Dry	**35**
North-High Rainfall	46
North-Medium Rainfall	27
South-Medium Rainfall	35
South-Low Rainfall	15

Table 2 - Land Value Indices in the GAP Region for Year 2010 by Land Classes (Irrigated Land Value = 100)

	Land Class			Weighted
Land Type	I	II	III	Average
Irrigated	148	93	53	100
Dry	62	43	23	35

The shadow prices for land presented show the marginal values of land in terms of their contributions to producer and consumer welfare. Of course the shadow prices reflect the scarcity as well as the crop value added of a specific land group. This information can be employed to differentiate the price of water in the different irrigation project regions. The absolute values of the shadow prices, which are not presented here, can be used to determine the absolute prices as well.

The presented shadow prices for land, support the argument that the value of water differs significantly by regions, crop pattern and quality of land. On the average, the shadow price of irrigated first class land is 50 percent higher than that of second class land. The marginal value of third class land is one third of the marginal value of first class land. By year 2010, the average value of irrigated land in the irrigated areas is projected to be nearly three times that of non-irrigated areas in the GAP region (Table 2). The projected shadow prices for land in irrigation project regions show that the marginal value of land in 2010 will in general be higher in the southern GAP area than those in the northern GAP. The lowest marginal land value index is registered in Adýyaman-Kahta in the south with 77 and the highest in Nusaybin-Cizre-Idil in the north with 126. The difference is a significant one and illustrates very clearly the need for proper price differentiation in water charges (Table 1).

Model results also suggest that, between 1995 and 2010, the total welfare in Turkish agriculture increases by $75 billion. The increase in consumer welfare in the same period is $40 billion and the increase in producer welfare is $35 billion. These results suggest that, the producers as well as consumers almost equally benefit from the investment in irrigation projects and it is not justified to transfer the full cost of irrigation projects to the producers (Henrichsmeyer, *et. al.*, 1992).

Finally it should be pointed out that the model results could have been employed to assess the value of water for smaller sub-regions and for different time periods in the year. It would also be possible to present water values for different crops and/or rotation activities.

REFERENCES

- **Anderson, T.L. and Leal, D.R.** (1991), *Free Market Environmentalism*, Pacific Research Institute for Public Policy, Oxford.
- **Brajer, V. and Martin, W.I.** (1990). Water Rights Markets: Social and Legal Considerations. *The American Journal of Economics and Sociology*, Vol. 49, No:1, January: 35-44.
- **Çakmak, E. H.** (1994). *Water Resources in Turkey: Availability, Use and Management.* International Conference on Coordination and Decentralization in Water Resources Management, Rehovot, Israel, October 3-6.
- **Easter, K. W. and Feder, G.** (1994). *Water Institutions, Incentives and Markets.* International Conference on

- **Henrichsmeyer, W., Kasnakoðlu, H. et. al.,** (1992). *Agricultural Commodities Marketing Survey, Planning of Crop Pattern and Integration of Marketing and Crop Pattern Studies.* Southeastern Anatolia Project Regional Development Administration, Vols. I and IV, Ankara.
- **Kolars, J.** (1986). The Hydro-Imperative of Turkey's Search for Energy. *The Middle East Journal*, Volume 40, No. 1, Winter:53-67.
- **Roumasset, J.** (1994). *Designing Schemes for Water Quantity and Quality Management.* International Conference on Coordination and Decentralization in Water Resources Management, Rehovot, Israel, October 3-6.
- **Whittington, D., Briscoe, J., Mu, X. and Barron, W.** (1990). Esimating the Willingness to Pay for Water Services in Developing Countries: A Case Study of the Use of Contingent Valuation Surveys in Southern Haiti. *Economic Development and Cultural Change*, Volume 38, Number 2, January:293-311.
- **Yoav, K.** (1994). *Allocation by Prices.* International Conference on Coordination and Decentralization in Water Resources Management, Rehovot, Israel, October 3-6.