PRICING IRRIGATION WATER: FOCUSING ON SUSTAINABILITY

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FACTORS AFFECTING FARMERS' PERFORMANCE IN SUSTAINABLE IRRIGATION MANAGEMENT

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1. Introduction

Conceptually, farmer performance in terms of efficiency and sustainability is influenced by decision-making environments and their personal characteristics. The way problems and opportunities are dealt with by the farmer is reflected in the decision-making process (categorized to include planning , implementation and control), and meant to influence the technical and biological process on the farm, which in turn determines the farm results. Each of these steps can be only partially controlled. Stochastic elements from the environment also play their parts (Rougoor, et al., 1998).

As shown in Figure 1, four features of environmental variables include:

- Institutional environment, such as regulation of water, land, property rights, land tenure systems, etc.
- Social environment, such as the composition of the farmer's family, dependency ratio, etc.
- Physical environment, including weather and the state of technology.
- Economic environment, which determines prices of inputs and outputs.

In addition to the environmental factors, personal aspects of farmers such as biography ,motivation and abilities affect decision-making process. Important characteristics and traits associated with management performance include the willingness to learn and the farmer's decisiveness and self-confidence. Measuring these characteristics is a problem to be addressed in studying farmer performance .

In this study, an attempt is made to measure some of these characteristics or use some proxies in order to quantify the relationship between farmers' personal characteristics and their management performance. It should be noted that, in assessing the quality of a decision, one can use not only outcome-oriented criteria such as efficiency and sustainability, but analysis requires process-oriented criteria as well. In other words, one can judge whether a decision is right before the outcome is apparent by looking at the process that led to the decision. Human decision-making can be characterized by satisfying rather than optimizing behavior and by bounded rationality, rather than by complete rationality. In making a decision, the farmer is bounded by his limited cognitive skills, with respect to the amount of information that he can process. Given those boundaries, he will try to act rational.

2. The Empirical Model

In order to determine factors affecting farmer performance in irrigation management, some performance criteria are needed. Following Khanna and

Zilberman (1997), the ratio of applied water to effective water (evapotranspiration) was used as an index of sustainability. In addition, irrigation water productivity was used as an index of water use efficiency. Assuming the maximization of economic net benefit from a given set of resources subject to a set of environmental qualities as the objective of sustainable irrigation system, the water management problem can be modeled.

One solution to the problems of irrigation management, such as water logging and salinity (resulting from the over application of irrigation water) is to adopt precision technology which would limit irrigation water application to the amount of water consumed by crops, defining precision technology as practices which result in the reduction of water relative to conventional practices. To model the choice of these technologies and their impacts, it is necessary to distinguish between *applied* water, which is the quantity of irrigation water applied in the field, and *effective* water, which is the quantity actually consumed by the crop (evapotranspiration). For irrigation water application, precision technology adjusts the applied quantity to the crop water requirements, as determined by an appropriate formula used by irrigation experts. It should be noted that improvements in irrigation water use entails higher costs per unit of land as well as per unit of water. Over-application of inputs such as irrigation water is partly due to the fact that farmers do not pay the full costs associated with the supplied water. If some adoption of improved technologies is observed, it is mainly due to their impact on yields and profitability. However, much adoption of such technologies has not been observed throughout the world, in spite of the possible contribution to sustainability (Khanna and Zilberman, 1997).

3. Methodology and Data

Trading irrigation water is not common in the region under investigation. Therefore, demand for irrigation water was estimated using both linear programming and functional analysis. The linear programming model was used to find a profit maximizing mix of enterprises, given a set of input prices and constraints. To determine the effect of price on the use of irrigation water, the price of water was varied. The model determined the activities that the farmers would likely select under the various prices and constraints assumed in the model, and hence, the amount of irrigation water they demand.

To construct the linear programming model, a random sample of farmers were selected from the Dorudzan region of Iran. In this region, farmers are mainly dependent on surface water supplied by the Dorudzan Dam, located

100 km north of Shiraz. Data were obtained from sample farmers by way of structured questionnaire and personal interviews. The general form of the linear programming model is as follows:

$$\text{Max.}: Z = \sum_{J=1}^{m} C_j \chi_j$$

$$\text{subject to:} \quad \sum a_{ij} X_j \leq b_i, \; X_j \geq 0$$

where Z is the objective function(total gross margin) to be maximized, Xj, Cj are activity levels and gross margin per hectare, respectively, and aij is the per unit requirement of activity j for input i, and Bi represents the amount of available resources (constraints).

To determine the productivity of irrigation water and the price elasticity of demand for individual crops, a production function was estimated for wheat, a major crop in the region. The function used for this purpose is as follows:

$$Y_i = a.\Pi x_{ij}^{a_{ij}} e^{u_{ij}}$$

To estimate the above function, the following linear form was used:

$$\text{Ln } Y_i = \text{Ln} a \sum a_{ij} \text{ Ln } X_{ij} + U_{ij}$$

where Yi is the output of wheat in tons, Xij represents the inputs of fertilizer, water, labor, seed, machinery, and land.

The demand function for irrigation water was derived from the profit function as follows:

$$\Pi = P_y Y_i - \sum P_{xi} X_i \;\Rightarrow\; Y_i = f(x_1, \ldots x_n | X_{n+1})$$

$$\frac{\partial \Pi}{\partial x_i} = P \frac{\partial y}{\partial x_i} - P_{xi} = 0$$

$$P \frac{\partial y}{\partial x_i} = P_{xi} \;\Rightarrow\; Vm_{xi} = P_{xi}$$

where Π is profit, Py is the price of wheat by kilogram, Pxi is the price per unit of irrigation water, and Vmxi is the value of the marginal product of irrigation water.

Average and marginal productivities of irrigation water were estimated as follows:

$$Apxi = \frac{Mpxi}{ei} \quad or = \frac{Y}{xi}$$

$$MPxi = \frac{\partial Y}{\partial xi} \Rightarrow exi \, . \, Apxi$$

where Apxi is the average productivity of irrigation water, MPxi is the productivity of irrigation water, and eixi is the production coefficient for irrigation water.

To determine the willingness of farmers to participate in the management of irrigation projects, a separate questionnaire was constructed. Farmers' responses to the questions were analyzed by computing means and variances of variables and using a t-test. The value of t-statistic was computed as:

$$t = \frac{(x1 - x2) - (\mu 1 - \mu 2)}{\sqrt{\frac{S1^2}{n1} + \frac{S2^2}{n2}}}$$

where:

n1, n2 = Sample sizes.

s1, s2 = Standard deviation.

x1, x2 = Sample means.

μ1, μ2 = Means of variables in the populations.

To determine the effects of various environmental factors (economic, social, physical, institutional and personal) on the productivity and loss of irrigation water, two approaches were used. In one approach, irrigation water productivity and loss were related to the above factors. Using the ordinary least squares method, the effects of these factors on the productivity and loss of irrigation water were estimated. In the second approach, correlation coefficients between each factor and irrigation productivity and loss were computed. Farmers were classified into groups according to some pre-specified (personal and environmental) factors assumed to influence the sustainable use of irrigation water. Specifically, factors considered to affect the performance of farmers in irrigation management are represented in tabular form below.

An index of management ability (skill) was estimated as follows:

$$Si = \frac{mi}{m} \times 100$$

$$mi = \frac{1m1 + 2m2 + 3m3}{6}$$

where:

Si = index of ith farmer's ability

mi = level of management ability of the ith farmer

m1 = years of school

m2 = years of experience

m3 = years of on-the-job training (extension).

To determine the effect of fertilizer subsidies on the demand for fertilizer and irrigation water, a demand function for fertilizer were derived from the same production function. Then, by varying the price of fertilizer, demand for fertilizer and irrigation water were estimated.

To gain more insight into the factors causing the irrigation productivity differential among the farmers, technical efficiency of wheat growers in Dorudzan Basin were estimated using the COLS method. The relation between technical efficiency and the ratio of *crop water requirement* to *applied water* was then determined.

To identify technical efficiency, residual terms were first computed from the estimating production function. Then, the largest residual was added to the intercept to estimate Y as follows:

$$\hat{Ln}\ Y = (\text{ max. residual + intercept }) + a1lnx1 + a2lnx2 + \ldots$$

After estimating Y, technical efficiency was computed using the equation:

$$Te = \frac{Y^{\wedge}}{Y}$$

where: $Y^{\wedge}$ = estimated production of wheat.
Y = observed production of wheat.

4. The Region

To determine the performance of farmers with respect to the chosen criteria, vis-a-vis irrigation water productivity and the over use of irrigation water, two major agricultural areas were selected in the Fars province. They are the Dorudzan Basin in Marvdasht plain, and the Sarvestan Plain. Marvdasht is a major wheat producing region in Iran. In this region, the Dorudzan plain was studied. The plain consists of two areas, Korbal and Ramjerd. Agriculture in both areas is dependent on surface water supplied by Dorudzan irrigation canal network, located 100 kilometers north of Shiraz, the capital of Fars province. With 668 kilometers of irrigation and 690 kilometers of drainage networks, the project is one of the most modern irrigation works in Iran. The project supplies about 500 million cubic meters of regulated water to some 50,000 hectares annually.

Cereal is dominating cropping patterns in Korbal, comprising about 92 percent of cropped area. The remaining areas are dedicated to legumes (3.7 percent), vegetables (1.8 percent), sugarbeet (1.5 percent), and pulses (1.1 percent). In Ramjerd, cropping patterns consist of wheat (53 percent), barley (35 percent), legumes (5.5 percent), rice (4.5 Percent), and cucurbits (2 percent). Both areas receive irrigation water from Dorudzan Dam.

The Sarvestan plain is located to the southwest of Shiraz. The plain is suitable for the production of both field (broadacre) and horticultural crops. At present, ground water is the only source of irrigation in the Sarvestan Plain. Due to the shortage of ground water and depletion of the aquifer, the government is encouraging the adoption of water-saving technologies by supplying easy credits to the farmers. According to the latest statistics, there are some 765 tube wells extracting groundwater for irrigating some 15,000 hectares in the plain. Prevalent crops in Sarvestan include wheat, barley, corn, and cotton. In addition, sugarbeet, alfalfa, potato ,tomato, and melon (i.e. summer crops) are grown in the Sarvestan plain.

5. Results and Discussions

5.1. Dorudzan Basin

Input-output and biographic information of sample farmers are shown in Tables 2 and 3.

Using data collected from sample farmers, the wheat production function was estimated as follows:

$$Ly = 8.5 + 0.75\ LX1 + 0.32\ LX2 - 0.22\ LX3 - 0.03\ LX5 + 0.17\ LX6 + 0.15LX7$$

t: (5.93) (3.16) (3.54) (-1.22) (-0.95) (2.73) (2.105)

$R^2 = 0.87$ $\quad R^{-2} = 0.80$ $\quad F = 46.77$

where:

X1 = Land
X2 = Fertilizer
X3 = Seed
X5 =Machinery Cost
X6 =Irrigation water
X7 =Labor

Since farmers are growing a number of crops in the region, wheat was selected because it is grown by all farmers. As indicated, 87 percent of variations in wheat output are explained by the variables included in the model. Also, the value of F indicates that the regression model is statistically significant.

Of the variables included in the model, X3 (Seed input) and X5 (Machinery) are not significant, and X4 is omitted from the model because it is linearly dependent. Other Variables are significant at 1, 5, and 10 percent levels. In this study, irrigation water (X6) is of main interest, with the production coefficient of 0.07 being significant at 5 percent. Since the production coefficient for irrigation water is positive and significant, we can estimate the demand function for irrigation water using the following equation derived from the maximizing profit function :

$$Vmpx6 = Px6 \Rightarrow MPx6 \cdot Py = P\,X6 \qquad (I)$$

where VmpX6 is the value of the marginal product of water and PX6 is the price per unit of water.

The marginal product of irrigation water is derived from the estimating production function. Hence, the water demand function becomes :

$$X6 = \left[\frac{Px6}{Py.\ a6\ A x1^{a1}\ x2^{a2}\ x3^{a3}\ x4^{a4}\ x5^{a5}\ x7^{a7}} \right]^{\frac{1}{a6-1}} \qquad (II)$$

Using average prices of irrigation water and wheat, price elasticity of demand for

irrigation water, after some manipulations, is derived to be :

$$Epx6 = \frac{1}{a6-1}$$

Therefore, the price elasticity of demand for irrigation water is estimated at -1.22. This shows that wheat growers are responsive to the price of irrigation water. That is, increasing the price of water is likely to lower the amount of water applied to the field. Hence, water pricing can be used as an effective measure for achieving water conservation in the case of individual crops.

As indicated earlier, a linear programming model was constructed to estimate demand for irrigation water in Dorudzan Basin. Major crops included in the model included wheat, barley, sugarbeet, corn, beans, tomatoes, and rice. The purpose of using the liner programming model was to study farmers' responses to the price of irrigation water in the region. To derive the normative demand, water prices were varied from 0 to 800 Rials per cubic meter. The results are shown in Table 4.

As shown in Table 4, increasing the price of irrigation water is not likely to result in reduced demand until the total gross margin from cropping becomes negative. This finding is supported by the behavior of farmers in the drought season of the last cropping year, during which time the irrigation water was not supplied to the farmers by the irrigation organization in order to meet urban demand for water. It should be noted that the project was designed to supply water to the city of Shiraz, in addition to supplying irrigation water.

Facing water shortages, many farmers have invested in tube wells to use ground water for the irrigation of summer crops that were not allocated canal water. This indicates that farmers in this region are willing to pay higher prices for water in the dry seasons despite their objections to rising canal water charges in normal years.

As indicated, farmers in this region are not responsive to water price increases. They appear to maintain their total water consumption unchanged, while reallocating their limited water supplies among various crops. This finding is supported by the magnitude of demand elasticity in the case of irrigated wheat. It is also supported by the findings of researchers elsewhere (2000). With regard to the objective of this research, it should be emphasised that water pricing as a single instrument for controlling water use in the region is not an appropriate means for achieving a significant reduction in irrigation water use .

This is at least in part because water use is not reduced until prices reach a level that negatively affects farm income. While price increases are not likely to lower water consumption, water charges can be used as a means to achieve financial objectives by collecting sufficient fund to meet financial needs. In addition, water pricing may be used to make farmers aware of the scarcity of water resources and encourage the adoption of water saving technologies and more sustainable cropping patterns.

Since demand for irrigation water is indirectly related to the price of output, increasing the price of wheat (other factors remaining unchanged) results in higher demand for irrigation water. The demand function for fertilizer was derived from the wheat production function using the same approach used to derive demand for irrigation water. The function so derived is of the following form :

$$X2 = 632861.5 \ PX2^{-1.22}$$

Using the market price of fertilizer in the above function, demand for fertilizer was estimated. The quantities of fertilizer demanded were used in the demand function for irrigation water to determine the effect of fertilizer price on the use of fertilizer and irrigation water. The results are shown in Table 5.

As indicated, increasing the price of fertilizer is likely to reduce the demand for fertilizer, as well as the demand for irrigation water. Hence, fertilizer and irrigation water subsidies contribute to the over application of both inputs.

As mentioned above, in order to determine the impact of some management and environmental factors on irrigation management, both irrigation productivity and loss were used as index of sustainability. Irrigation loss was computed as the ratio of crop water requirements to actual water applied in the field. The higher this ratio, the more sustainable the use of irrigation water should be.

To determine the impact of some management factors on the productivity of irrigation water, the average and marginal productivities of irrigation water were related to factors such as age , education, farmer's family size, experience and extension education. Results are shown in Table 6.

As indicated, only family size has negative and significant impact on the productivity of irrigation water. This means that farmers with larger family are likely to be less productive with respect to the use of irrigation water. Correlation coefficients between the above factors and irrigation water productivity were estimated as shown in Table 7.

As indicated, farmer education is positively related to the productivity of irrigation water. However, extension education does not have a significant impact on the irrigation management in the region (see Table 8). This is mainly due to the fact that extension agents in Iran are not being trained in subjects that include sustainable farming, nor they are concerned with sustainable irrigation management.

To determine the impact of some management factors on the use of irrigation water, the ratio of crop water requirements to the applied irrigation water were regressed against some personal factors mentioned above. The results are shown in Table 8.

In the above function, only the age and education of farmers have positive effects on the use of irrigation water. In other words, older farmers with more education have used more appropriate amounts of irrigation water than younger and less educated ones. Based on the findings of this study, farmers having more contact with extension agents are less efficient in using irrigation water than others. As indicated, extension education in the region is not oriented toward the sustainable use of irrigation water.

To determine the correlation between social factors and the productivity of irrigation water, family size and number of dependent members were used as proxies for social factors. As indicated in Tables 9 and 10, there is a positive correlation between the dependency burden and water use efficiency. With respect to size, families with 3 to 5 members have achieved the highest level of efficiency. However, as indicated in Table 9, the correlation between these factors is not statistically significant.

Farm income, access to credit and insurance were used as economic factors. As indicated in Tables 11 and 12, while there is a positive relation between economic factors and irrigation water productivity, the magnitude of correlation coefficient between these factors indicates that they are not significantly correlated.

Physical factors such as the number of land parcels, size and fallow, tillage practice, and size of land are likely to affect the productivity of irrigation water. As shown in Table 13, there is a negative relation between the size of land and average and marginal productivities of irrigation. This indicates that small farmers are likely to be more efficient in using irrigation water than large farmers in the region. The finding indicates that there is a negative relation between the number of tillage and irrigation productivity. The correlation coefficient shows that the correlation between the size of the holding and irrigation productivity is significant. However, there is no significant correlation between the number of tillage and irrigation productivity, as shown in Table 14. Also, the correlation coefficient between the number of land parcels and irrigation productivity is positive and significant.

Land tenure and water right systems where used as institutional factors. As shown in Table 15 and 16, farmers who buy irrigation water and those who have water rights are equally productive in using irrigation water. Also, while farmers who own the land have achieved higher productivity than those renting it, the difference between the irrigation productivity of the two groups is not significant.

In addition to the lack of any significant relation between land and water rights and irrigation productivity, the study showed that management ability is not likely to have significant impact on the productivity of irrigation water. Correlation and ANOVA tests between farmers age, experience, formal and extension education, and irrigation water overuse in Dorudzan Basin revealed a negative relationship between farmers age and experience and irrigation water overuse, as presented in Table 17. This conforms with the expectation that experienced farmers use irrigation water more efficiently than others. However, the results of correlation and ANOVA tests show that the differences among various age and experience groups with respect to over-irrigation are not statistically significant. On the other hand, the results of regression analysis indicated that only formal education has significant effect on irrigation overuse (see Table18). As before, extension education has not contributed to improved irrigation management in the region. This is mainly due to the content of extension education, discussed above.

In order to study the above relationships, the number of dependent and total members of farm families were used separately. The results are shown in Table 19.

Based on the results shown in Table 19, there is a positive relationship between the number of family members, as well as the number of dependent members, and irrigation water overuse. However, significance tests show that these relationships are not statistically significant.

Factors such as farmers' income, crop insurance, and access to credit were used in relation to over-irrigation. The results indicate a negative relationship between farmers' income and over-irrigation. Correlations between these factors are significant at the 10% level. The findings indicate that farm income is likely to be a contributing factor in sustainable irrigation management. Correlation and ANOVA tests show that there is significant difference among various income groups with respect to over-irrigation, as explored in Table 20. With regard to credit and crop insurance, the findings indicate that farmers with easy access to agricultural credit and crop insurance use more irrigation water than other groups. However, correlation tests and analysis of variance do not indicate significant behavioral difference between the groups of farmers with respect to irrigation water management.

Physical factors likely to affect the sustainable use of irrigation water include cropping patterns, climate, irrigation method, number of land parcels (scattered holdings), tillage practices, fallowing, etc. Since, cropping patterns, climate, and irrigation method were similar in the sample farms under investigation, the number of land parcels, tillage practices, fallow area and size of holdings were used as physical factors to study their impact on irrigation water over-use.

As shown in Table 21, the relation between farm size and irrigation water over-use is positive and significant. This indicates that small farmers in the region have used irrigation water more sustainably than larger farmers. This is due to the fact that irrigators with small holdings are able to control irrigation water using labor-intensive methods of irrigation. In many parts of Iran, especially in arid region facing water shortage, small farmers are attaining high irrigation efficiency using conventional (surface) irrigation techniques. This is called induced water-saving technology, which is labor-intensive, as opposed to the modern water-saving technologies, which are capital-intensive. Correlation between factors such as access to credit, crop insurance, fallow areas, tillage method, and irrigation water over-use are not significant. Hence, among the physical factors considered, only farm size has a positive and significant correlation with irrigation efficiency in the region.

Land tenure and water rights were used in relation to over-irrigation to determine the correlation between institutional factors and the use of irrigation water by the farmers in the selected region. As shown in Table 22, correlation coefficients between property rights over land and water, one the one hand, and irrigation water use are 0.01 and- 0.07, respectively. The finding shows that farmers who buy water and rent their land are using irrigation water more efficiently than those who own land and hold water rights. However, tests of correlation coefficient and analysis of variance indicate that there is no significant difference among various institutional groups with respect to irrigation practice. Therefore, institutional factors such as property rights are not likely to affect the sustainable use of irrigation water in the region.

As indicated earlier, an index of management ability was computed using variables such as formal education, experience, and extension education . The relation between this index and the use of irrigation water revealed that management ability is not likely to have significant effect on the management of irrigation water in the region.

Technical efficiency of sample farmers was estimated at 0.469 and varies between 0.21 and 0.99. To determine the relation between technical efficiency and applied irrigation water, farmers were classified in to two groups, namely, those with the ratio of crop water requirements to applied water less than one and those with the ratio of crop water requirements to applied water greater than one. Then, the technical efficiencies of the two groups were compared. As indicated in Table 24, the technical efficiency of the second group is greater than that of the first group. This indicates that farmers who apply less than the required crop water are more technically efficient than others.

Finally, the effect of technical efficiency on over-irrigation was determined using regression analysis. Results are shown in Table 25.

As indicated, the relation between dx12 (the ratio of crop water requirement to applied water) and technical efficiency is positive and significant. This means that as the technical efficiency of farmers increases, the amount of over-irrigation is likely to decrease. In other words, increasing technical efficiency leads to lower irrigation water loss.

Water users' willingness to participate in the management of irrigation projects and their views on other irrigation issues were studied using questionnaires and interview techniques. Table 26 represents the results.

At present, the majority of farmers are not participating in the management of irrigation projects. In fact, many of them are not familiar with the concept, let alone the benefit of participatory management. After explaining the concept and the rationale behind it, farmers expressed their willingness to participate in the operation and maintenance of irrigation project. They also were willing to cooperate with the irrigation organization in the distribution of irrigation water and collection of water fees. According to the majority of farmers, measures such as land consolidation, education, financial assistance, and performance monitoring contribute to water users' participation in the management of irrigation systems. Table 27 shows how farmers evaluate water organization performance.

Most farmers are dissatisfied with the performance of irrigation organizations. Table 28 shows the response of farmers to the questions and issues involved in the management of irrigation projects in the region.

As indicated in the table above, while most water users are dissatisfied with the performance of the water organization, they are willing to participate in the management of irrigation projects. According to most respondents, factors contributing to the inefficient management of irrigation projects include unlined canals, corruption, the violation of water rules and regulations, discrimination with regard to the enforcement of rules and regulations, and insufficient investment in the maintenance of irrigation projects.

According to farmers' perception of irrigation sustainability, the following factors are major causes of unsustainable irrigation management. They are mentioned in the order of importance, as ranked by respondents.

According to respondents, the following policy measures should be adapted by government to promote sustainable use of water resources:

Farmers were asked to name major factors positively affecting their economic well-being. Following factors were mentioned in the order of importance:

As indicated in Table 31, factors which have positive effect on farmers' utility (satisfaction) are likely to have an adverse impact on sustainability. This shows that while farmers are aware of unsustainable irrigation practices, they are operating in an economic environment unfavorable to the sustainable use of irrigation water. In other words, they know that factors such as soil and water pollution, over-pumping and the increasing salinity of ground water and soil compacting are results of the irrational use of land and water resources. Despite such awareness, however, they do not consider measures to remedy (or prevent) the unsustainable use of irrigation water and farming practices to be beneficial to them in the short-run. As indicated in the above tables, the majority of farmers support input (irrigation water and fertilizer) subsidies without considering their possible long-run adverse impact on sustainability.

5.2. The Sarvestan Plain

As indicated earlier, ground water is the main source of irrigation in the Sarvestan plain. To determine the relative scarcity of land and water resources in the region, an index was computed as follows:

$$k = \frac{\text{Available water resources}}{\text{(Irrigated land) * (Average crop water requirement per hectare)}}$$

k = 0.7353

Since the ratio of available water resources to total irrigation water requirements in the plain is less then one, water resources are relatively more scarce than irrigated land in Sarvestan. At present, some 15,000 hectares are irrigated using ground water. Since ground water is a more limiting factor than land, deficit irrigation with the following cropping patterns has been recommended to prevent the depletion of ground water and increase the returns to irrigation water.

The difference between crop water requirements and the actual water applied by sample farmers were used as an index of over-irrigation. Average annual pumping discharge in selected tube wells was measured to estimate the actual volume of irrigation water used by farmers in the sample. Crop water requirements were computed using the Hargrave and Samani method. The results are shown in Table 33.

As in the Dorudzan plain, the magnitude of over-irrigation in the Sarvestan plain was related to various personal and environmental factors. The distribution of sample farmers with respect to these factors is shown in Table 34.

Description of codes:

1- Water rights	0	Buys irrigation water

	1	Owns tube well
2 - Water use behavior	0	Not affected by water use of neighbors
	1	Affected by water use of neighbors
3 - Crop diversification	0	Not diversified
	1	Diversified
4 - Tractor Use	0	Rents tractor
	1	Owns tractor
5 - Credit	0	Have not used credit
	1	Have used credit
6 - Land leveling	0	Do not practice land leveling
	1	Do practice land leveling
7 - Crop insurance	0	Do not have crop insurance
	1	Have crop insurance

Quantities of inputs used in the production of wheat in Sarvestan are shown in Table 35.

Variable costs for irrigated wheat production in the region was estimated as Table 36.

As indicated, water is the highest cost item in the production of wheat in the region. Cost per cubic meter of water extracted from the aquifer varies between 60 and 67 Rials, depending on the energy used for pumping the ground water.

Using a Cobb-Douglas production model, production function for irrigated wheat was estimated as:

$$Ly = 2.08 + 0.25\ Lx1 + 0.87Lx2 + 0.32\ Lx3 + 0.45\ Lx4 + 0.0175\ Lx5$$

t : (3.14) (2.18) (2.45) (3.2) (3.18) (2.13)

$R^2 = 0.87$ $F = 35.64$ Signf. = 0.000

where:

y = wheat output in kilogram.
x1 = manure in tons.
x2 = phosphate in kilogram
x3 = waged labor in man days.
x4 = irrigation water in cubic meter.

x5 = seed in kilogram.

All inputs are statistically significant at less than 5%, explaining 87% of variation in wheat output. Using the current price of wheat, the value of the marginal product of irrigation water is estimated at 211 Rials. Since the cost per unit of irrigation water is much lower than the marginal contribution of water to wheat output, farmers have an incentive to use an excessive amount of water to maximize profit, disregarding the external cost of over pumping in the region.

Demand for irrigation water was estimated by maximizing the profit function derived from the production function:

$$\pi = P. yi - C \qquad \textbf{. I}$$

$$C = \sum \gamma xi + F \qquad \textbf{. II}$$

where:

P = price of output

Yi = production function

γ = price per unit of inputs

Xi = quantity of inputs

C = cost of production

F = fixed cost

By taking a partial derivative of the profit function with respect to inputs and substituting the resulting quantities of other inputs in the production function, demand function for irrigation water was estimated to be:

$$D_w = (Py.A)^{9.95} \left[\frac{0.25}{\gamma 1}\right]^{0.24} \left[\frac{0.87}{\gamma 2}\right]^{0.86} \left[\frac{0.32}{\gamma 3}\right]^{3.18} \left[\frac{0.45}{\gamma 4}\right]^{5.47} \left[\frac{0.0175}{\gamma 5}\right]^{0.17}$$

Given the production, profit, and demand functions, the elasticity of demand for irrigation water would be:

$$Edw = \frac{-\beta w \ Py}{\gamma w \ xw}$$

With the current cost of irrigation water, price elasticity of demand is estimated at -3.17, indicating that farmers are likely to respond positively to changing the cost of ground water in the region. As indicated, ground water overdraft in the Sarvestan plain is causing the rapid depletion of the ground water aquifer. Given the farmers elastic demand, water pricing can be used as a policy measure for ground water management in the region. As indicated above, most farmers in the region are using electric pumps to extract groundwater. Hence, one approach to ground water pumpage control is to charge an increasing block rate tariff for the electricity used in excess of what is required for ground water pumpage on sustainable bases.

As in Dorudzan study, the over-irrigation in Sarvestan was related to the personal characteristics of water users and some environmental factors that were assumed to affect their performance in irrigation management. Three important personal characteristics that were considered include:

1. Drive and motivation
2. Ability
3. Biography

Factors considered as proxies for the above characteristics include:

1. Willingness to learn, measured by the number of contacts with the agricultural service center and extension agents.
2. 2. Farmer's age, formal education, and experience, and the computed management ability index discussed above.

Correlations between the magnitude of water over-application and each of the above factors were estimated as presented in Table 37.

The correlation between age, experience, extension education, agricultural service contact and over-irrigation are statistically significant. However, while extension education and contact with agricultural service centers are negatively related to over-irrigation, age and experience have positive effect on over-irrigation. The correlation coefficient between the management ability index and over-irrigation is not significant. In addition, further analysis indicated that there is no significant relation between irrigation water productivity and management ability (see Table 38).

The difference between the use of irrigation water by various factor groups was tested using analysis of variance. Results are shown in Table 39.

As indicated, older farmers are more likely to over irrigate their crops than younger ones. However, with respect to experience and education, there is no significant difference in the water use behavior of different groups. In the case of formal education, a majority of farmers in the region are illiterate or have low levels of education. Therefore the result of the analysis of variance among different education groups should not be considered meaningful. As for extension impact, farmers not attending extension classes are more likely to over irrigate their crops. This finding is contrary to the findings in Dorudzan region where extension education was a contributing factor to over-irrigation.

The relation between personal factors and irrigation water productivity is shown in Table 40. As indicated, more experienced farmers have obtained higher productivity. In addition, extension education has had a negative effect on water productivity. Also, farmers over 75 years of age and those having 5 to 9 years of formal education have obtained the highest level of productivity in irrigation water use.

Personal characteristics such as age, experience, participation in extension education, and number of contacts with agricultural department are likely to be significantly associated with the problem of over-irrigation in Sarvestan. Now, the question is remains as to which character combination would best enable an irrigator to obtain the highest irrigation water productivity. Given the number of categories (groups) considered for each character, (age = 4, experience = 4, extension course = 2 and agricultural dep. Contacts = 2), there are 64 possible combinations to be considered as plots. Since the sample size is 82, some plots are empty; but those plots with irrigation water productivity and frequency are shown in Table 41. Farmers who have between 60 and 75 years of age, with more then 30 years of experience, who do not attend extension education courses, but have contact with the agricultural department at least once a year achieve highest irrigation productivity. As indicated, there are only two farmers in the sample with the above characteristics.

On the other hand, least efficient farmers are 20 - 40 years old, with less then 10 years of experience, who do neither attend extension education courses nor contact the agricultural department. There are only two farmers in the sample with such characteristics. As shown in table 41, a majority of farmers are between 40 to 65 years old and have between 20 to 30 years of experience without taking any extension education course or contacting agricultural department for help or consultation.

Economic factors affecting the sustainable use of irrigation water may be classified into two main groups. At the micro-level, factors such as farmer's access to modern production inputs, crop insurance, cash or operating capital, etc. can be mentioned. At the macro-level, inflation and price levels, price policy and input subsidies, are likely to affect irrigation water use by the farmers.

In this study, the effects of factors such as access to credit, crop insurance, and access to production inputs on irrigation water management were studied. For this purpose, farmers were classified into two groups. One group of farmers use credit, insure their crop and have easy access to inputs. The other group has no access to credit and insurance, and faces difficulty in buying or accessing needed inputs. The correlation coefficient between the above factors and over-irrigation is shown (Table 42).

As indicated in Table 42, of the three factors considered, only crop insurance is significantly associated with over-irrigation. In other words, farmers who have insured their crops against the risk factors are likely to use irrigation water more efficiently than others. On the other hand, as shown in table 43, irrigation water productivity differences between the two groups of farmers is not statistically significant.

Since the insurance variable is non-parametric, analysis of variance was performed between two groups (0, 1) in relation to over-irrigation. Results indicated that there is no significant difference between the two groups of farmers with respect to the extent of over-irrigation.

All farmers included in the sample are nearly homogenous with respect to physical factors such as irrigation technology, agroclimate and timing of irrigation. Hence, in this analysis physical factors which vary among sample farmers, such as cropping patterns, number of land parcels, and tillage operations were considered. Table 44 shows the degree of association between these factors and over-irrigation. Only tillage operation is significantly associated with over-irrigation. That is, decreasing the number of tillage is likely to improve water use efficiency.

Socioeconomic factors considered to be related to irrigation management include the water use practices of neighbors, family size, the number of dependent family members, use of family labor, off farm income, and income of employed family members. In the case of the first factor, farmers were classified in to two groups, those who are influenced by the water use practices of their neighbors, and those who are not influenced. Values of 0 and 1 were assigned to the first and second group, receptively. Correlation coefficients between socioeconomic factors and over-irrigation is shown in Table 45.

Of the five socioeconomic factors considered, therefore, farmers are only influenced by the water use behavior of their neighbors. In other words, farmers in the region are competing in the use of ground water resources. They are not concerned with sustainable use of ground water resources in the region. Here, we can observe a typical case of the “Tragedy of Commons,” resulting from uncontrolled ground water pumpage. In competing for the use of ground water in the Sarvestan plain, farmers are going deeper, using more power and energy. In addition to the increasing cost of energy and fixed cost of increasing depth of tube wells, ground water is becoming saline, adversely affecting the yield of wheat, a major staple crop in the region. If this trend continues, wheat is expected to be omitted from the cropping patterns in the plain. While correlation coefficient between the use of family labor and over-irrigation is not significant, its sign indicates that using more family labor may result in better control over the use of irrigation water.

Institutional factors such as water rights and law enforcement may also affect the sustainable use of ground water resources. In this study, for farmers who believe that lack of law enforcement leads to over-irrigation, a value of one was assigned, whereas zero was used for those who believe otherwise. Correlations between institutional factors and over-irrigation are shown in Table 46.

The finding indicates that farmers who consider over pumping a major cause of ground water depletion in the region are using irrigation water more efficiently. This is a positive attitude which should be rewarded. On the other hand, those who violate the laws and regulations governing the use of ground water should be penalized. In the case of water rights, the majority of farmers (about 80 percent) own tube wells and pumps. Only 20 percent of farmers buy irrigation water. As shown in table 46, correlation between water rights and over-irrigation is positive and significant. This indicates that over-irrigation is more prevalent among the farmers who own irrigation system.

To determine the combination of factors resulting in highest irrigation water productivity, following steps were taken:

1. From each characteristic type, one factor with a significant relation to the over-irrigation problem was selected. Factors to be considered include age (for personal factors), crop insurance (for economic factors), number of tillage (for physical factors), neighbors' water use behavior (for social factors), and water rights (for institutional factors).
2. 2. Possible combinations of these factors were estimated and the frequency of samples in each plot were determined. Plots with the highest average and marginal productivities of irrigation were considered optimal factor combinations, or the requisite combination for achieving the best results. The ranking of sample plots according to the productivity of irrigation water are shown in Table 47.

As shown in Table 47, the highest level of irrigation water productivity belongs to the farmers in age group between 60 to 75, who have insured their crop, tilled their soil more than once, own irrigation facilities, and refer to agricultural service centers at least once a year to consult with agricultural experts. They also believe that the ground water pumping behavior of neighbors influence the extraction of ground water by others. Only three farmers in the sample posses the above characteristics, achieving an irrigation water productivity level of about 0.52 kg of wheat per cubic meter of water.

As indicated in the above table, the most frequent character combination includes farmers who are in the age group from 40 to 60 years, who have not insured their crops and have tilled their land more than once. They own their irrigation water facilities and believe that neighbors pumping behavior affect the water using practices of others. This group of farmers however, do not contact agricultural service centers for consultation.

In comparison it is shown that the only difference between the two groups of farmers is in their contact with agricultural service centers. That is, farmers who seek the advice of agricultural experts are likely to gain higher productivity with respect to irrigation water applied to fields.

To determine farmers' knowledge of ground water characteristics and sustainability, they were asked to name some important factors contributing to declining ground water table in the region. The answers given by respondents are represented in Table 48.

According to farmers' perception of sustainability, following factors are contributing to unsustainable use of ground water. They are mentioned in the ordered of importance.

As shown in Table 49, most farmers believe that poor performance regulation and enforcement is the main cause of groundwater overdraft in the region. Shortage of capital is another problem facing farmers. This problem can be resolved by providing easy credit and assisting farmers in adopting water saving methods of irrigation, thereby easing pressure on ground water resources in the plain. As indicated by 19.2 percent of farmers, low income is forcing them to increase their cropping area to cover their living expenses and production costs, leading to over-extraction of ground water.

According to the farmers view, following policy measures should be adopted by the government to achieve groundwater conservation in the region:

As indicated, 29.2 percent of farmers believe that crop insurance, especially during drought periods, is a positive measure designed to reduce the risk of crop failure. Providing technical assistance for the operation and maintenance of irrigation systems and educating farmers in the use of more efficient pumping and the proper operation and maintenance of pumps and motors are also essential measures for promoting sustainable ground water management.

Most farmers believe that ground water pumping in the plain can only be controlled by regulating the investment in irrigation systems (tube wells and pumps) and promoting the impartial and committed enforcement the rules governing ground water extraction. They also believe that the agricultural extension service should be responsible for educating farmers in sustainable irrigation management. In addition, by encouraging farmers to visit farms facing problems of soil salinity and declining water tables, or water logging, they become more aware of the consequences of unsustainable ground water management.

Water users' knowledge of resource characteristics is essential for successful implementation of conservation measures. In order to test their knowledge, water users were asked to answer following questions:

1. How is the ground water aquifer recharged?
2. What does "unsustainable use of ground water" mean?

Their answers to the above questions are presented in Table 51.

Most farmers believe that during the rainy season they will not face the problem of a declining water table and water shortage. Only 6 percent of farmers could not answer the first question. Interestingly, the latter group were all illiterate. As shown in Table 51, about 68 percent of respondents believe that unauthorized use of groundwater and uncontrolled pumping is the cause of groundwater depletion in the plain. Twenty-one percent of farmers believe that primitive (inefficient) methods of irrigation are contributing to the over-extraction of water and depletion of the aquifer. It should be noted that none of the respondents were aware and concerned about the long-run consequences of the current rate of ground water use. Hence, extension education should close the existing knowledge gap with respect to the conservation and sustainable use of ground water resources.

An important finding of the field survey and informal conversations with the farmers is that their planning horizon is extremely short. Therefore, we cannot expect investment in water conservation without government technical and financial assistance. In addition, water users' participation in long-run conservation programs requires a combination of personal, physical, socioeconomic and institutional environmental features favorable to participatory management.

A first step towards such institutional reform is the establishment of a water users association to help address some of the problems of enforcement.

Farmers in both surface and groundwater irrigation projects consider law enforcement as a common problem in the use of irrigation water. In addition, corruption, cheating and discriminatory practices have seriously weakened the trust and credibility of irrigation department officials in charge of water allocation and distribution in Dorudzan irrigation project.

Finally, avoiding the so-called prisoner's dilemma and free-riding problem in the use of irrigation water requires conditions in which a group of farmers voluntarily subscribe to rules restricting access to irrigation water. Imposing penalties against rule violation may lead to the socially desirable outcome in developed countries. Conditions in much of the developing world, however, mean that legal mechanisms and government authority are simply not powerful enough to make a sufficiently plausible threat across myriad of micro-situations.

In some situations, creating trust and an ethic of mutual obligation between farmers and irrigation officials is likely to be a more cost-effective method of avoiding free rider problems than relying on a calculus of punishment. The question of how to stop farmers from stealing or offering bribes for more than their share of water translates into the question of how to enhance the legitimate authority of the irrigation staff. Legitimacy depends on farmers' judgments regarding the competence and trustworthiness of the staff (Wadi, 1988).

References

Berbel, J. J. and A. Gomez-Limon. 2000. "The impact of water pricing policy in Spain : An analysis of three irrigated areas." *Agricultural Management* 43: 219-238.

Casswell, M. and D. Zilberman. 1985. "The choice of irrigation technologies in California." *American Journal of Agricultural Economics* 67: 224-234.

__________. 1986. "The effect of well depth and land quality on the choice of irrigation technology." *American Journal of Agricultural Economics* 68 : 798-811.

Dinar, A. and D. Yaron. 1992. "Adoption and abandonment of irrigation technologies." *Agricultural Economics* 6: 315-332.

Goodger, W.J., R.Ruppanner, Slenning, B.D., and J.E. Kushman. 1984. "An approach to scoring management on large scale Dairies." *Journal of Dairy Sciences* 67: 675-685.

Meeusen,W. and J. Van Den Broek. 1997. " Efficiency estimation from Cobb-Douglas production Function with composed error." *International Economic Review* 18:437-444.

Rougoor, C. W., G. Trip, R. B. M. Huirne, and J. A. Renkema. 1998. "How to define and study farmersmanagement capacity : Theory and use in agricultural economics." *Agricultural Economics* 18:261 272.

Wade, R. 1998. "The Management of Irrigation System: How to Evoke Trust and Avoid Prisoner's Dilemma." *World Development* 16: 489-500.

Zilberman, D., M. Khanna, and L. Liper. 1997. "Economics of New Technologies for Sustainable Agriculture." *Australian Journal of Agricultural and Resource Economics* 41: 63-80.

Figure 1: Management Performance in Relation to Environmental and Personal Aspects of Managers

	ENVIRONMENT		
INSTITUTIONAL			SOCIAL
	Personal Aspects of Managers:	Motivation Abilities Biography	
	?		
	Decision-Making Process	Planning Implementation Control	
	?		
	Technical and Biological Processes		
	?		
	Farm Results	Technical efficiency Pricing efficiency Economic efficiency Sustainability	
PHYSICAL			ECONOMIC

Table 1: Factors Affecting the Sustainable Use of Irrigation Water

Category	Factors
Personal factors	Age
	Experience
	Formal education
	Extension training classes
	Contact with Agricultural Department staff
	Index of management ability
Economic factors	Agricultural credit
	Agricultural insurance
	Off-farm income
	Price elasticity
	Access to production input
Physical factors	Cropping patters
	Number of land parcels
	Tillage practices
Social factors	Consumption behavior of neighbours
	Number of family members
	Dependency ratio
	Use of family labor
Institutional factors	Land tenure
	Water rights
	Property rights
	Law and regulation enforcement

Table 2: Average Wheat Inputs and Outputs in Dorudzan

Input/Output	Mean	Maximum	Minimum	Standard Deviation
Output (tons)	19.54	50	3	11.17
Crop area (ha)	3.31	7	.06	1.74
Irrigation water (m^3)	26535	75000	5000	14949
Labor(man-days/ha)	36.50	85	5	19.56
Fertilizer (Kg)	592	-	-	1290
Machinery cost (Rials*)	100839	250000	100	501416

Notes: *Official exchange rate is 1750 Rials = 1 US dollar.

Table 3: Biographic Information of Sample Farmers

Variable	Mean	Maximum	Minimum	Standard Deviation
Education level (yr.)	5.21	12	0	3.99
Experience (yr.)	28.19	55	6	10.6
Extension education*	0.55	1	0	0.5
Age (yr.)	46	68	25	10

Notes: *Extension education is considered to be a dummy variable with values 0 for no education and 1 for education.

Table 4: Farmer Demand for Irrigation Water

Water Price (Rials)	Spring consumption (m^3)	Summer consumption (m^3)	Autumn consumption (m^3)	Seasonal consumption (m^3)
0	16205	50527	6605	73337
100	16205	50527	6605	73337
600	16230	50442	6558	73258
800	16230	50442	6558	73258

Table 5: Effect of Fertilizer Price on the Use of Fertilizer and Irrigation Water

Price (Rials/Kg)	Fertilizer demand (Kg/ha)	Irrigation water demand (m^3)
3500	498.4	7067.4
4500	366.8	6614.4
6000	258.2	6131.6
7000	213.9	5885.4
8000	181.8	5685.0
9500	147.5	5432.0
10000	138.4	5359.3

Table 6: Regression Results of Factors Affecting Irrigation Productivity

Variable	APw	MPw
Intercept	634.2 (2.79)*	160.6 (2.79)*
Size	-68.1 (-2.08)**	-17.2 (-2.08)**
Age	-0.014 (-0.095)	-0.015 (-0.095)
Education	0.107 (0.694)	0.11 (0.69)
Experience	-0.063 (-0.405)	0.063 (0.405)
Extension	0.125 (0.952)	0.13 (0.96)
R^2	0.67	0.067
F	4.33	4.33

Table 7: Correlation between Irrigation Productivity and Personal Factors

Variable	APw	MPw
Age	-0.176 (0.17)	-0.176 (0.17)
Education	0.219 (0.09)***	0.22 (0.09)***
Experience	-0.21 (0.10)***	0.21 (0.10)**
Size	-0.259 (0.04)**	-0.25 (0.04)**
Extension	0.12 (0.33)	0.13 (0.33)

Notes: ** Significant at 5%

*** Significant at 10%

Table 8: Regression Results of Personal Factors Affecting the Ratio of Crop Water Requirements to Applied Water

Variable	Coefficient	t	Probability level
Intercept	0.43	1.37	0.18
Age	0.014	2.67	0.009*
Education	0.113	1.86	0.067***
Size	0.043	2.65	0.79
Experience	-0.31	-0.84	0.40
Extension	0.12	0.97	0.53

Table 9: Irrigation Water Productivity in Relation to Social Factors

Factor	Group	mpw	Apw
No. of dependents	≤ 2	0.054	0.77
	3-4	0.056	0.80
	>4	0.061	0.87
Family size	≤ 3	0.047	0.67
	3-5	0.063	0.90
	5-8	0.054	0.77
	>8	0.052	0.74

Table 10: Correlation Coefficients and ANOVA

Factor	Correlation Coeff.	Significance level	F-ratio	F-probability
Dependency	0.04	0.68	0.08	0.91
Size	0.04	0.71	0.77	0.51

Table 11: Irrigation Water Productivity in Relation to Economic Factors

Factor	Group	Mpw	Apw
Farm income	≤ 6 m. Rials	0.052	0.74
	6-12 m. Rials	0.052	0.74
	13-20 m. Rials	0.054	0.77
	>20 m. Rials	0.068	0.97
Credit	0	0.054	0.77
	1	0.057	0.81
Insurance	0	0.54	0.77
	1	0.57	0.81

Table 12: Correlation Coefficient and ANOVA

Factors	Correlation Coeff.	Probability level	F-ratio	F-probability
Farm income	0.16	0.15	1.05	0.37
Crop insurance	0.13	0.26	0.04	0.21
Credit	0.05	0.64	0.21	0.64

Table 13: Relation between Irrigation Productivity and Physical Factors

Factor	Group	Mpw	Apw
Size of land holding	≤ 4 ha.	0.07	0.86
	4-8 ha.	0.05	0.71
	8-12 ha.	0.04	0.57
Number of tillage	3	0.057	0.81
	4	0.053	0.76
	5	0.051	0.73

Table 14: Correlation Coefficient and ANOVA

Factor	Correlation Coeff.	Probability level	F-ratio	F-probability
Size of holding	-0.21	0.087**	2.44	0.07
Number of tillage	0.04	0.70	0.27	0.60
Fallow area	0.037	0.78	0.41	0.50
No. of land parcels	0.13	0.047*	1.94	0.05

Notes: * significant at 5%

** significant at 10%

Table 15: Marginal and Average Productivities of Irrigation in Relation to Institutional Factors

Factor	Group	Mpw	Apw
Water rights	0	0.042	0.60
	1	0.041	0.59
Land tenure system	0	0.049	0.70
	1	0.047	0.67

Notes: 0 = buys or rents

1 = owns

Table 16: Correlation Coefficients and ANOVA

Factor	Group	Correlation Coeff.	Probability level	F-ratio	F- probability
Water rights	0	0.04	0.78	0.67	0.51
	1	0.02	0.86	0.62	0.62

Table 17: Relation Between Pe rsonal Managerial Factors and Irrigation Overuse

Factor	Group	Overuse (m^3)	Correlation Coeff.	Prob. Level	F-ratio	F-probability
Age	< 30	2880	-0.06	0.14	0.38	0.76
	30-44	4238				
	45-60	2752				
	> 60	2732				
Experience	≤ 15	4292	0.07	0.54	0.29	0.82
	15-30	3174				
	30-40	2374				
	≥ 40	3163				
Formal education	0	2598	-0.1	0.41	1.08	0.37
	1	5092				
	2	2758				
	3	1795				
	4	1890				
Extension education	0	3355	0.06	0.62	0.82	0.36
	1	6300				

Table 18: Regression Results for Factors Affecting Irrigation Water Overuse

Variable	Coefficient	Significance level
Constant	1.5	0.00
Formal education	-0.032	0.00
Extension education	0.067	0.103
Experience	0.0054	0.126
Age	0.0047	0.18

Notes: Sig. F = 0.00

D.W.= 2.07

R^2= 0.96

Table 19: Relations between Social Factors and Irrigation Water Overuse

Factor	Group	Overuse (m^3)	Correlation Coeff.	Prob. Level	F-ratio	F-prob.
No. of dependent members	≤ 2	2620	0.15	0.21	1.27	0.28
	2-4	4855				
	>4	2610				
No. of family members	≤ 3	2644	0.02	0.84	0.11	0.95
	3-5	3161				
	5-8	3733				
	>8	3018				

Table 20: Relation Between Economic Factors and Irrigation Water Overuse

Factor	Group	Over-use (m^3)	Correlation Coeff.	Prob. level	F-ratio	F-probability
Income	≤ 6 m. Rials	5540	-0.22	0.06*	1.96	0.08
	6-12 m. Rials	4209				
	13-20 m. Rials	2796				
	>20 m. Rials	1173				
Insurance	0	2709	0.17	0.14	1.71	0.21
	1	4844				
Agricultural credit	0	3247	0.01	0.92	0.009	0.92
	1	3375				

Table 21: Relation between Physical Factors and Irrigation Water Over-use

Factor	Group	Water Over-use	Correlation Coeff.	Prob. level	F-Ratio	F-Prob.
Size	=4 ha.	1827	0.38*	0.001	4.9	0.005
	4-8 ha.	2715				
	8-12 ha.	8235				
	>12 ha.	7695				
Tillage	3	3229	0.003	0.97	0.02	0.88
	4	3425				
	5	1440				
Fallow area	-	-	0.08	0.63	0.11	0.99
Land parcels	-	-	0.07	0.50	1.04	0.42

Notes: - Fallow area and land parcels were not grouped.
* Significant at 1%.

Table 22: Relation between Institutional Factors and Over-Irrigation

Factor	Group	Over-use (m^3)	Correlation Coeff.	Prob. level	F-ratio	F-prob.
Water rights	0	3120	0.07	0.66	1.02	0.50
	1	3306				
Land tenure	0	4017	0.01	0.70	0.97	0.60
	1	4212				

Notes: 0: Those who buy irrigation water and rent the land.

: Those holding water rights and own land.

Table 23: Relation between Management Ability and Over-Irrigation

Factor	Correlation	Probability	F-ratio	F-probability
Management ability	-0.08	0.50	0.73	0.82

Table 24: Technical Efficiency of Sample Farmers

Group	Number	Percent	Technical efficiency	F
Ratio <1	20	35	0.42	3.5
Ratio >1	37	65	0.49	P(0.06)**

Notes: ** Significant at 5%

Table 25: Regression Results

Variable	dx12	dx1
Constant	0.77	5160.5
	(4.2)*	(2.1)**
Technical efficiency	92	-10855.8
	(2.5)*	(-2.2)**
R^2	0.10	0.085
F	6.1	4.9

Notes: * significant at 1%

** significant at 5%

dx1 = difference between required and applied water.

Table 26: Farmers' Willingness to Participate in the Management of Irrigation Projects

Response	Unwilling (0)	Low (1)	Med. (2)	High (3)	Very high (4)	Average (2)
No. of observations	0	12	8	22	12	2.53
Percent	0	21	14	39	21	

Table 27: Water Users' Evaluation of Water Organization Performance

Case Score	Degree of Satisfaction					
	Unsatisfied	**Somewhat satisfied**	**Relatively satisfied**	**Satisfied**	**Very satisfied**	**Average Score**
	0	1	2	3	4	2
No. of observations	45	12	3	0	0	0.3
Percent	75	20	5	0	0	

Table 28: Farmers' Response to Questions Regarding Irrigation Management

Issues and questions	Yes		No	
	Number	*Percent*	*Number*	*Percent*
Cheating and violation of water regulation	48	80	12	20
Knowledge of participatory management	17	28	43	72
Willingness to participate	54	90	6	10
Satisfied with water distribution	58	97	2	3
Attending extension education classes	4	7	56	93
Willingness to pay water charges if delivered on time	52	87	8	13
Willingness to sell water rights	26	43	34	57
Willingness to buy water rights	52	87	8	13
Satified with the performance of water authority	6	10	54	90

Table 29: Major Causes of Unsustainable Water Use

Factor	Percent of Respondents
Problems enforcing rules and regulations	62.5
Shortage of capital	45.8
Low income	22.2
High production costs	12.5
Family size/population pressure	12.5
Small holdings	9.7
Attenuated and/or insecure property rights	8.3
Inflation	5.5

Table 30: Policies Aiding Sustainable Water Use

Policy Measure	Percent of Respondents
Secure property rights	44.5
Easy credit	40.2
Extension education in sustainable irrigation	33.3
Guaranteed prices	22.6
Crop insurance	19.4
Technical assistance	16.6
Marketing facilities	9.7

Table 31: Factors Contributing to Farmers' Economic Welfare

Factor	Percent of Respondents
Input subsidy	54.3
Marketing facilities	11.4
Fair prices	8.6
Social services	8.6
Effective agricultural service centers	5.7
Sufficient land	5.7
Other	5.7

Table 32: Cropping Patterns Using Deficit Irrigation

Crop	Hectares
Wheat	8190
Barley	1512
Alfalfa	630
Sugarbeet	630
Cotton	630
Corn	2160
Fallow	3150
Total	**16904**

Source: Parab Consulting Engineers (1990)

Table 33: Crop Water Requirements per Hectare

Crop	Water Requirement (m^3)
Wheat	8944
Barley	4799
Sugarbeet	22150
Alfalfa	35036
Cotton	20354
Corn	11949
Potato	7065
Melon	14294
Tomato	17686
Tobacco	4000

Table 34: Distribution of Sampled Farmers According to Personal and Environmental Factors

Factor	Group	Frequency	Percent
Family size	=2	3	3.7
	2-5	29	35.4
	5-8	32	39
	>8	18	22
Age	≤ 40	13	15.9
	40-60	48	58.5
	60-75	16	18.3
	>75	6	7.3
Experience	≤ 10	13	12.2
	10-20	18	22
	20-30	18	22
	> 30	36	43.9
Formal education	≤ 5	42	51.2
	5-9	14	17.1
	9-12	16	19.5
	> 12	10	12.2
Extension course(s) attended	≤ 2	81	97.8
	2-5	2	2.2
	5	0	0
Water rights	0	7	8.5
	1	75	91.5
Water using behaviour of neighbours	0	17	20.7
	1	65	79.3
Number of tillage	1	1	1.2
	2	71	86.6
	3	10	12.2
No. of land parcels	1	52	63.4
	2	25	30.5
	≥ 3	5	6.1
Crop diversification	0	29	35.4
	1	53	64.6
Tractor ownership	0	60	72.2
	1	23	27.8
Credit	0	13	15.6
	1	73	84.4
Land leveling	0	68	81.9
	1	15	18.1
Crop insurance	0	71	85.3
	1	11	14.7

Table 35: Quantities of Inputs Used in Wheat Production

Input	Min.	Max.	Mean	Standard Dev.
Seed	160 kg	186	175	6.52
Spray	0.0 Liter	1.5	0.82	0.33
Nitrogen Fert.	100kg	400	331	0.679
Family labor(Man days)	1.0	21	10	5.02
Wage labor	5	22	15.89	4
Water(Cubic meter)	9133	11598	9998	620.7
Phosphate	100	400	296	32.95
Acreage	5	26	12.59	4.95
Over-irrigation (m^3)	59	1631	932	455

Table 36: Variable Costs of Irrigated Wheat per Hectare

Input	Cost (Rials)	Percent
Spray	73460	4.5
Labor	148310	9.0
Seed	181800	11.0
Fertilizer	190650	11.5
Machinery	389670	24.0
Water	649882	40.0

Table 37: Correlation between Over-Irrigation and Personal Management Factors

Factor	Mean	Coefficient	Probability	Standard Dev.
Age	54.8	0.2696	0.014***	12.65
Experience	31.7	0.2218	0.044**	17.41
Education	6.74	-0.15	0.175	5.68
Extension education	0.241	-0.205	0.052*	0.59
Agricultural Dept. service	1.55	-0.7512	0.001***	2.00

Notes: * significant at 10%.

** significant at 5%.

*** significant at1%.

Table 38: Correlation between Management Ability and Irrigation Water Productivity

Variable	Mean	Coefficient	Probability	Standard Dev.
Average product	0.4417	0.062	0.575	0.0982
Marginal product	0.0167	0.0627	0.575	0.0036

Table 39: ANOVA for Personal Factors and Over-Irrigation

Factor	Group	Frequency	F-ratio	F-probability
Age	<40 years	13	3.2946	0.0248
	40-60	48		
	60-75	15		
	>75	6		
Experience	< 10 years	10	0.9996	0.3976
	10-20	18		
	20-30	18		
	>30	36		
Formal education	< 5 years	42	1.245	0.299
	5-9	14		
	9-12	16		
	>12	10		
Extension education	0	81	0.899	0.345
	1	1		

Table 40: Irrigation Water Productivity in Relation to Personal Factors

Factor	Group	Frequency	Mpw	Apw
Age	< 40 yr.	13	0.0156	0.4218
	40-65 yr.	48	0.0163	0.4407
	65-75 yr.	15	0.0161	0.4363
	> 75 yr.	6	0.0187	0.5055
Experience	< 10 yr.	10	0.0146	0.39.42
	10-20 yr.	18	0.0162	0.4373
	20-30 yr.	18	0.0164	0.4432
	> 30 yr.	36	0.0169	0.4563
Formal Education	> 5 yr.	42	0.0168	0.4534
	5-9 yr.	14	0.01777	0.4774
	9-12 yr.	16	0.0157	0.4241
	> 12 yr.	10	0.0137	0.3704
Extension	0	81	0.0164	0.4424
Courses	1	1	0.0140	0.3790

Table 41: Ranking Personal Character Combinations for Farm Operators According to Irrigation Water Productivity

Age group	Experience	Extension	Ag. Dept. contact	Apw	Frequency
3	4	0	0	0.55	2
4	4	0	0	0.517	4
4	3	1	1	0.4831	2
3	3	0	0	0.4755	1
2	3	0	0	0.4657	5
2	4	0	0	0.4653	4
2	2	0	0	0.4536	4
2	4	0	0	0.4532	4
3	4	1	1	0.4051	13
1	2	0	0	0.4516	1
1	2	1	1	0.4501	3
2	2	0	0	0.4379	1
2	3	0	0	0.4311	4
3	2	0	0	0.4305	12
2	1	1	1	0.4286	1
1	2	1	1	0.4209	1
1	1	0	0	0.4258	2
3	4	0	0	0.4133	2
2	1	0	1	0.4042	10
1	1	0	1	0.3878	3
2	1	0	0	0.346	2

Table 42: Correlation between Economic Factors and Over-Irrigation

Factor	Mean	Correlation Coeff.	Probability level	Standard dev.
Credit	0.843	-0.0895	0.421	0.366
Insurance	0.133	-0.2039	0.064	0.341
Access to inputs	0.621	0.219	0.615	0.215

Table 43: Productivity of Irrigation Water in Relation to Crop Insurance

Group	Frequency	Average product	Marginal product
Insured	11	0.4272	0.0158
Not insured	71	0.4439	0.0164

Table 44: Correlation between Physical Factors and Over-Irrigation

Variable	Mean	Correlation Coeff.	Prob. level	Standard dev.
Cropping patterns	0.651	0.1124	0.312	0.48
No. of parcels	1.422	-0.0413	0.711	0.607
No. of tillage	2.108	0.1993	0.071*	0.35

Notes: * significant at 10%

Table 45: Relation between Socioeconomic Factors and Over-Irrigation

Variable	Mean	Correlation Coeff.	Prob. level	Standard dev.
Neighbors' irrigation practice	0.798	0.568	0.001***	0.406
Dependency ratio	6.45	0.0311	0.780	2.339
Use of family labor	10.816	-0.1158	0.297	5.029
Off-farm income	11566.36	0.0184	0.899	25874.08
Income of family members	17110.05	0.009	0.714	32113.11

Notes: *** Significant at 1%.

Table 46: Relation between Institutional Factors and Over-Irrigation

Variable	Mean	Correlation Coeff.	Prob. level	Standard dev.
Lack of law enforcement	0.734	0.293	0.0471**	0.593
Water rights	0.916	0.3285	0.002***	0.28

Notes: ** significant at 5%

*** significant at 1%

Table 47: Ranking of Management Factors (Characteristics) According to Irrigation Water Productivity

Age	Insurance	Tillage	Water Rights	Ag. Dept. Contact	Neighbor Behavior	Apw	Mpw	Freq.
3	0	1	1	1	1	0.5196	0.0190	3
4	0	1	1	0	1	0.517	0.0190	4
4	0	1	1	1	1	0.4831	0.0179	2
3	1	1	1	0	1	0.4772	0.0177	1
2	0	1	0	1	0	0.4677	0.0173	5
1	1	1	1	1	1	0.4628	0.0171	1
2	1	1	1	1	1	0.4439	0.0164	4
2	0	1	1	0	1	0.4390	0.0162	30
3	0	1	1	0	0	0.4377	0.0162	3
1	0	1	1	1	1	0.4369	0.0162	2
1	0	1	1	0	1	0.4339	0.0161	4
2	0	1	1	1	1	0.4187	0.0155	5
3	0	1	1	0	1	0.4104	0.0150	9
3	1	1	1	1	0	0.4051	0.0149	1
2	1	1	1	1	0	0.4017	0.0143	1
1	1	1	1	0	1	0.3876	0.0140	2
1	1	1	1	1	0	0.3790	0.0140	3
2	1	1	1	0	1	0.3389	0.0125	2

Table 48: Farmers' Responses Regarding Causes of Declining Water Table

Factor	No. of farmers	Percent
Low rainfall	37	45.2
Expansion of cropland	13	15.8
Rate of extraction by others	32	39

Table 49: Factors Contributing to Over-Pumping in Sarvestan

Factor	Percent of respondents
Poor law enforcement	50.2
Low income	19.2
Shortage of capital	13.4
High production costs	8.5
Inflation	6
Population pressure (family size)	2.4

Table 50: Policy Measures to Promote Groundwater Conservation in Sarvestan

Policy measure	Percent of respondents
Crop insurance	29.2
Technical assistance	27.2
Guaranteed price	13.4
Easy credit	12
Extension service	9.7
Marketing service	8.5

Table 51: Water Users' Responses to Questions about Resource Characteristics

Question No.	Answer	No. of respondents	Percent
1	Rainfall	77	94
	Do not know	5	6
2	Digging unauthorized wells	56	68
	Electrifying irrigation	6	7
	pumps	17	21
	Wasting water	3	4
	Do not know		

I. Introduction

Growing population, improved lifestyle, and dwindling water supplies (both in terms of quantity and quality) in MENA countries have exacerbated the competition for scarce water resources. It is thus of great importance that existing water resources be allocated efficiently. For economically efficient allocation, the marginal benefit of water use should be equal across all users. a useful mean for achieving efficient water allocation is to put the right price tag on it. A variety of methods for pricing water have been developed. They differ in their goals, and implementation, the institution they require, and the information on which they are based. In this report, the economic principles and goals of irrigation water pricing are discussed first. Then, some of the more common pricing methods is described and their performance, in terms of efficiency, equity and sustainability are evaluated. A brief review of irrigation water pricing in Iran and some other MENA countries will be presented. An imperial analysis of the effect of price on the use of irrigation water is followed. Finally a pricing model is proposed and applied in an irrigation project in Iran.

II. Economics of Water Pricing

Water is an economic commodity having value in use and requiring resources for its development and allocation. If a resource is likely to become increasingly scarce, it is important to apportion its use in such a way as to obtain the maximum beneficial return to society. That is, the limited supply of water should be allocated by some means to the uses where it will be most productive. An effective way of achieving this goal is through the price mechanism . Water resources will then be shifted to their most productive use, provided it can be transferred between uses. The principal problem in pricing is to determine which costs should be recovered and from whom.

Theoretically, the efficiency goal of pricing requires that the price or willingness to pay for water equals the marginal cost of providing it. If price is greater than marginal cost, all of water supplied will not be demanded (excess capacity) and if it is less than marginal cost,

investment in the expansion of supply will not be economical. Only, when price equals marginal cost, irrigation efficiency would be achieved (total economic rent to society will be maximized).

It should be noted that, only a competitive water market results in equilibrium of supply and demand. In this situation, long-run marginal cost would be equal to marginal benefit. Since at equilibrium point, average cost of water supply equals marginal cost, under perfect competition, economic (efficiency) and financial (cost-recovery) goals of pricing would be attained simultaneously.

Economic basis of irrigation water pricing is willingness to pay of water users. In fact, willingness to pay is a measure of utility one derives from the use of water. Some uses of water such as drinking or residential, constitute a small fraction of total consumption, but have high value. Some competitive uses of water such as agricultural and industrial have lower values (price). Willingness to pay for these uses is much less than residential use. Hence, water management decision should focus on these uses. Information about the value of water in these uses can help management in making rational decision regarding the pricing and allocation of water resources. It should be noted that, willingness to pay in these uses is based on the contribution of water in the production process. In other words, water for agricultural and industrial uses is regarded as inputs to production process. As such the price the users of water are willing to pay depends on the benefits it generates. Hence, the upper limit for the price they can pay would be equal to the value of marginal product less the additional costs incurred for providing additional output. If the marginal benefit of water is greater than its costs (price) additional uses of water would result in greater total productivity of water. When the marginal benefit of water is less than its costs, a rational user avoids using it. As a result more water is available for more beneficial uses leading to increased efficiency of water.

According to production theory, the efficient price of water for existing irrigation schemes is the short-run marginal cost of providing it. The short-run marginal cost includes all variable cost associated with water supply to farms, but would exclude the sunk cost of past capital investment and the capital costs of infra structure maintenance. Different sets of prices would therefore be necessary to cover the difference in the marginal cost of supply among locations. However, in practice many factors preclude using this principle. First, given the existing data in many developing countries, the exact identification of marginal cost does not seem possible. For a given water supply system of fixed capacity, marginal delivery cost are usually low compared with the fixed costs, and average delivery costs continue to decrease up to the limit of capacity. As quantity demanded eventually exceeds capacity, marginal cost of supply increases because opportunities for inexpensive extension to the system capacity are exhausted. Hence, further expansion beyond this point should be carried out at the expense of the beneficiaries. Under-pricing relative to the full cost of water and delivery encourages excessive use of water. A move to full short-run cost recovery would therefore seem desirable. Short run cost recovery would include the capital costs of infra structure maintenance but exclude historical sunk cost.

For investment decisions, water should be valued at its long-run marginal cost. In other words, the beneficiaries of the capital expenditure on replacement should pay for it. If a replacement investment were determined to be economically feasible, existing holders of water entitlements should be given the option of taking up water rights at a "cost-recovery" price, which could include the replacement capital costs of the new works. Those not willing to pay the new charges should be free to sell their water entitlements to those users who are supplied through the new distribution systems. In summery, some simple rules of marginal cost pricing are:

1. If there is an excess capacity year around, main component of marginal cost is the operating cost of providing water. In this case, the costs of fixed facilities (sunk costs) should be ignored or the amortized cost of salvage value included as part of marginal cost.

2. If facilities must be expanded to meet a peak demand, marginal cost in peak period should include the fixed cost of the new facilities and the operating costs. Off-peak marginal cost and price should reflect only the operating cost of providing additional service in the slack periods.

3. Marginal cost pricing should be related to the elasticity of demand for water. When price elasticity is very low, setting the price away from the marginal cost has very little effect on the quantity used and social welfare. In the vary short run and at lower water prices, the elasticity of demand for water is likely to be low. However, as the prices rise and the length of run increases the price elasticity is likely to increase.

4. When average cost of supply is decreasing, marginal cost pricing may not provide sufficient revenue to cover the full cost of water supply. On the other hand, average or full-cost pricing may limit the optimal use of water. To resolve this problem following measures could be used:

a) Discriminate pricing. Since the implementation of discriminatory pricing in agriculture is not possible (difficulty of classifying water users according to benefit received) , in practice, instead of farmers, different uses (industrial VS. Agricultural uses) are discriminated.

b) Designing a system of subsidy. In this solution, a subsidy equal to the difference between marginal and average cost of supply is paid. In public irrigation schemes, government assumes this responsibility.

c) A third solution to recover the deficit, while using marginal cost pricing is to charge a fixed amount equal to the deficit of (P2 – P1) Q1 (see Fig 1.) in the form of tax or capacity sharing charge which is independent of the quantity used.

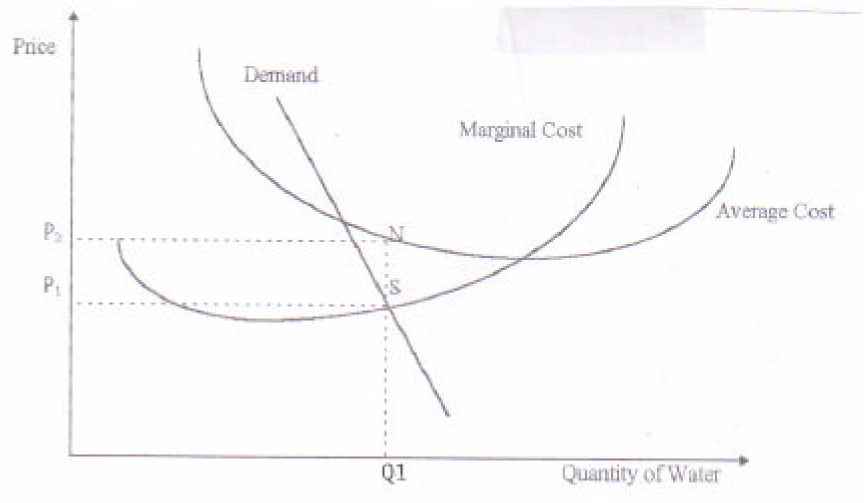

Fig.1

III. Goals of Pricing System

The main goals of irrigation water pricing are: equity, efficiency and sustainability. Equity consideration for water pricing may include some subgoals as follows:

Recovery of cost of irrigation project so that the money can be used in the operation and maintenance of irrigation system. Other goals might be to improve income distribution, to prevent the transfer of large economic gains, or to redistribute income and wealth from larger to smaller farmers. In many developing countries, food production is subsidized by reducing cost of production including irrigation water.

Efficiency is a major goal of water pricing. Efficiency in the allocation of irrigation water includes :

1) Allocation of a given supply of water among farmers, crops, regions and time periods so that to maximize the net contribution to production.

2) Provision of signals for optimum investment in new supply of water and irrigable lands.

3) Restriction of excessive use of water by some farmers, which can damage the lands of others.

As the value of water increases, it becomes economically viable to increase physical efficiency (the ratio of water used by crops to water diverted) by adopting improved methods of controlling, measuring and applying water and to design better systems of prices which will improve allocation efficiency. Allocation efficiency requires that, if marginal benefit is higher for one use than for another, total benefit of a given supply of irrigation water might be enhanced by allowing some water to be reallocated to the better opportunity. If it is possible to increase water supply at long-run marginal cost less than its marginal value product, then, such expansion should be made.

When marginal cost of water is high for small farmers (low income farmers), an alternative is to use a low initial fee for quotas plus a marginal charges for any units of water purchased in excess of assigned quota. Economic efficiency will also be increased if water is made transferable among users. Initial assignments or quotas should be based on historical water rights or on a minimal quotas of water per hectare that is thought to maximize net return per unit of water. The higher marginal prices charged for water purchase in excess of one's quota could be based on opportunity cost.

In the absence of distortions (taxes) or implementation costs (costs of collecting water fees, monitoring and enforcing quotas), an allocation which maximizes the total net benefit from the given supply of water is first-best or Pareto efficient. In the presence of implementation costs, allocation that maximizes the total benefits net of all costs (including implementation costs) is second-best efficient (Baumol and Bradford 1970).

When flows are uncertain, share or number of hours that farmers will receive water may be known, whereas the volume that will arrive is uncertain. Under this situation, farmers might be permitted to rent or buy share or hours of water from one another or from the government. The allocation of water among users could be highly efficient under such a system. Since all farmers have approximately the same marginal value for the last share purchased.

Studies are needed for the impact of alternative water pricing systems on irrigation efficiency, cost recovery and distribution of income.

Tsur and Dinar compared alternative irrigation water pricing based on the efficiency of irrigation (1997). The methodology and the findings of theses researchers are presented later in the report.

Even if, determination and implementation of efficient water price is possible, it may be in conflict with the equity goal of water pricing, because, water charges may be higher than some water users' (mainly low income farmers) ability to pay. On the other hand, if water charge is too low, water authority will have insufficient fund to cover operation and maintenance expenditures. In this situation the goal of providing reliable water supply will not be attained leading to decreased yields. Hence, pricing based on ability to pay is a policy which may be adopted by the governments for income redistribution purpose. In this case, the price of water for some farmers' group or some uses (notably agriculture), is much less than the cost of supply. The deficit would be financed from other sources such as from sale of electricity in multi-purpose projects.

As indicated, water pricing system may pursue different and conflicting goals. There are always trade-off among these goals. In any given period, some pricing goals may have priority

over other goals. Nevertheless, due to increasing the water scarcity, trend in irrigation water pricing will be in favor of achieving efficiency goal.

IV. Pricing and sustainability

Economic and financial viability are necessary conditions for sustainable irrigation management. Social marginal cost pricing is considered to be a necessary step toward insuring this goal (Auty and Brown 1977, Dubourg 1994). Social marginal cost, encompasses marginal supply cost, marginal users cost and marginal external costs.

Economically, if the full social cost of using a resource can be captured in its price, then, consumption based on this price can be regarded as "sustainable". Hence, the traditional concept of marginal cost pricing should be modified to produce the following rule:

The price of a unit of water should equal to its marginal social opportunity cost, comprising its, marginal cost of production, its marginal environmental cost, and its marginal user cost.

The marginal cost is the quantity of resources which must be diverted from some other valuable use to produce an extra unit of commodity in question. The cost of production should be interpreted more widely to include the impact on the environment. The true social cost of production are all those costs which result in a loss of welfare elsewhere.

In some cases the cost of drainage water disposal are becoming very high so the institution of incentives for the farmer to reduce drainage volumes and pay for their safe disposal are appropriate. As Dinar, et al. Study showed, adoption of water pricing policy to induce efficiency would be appropriate, even through it may be impossible to accurately set the fees to achieve the maximum efficiency (1989). It is worth remembering that in irrigation it is possible to have both positive and negative externalities. Positive externality, such as a useful return flow, means that irrigation water has a higher social value than the value to the individual farmer. Negative side effects, such as drainage problem, usually suggest restriction on wasteful usage upstream, or raising the water pric e to include social costs.

In some cases, it is possible to design pricing system to bring social and private costs move to into line. Fisher and Thrope (1990), have indicated that, in Australia many of the existing problems with irrigation salinity might be solved if farmers paid the correct price for water. Removal of any implicit subsidies in water prices would encourage the adoption of induced water conserving irrigation technologies and may result in sustainable irrigated agriculture. For example, Caswell, et al. (1990), have shown that in arid San Joaquin valley of California, early adoptors of water conserving irrigation technology are producers with higher water prices and more severe drainage problems.

In other cases a system of dual fees can be used to give farmers incentives to reduce excessive irrigation. Quotas for minimal amounts of water needed plus penalty charges for exceeding quotas could be used to reflect the external cost of damages created by excessive irrigation such as water logging and salt accumulation.

When the resources are non-renewable (like groundwater acquire or lake which is being used in excess of its recharge rate), any current use must reduce the amount of water available to use in future. The continued exploitation of acquiter, or lake must sometimes lead to exhaustion. Hence, use of the resource has an opportunity cost which is the cost of use forgone in the future. This cost is known as the use cost, or depletion premium. It is exactly the same concept as the depletion premium used in costing natural gas and petroleum. User cost depends on :

1) The rate of exploitation

2) Size of the stock

3) The cost and availability of substitute in the future, and

4) The rate at which future consumption is discounted.

Despite its importance, social marginal cost pricing is formidable to implement in practice. Hence, reliance on pricing alone is unlikely to ensure sustainable use of water in agriculture.

V. Alternative Methods for pricing irrigation water

Because water is renewable resource in public ownership and a water right system that legitimize its use, water supplies have been developed with no formal price structure other than costs recovery by suppliers. Nevertheless, with increasing scarcity, a useful means for achieving efficient water allocation is to put the right price tag on it. Consequently, a variety of methods of pricing water have been developed. They differ in their implementation, the institutions they require, and the information on which they are based.

A number of literature deals with irrigation water pricing methods (see for example, Gardener, et al. 1974; Griffin and Perru 1985; Pasad and Rao 1991; Sampath 1992; Seagraves and Easter 1983, and Tsur and Dinar 1997). The description of alternative methods for pricing irrigation water in this report mainly draw on Seagraves and Easter 1983; Sampath 1992 and Tsur and Dinar 1997.

Generally speaking irrigation water pricing are either based on benefits received or the cost of supplying water. A brief description of the more common pricing methods and their relative efficiency and equity performances are presented here:

The more common pricing methods are: Volumetric pricing, output and input pricing. Area pricing, two-part tariff pricing and water markets.

It should be noted that the feasible pricing method in each region is affected by the method of delivering water. Three methods of delivering water are Demand, Rotation and Contineus flow. World wide, in over 60 percent of cases, authorities charge for water on a per unit area bases; less than 15 percent use a combination of area and volumetric methods and about 25 percent of projects charge for water using volumetric methods (Tsur and Dinar 1997).

The demand system involves the delivery of water to the farms at times and quantities as requested by the water user. In this system volumetric pricing is feasible. In this case a uniform price for whole volume demanded or gradually increasing block rates are both feasible. Farmers also could pay a capacity charge for their share of the system capacity plus a volume charge on the metered water.

With the rotation system water is delivered to the user along a canal in turns according to some prearranged schedule. A practical way to charging farmers may be by the number of shares or the proportion of water they receive. This ties the usage with the price of water. But, often they are charged by hectares served or hectares of each crop times the estimated volume of water for that crop. In this case, water is simply a land tax or differential land tax for different crops.

In continues flow system water flows continually through canal and each farm is free to access to the water. In this system , it is not practical to measure the quantity of water used or to base charges on the volume of water delivered.

In continues flow system water availability decreases as one moves down canal toward the end of delivery system (Bromley, et al. 1980).

Decisions regarding the pricing system also depends on the value of water when it is low, it may not be worthwhile to measure it or levy charges. This could be true even if the cost of irrigation project is very high. Water pricing, therefore, becomes more practical either when the cost of measurement and administration is low or the value of water is high. New technology can reduce measurement costs, while greater farmer participation in water distribution can reduce administration costs.

Without appropriate control structure and trained staff, it is difficult to deliver water to farms at the time and the quantity needed. If water in not delivered in timely manner, it may be of little value to farmers and the price they are willing to pay is low.

A related issue is the ease of collecting water charges and taxes. This is because the farmers are either unhappy with the way water is delivered or lack of any effective collecting agency or mechanism in rural areas.

Government may decide that the easiest and lowest cost (administration) place to collect fees is in the sale of inputs (fertilizer) to farmers or purchase of output from farmers. For example, in Egypt, the government pays the farmers a price much below the world price for cotton. The difference is used to finance government projects such as irrigation.

Efficient use of irrigation water requires that the pricing method affect demand. The volumetric, output and two-part Tariff methods all satisfy this condition and can achieve efficiency. Volumetric pricing requires information on the volume of water used by each user. That is, it requires facilities to meter water. In the absence of water market, a central water authority or water user organization is required to set the price, monitor use, and collect fees. The implementation cost of this method of pricing is relatively high.

Two-part Tariff pricing methods involve a constant marginal price per unit of water purchased and a fixed annual (or admission charge) for the right to use the water. As indicated before, this method is practiced, in situations when a public utility produces with marginal cost below average cost and must cover total cost (Variable and fixed cost).

Output pricing methods charge farmers a water fee for each unit of output produced. Its advantage is that it does not need to measure individual water consumption, which is an expensive task particularly in developing countries. However, the measurement of output can be as expensive (or formidable) as that of water. Hence, output is rather a poor means for pricing water.

Area pricing, charges for water used per irrigated area and the kind of crop. This method of pricing irrigation water is easy to implement and administer and does not require water conveyance facilities to be metered. It needs only land-by-crop data or only farm size data. Simplicity and low implementation costs explain the popularity of this method.

In recent years, pricing based on market forces (supply and demand) are being used in some arid and semiarid regions. Water markets exist in different forms throughout the world. This may be formal or informal. In this system, the participants trade the right to purchase some quantities of water at a particular price during specific periods of time. Water markets are likely to provide incentives for water to flow from less productive to more productive uses. How ever to operate properly, a water market requires a well-defined structure of water rights, a clear rules for trading and enforcing these rights, a judicial body for resolving disputes, and a well developed conveyance system for transporting water to all participants.

Other methods of pricing irrigation water

A conventional methods of pricing in utility industries including water is full-cost beneficiary pricing. In this method, price of water is determined in such a way that, in addition to O & M costs, all or part of capital cost of irrigation schemes are recovered. Some economists advocate using opportunity cost in determining the price of irrigation water. Accordingly water rate should be set at a level to recover the real cost of investment. The real investment cost is considered to be the return in best alternative.

Benefit based pricing is an alternative system of pricing irrigation water. Benefit pricing is an attempt to recover all or part of the economic rent or surplus generated by the irrigation project.

Gardener, et al. (1974), explain several ways that estimated benefits can be used to assign different prices to different regions. Net benefit per unit of water provides upper limit on prices, since they reflect the maximum amount a farmer could be willing to pay. Net benefit is estimated as the difference in net income, with and without irrigation.

VI. Comparison of alternative Pricing methods

In comparing the relative performance of various pricing methods vis-à-vis efficiency criterion, all costs involved in delivering irrigation water (including implementation costs) should be considered. Hence, the rule of marginal cost pricing in the presence of implementation costs would be:

Water price = Marginal delivery costs + Marginal implementation costs

The implementation costs include: Costs of maintaining and reading water meters, administrating and collecting of water fees, and resolving disputes with farmers.

Hence, if the implementation costs are not ignored, volumetric pricing may not be superior to other pricing methods such as those on output or area-based fees. Nevertheless, only in the absence of implementation costs, volumetric prices can achieve the first-best (efficiency) outcome. Without implementation costs, output pricing method (Pricing water by imposing direct or indirect tax on output), is inferior to volumetric pricing.

Area- based pricing does not affect input and output decisions but, it can affect the choice of crop, if per hectare fee varies with crop (Tsur and Dinar 1997). Hence, this method may result in in-efficient water allocation. But since implementation costs of area- based pricing is lower than both volumetric or output pricing, it could generate a higher social benefit. For example, Tsur and Dinar (1997), found that, with a moderate implementation costs of 10 percent (of each dollar raised as water fees), plus the cost of installing a water meters, area-based pricing with no implementation costs, is superior to volumetric pricing. In addition, their study indicated that, water pricing methods are more pronounced through their effects on the cropping patterns than through their effects on water demand for a given crop.

As the Tsur and Dinar study indicates, efficiency may not always warrant the social cost associated with implementing efficient pricing methods (e.g. Volumetric pricing). Nevertheless, considering the environmental costs of some low implementation cost methods (e.g. area-based pricing method), such conclusion may not be warranted. Other forces such as political or social considerations and fairness may also work against efficient pricing. Politicians may find that, it is in their interest to support farmers, because it increases their chances for reelection (deGroter and Tsur 1991) and manifestation of this support may be subsidized water.

Equity consideration in pricing irrigation water, implies that the pricing of water should not make farmers worse-off (Tsur and Dinar 1995).

In conclusion, the desired method is the one that yields the highest social benefit. Hence, in the absence of implementation costs, the volumetric or two part Tariff methods are likely to be optimal. But, with implementation costs, other methods may yield higher social benefits. Since, implementation costs vary from region to region, the net benefits associated with each method is expected to vary from region to region.

VII. The Real world of pricing :

1) Pricing irrigation water in MENA countries

Review of related literature indicates that in most MENA countries, irrigation water pricing are based on financial rather than efficiency considerations. While the needs to recover all of- O & M costs are increasingly being felt, nevertheless the actual costs of O & M of public irrigation schemes are not known.

Pricing irrigation water in Iran has a long history. From its inception in Sasanid dynasty until the present time, water pricing system has undergone significant changes. Description of the history of water pricing in Iran is beyond the scope of this report.

At present, pricing irrigation water is based on the so called equitable distribution law of 1988. According to this law, surface water charges is based on some percentage of the value of output (output pricing). The following formula for this pricing system is indicated :

a) Water charge in traditional irrigation networks equal one percent of crop's value.

b) Water charge in the combined traditional and modern networks equals two percent of crop's value.

c) Water charge in the modern irrigation networks equals three percent of crop's value.

Since this system of pricing is not based on the volume of water delivered, it lacks the incentive for efficient use of irrigation water.

In the case of groundwater resources, a system of fees are levied to cover only the cost of monitoring. The fees vary with the crop irrigated as shown in table 1.

As indicated, irrigation water in Iran is heavily subsidized. It has been estimated that, water charges in public irrigation schemes only cover 12 percent of the supply cost (Aryan and Zolfagar 1996). In a study undertaken by this author, water charge was substantially lower than its supply costs and irrigator's ability to pay (Soltani, 1995).

According to assistant minister of energy, Iranian government has recently decided to deliver irrigation water volumetrically in all public irrigation projects. In order to reduce implementation costs, water should be sold " wholesale" to water users' associations to be established in three years period (Irrigation and Drainage committee, 2000).

Generally speaking, the irrigation schemes in I ran as in most MENA countries, are not financially self-supporting (sustainable) mainly because the water charges are vary low. They constitute a small fraction of cash production costs, and in, most cases, have no accurate relation to yields values. A necessary condition for efficient operation and maintenance of irrigation schemes is to increase water charges.

Despite the considerable scope for increasing water charges in many irrigation projects (as indicated by crop income analysis), however, the government is not prepared to increase the water charges, mainly for political reasons. A more lasting solution to irrigation water pricing problem in Iran, where output prices are revised frequently, appears to be the indexation of water charges to the output prices.

In Jordan, government policy is to favor equity over efficiency by charging farmers between 10 to 40 percent of actual cost of irrigation water in five projects considered. However, government intends to increase water charges over a period of time until, the O & M costs recover. In Jordan valley, volumetric pricing is practiced but, water is greatly under-priced

(Hayward and Kumar 1994).

In Egypt, farmers pay no direct charges for irrigation water but, they are responsible for the maintenance of common irrigation canals.

According to Arar (1981), the agriculture sector in Egypt was a net subsidizer to the rest of the economy by producing food and exporting crops at producing price less than border price.

In the Haous irrigation district of Morocco, irrigators pay a discounted price by participating in the maintenance of irrigation system. Water volume is priced by participating in maintenance of irrigation system. Water volume are measured by gates in surface irrigation areas. In 1994, the collection rate for fees to cover the operational cost of monitoring water use and enforcing payments was 79 percent (Tsur and Dinar 1997).

In Turkey, farmers are charged an annual area-based fee that varies by crop and region. In the project operated by state Hydraulic works (DSI), the fee has two components : an O & M component and a capital cost recovery surcharge component. The latter is based on the land area. The reported collection rate fee in 1992 was 33% (Kasnakogula and Cakmak, Cited in Tsur and Dinar 1997).

2) Pricing Irrigation Water in Advanced Countries

In a number of advanced countries, irrigation is subsidized. For example in the U.S repayment of irrigation cost of multipurpose projects is interest free over a 40 years period but costs allocated to municipal and industrial uses require repayment including interest at the current Federal interest rate. Federal costs (with out interest) exceeding the irrigators ability may be reimbursed by the project's power revenue. Annual O & M costs are expected to be repaid by all users.

In California, the state sells water "whole sale" to irrigation districts. The district sign long term contracts for agreed quantities of water, before the project is commenced. The contracts with the US Bureau of Reclamation are at postage stamp rate policy that lumps all conveyance costs and charge a uniform rate per acre-foot regardless of contractor's location along the aqueduct. In recent years, California has been facing an increasing water shortage. In an attempt to provide incentive for efficient use of water in agriculture, water Banks has been established as a means for reallocating water from lower to high value uses.

In 1991, during the forth consecutive year of drought , a water Bank operated by California Department of water Resource Purchased about one billion m^3 of water, half of it coming from farmers who had decided to stop irrigating temporarily (OPIC 1999).

Facing the need to reduce drainage into the highly polluted San Joaquin river, The Broadview water district in California instituted a Tiered pricing system. For each crop, the district determined the average volume of water used in 1986-88, and then applied a rate of $16 Per acre-foot (1.3 ¢ Per m^3), which was the rate farmers were accustomed to paying, to 90 percent of this amount. Any deliveries above that level were charged at a rate of $40 per acre foot, 2.5 times higher. Even though they were still paying much less than the real cost of their irrigation water, farmers had incentives to conserve water. On average cotton growers used 25% less water over the period 1990-93 compared with 1986-89. Crop yield either held steady or increased.

In New Southwales of Australia, subsidies have been paid by government to support the irrigation scheme. The inflexibility of water transfer in the past encouraged high application rates. Given the low water charges, it has been economically rational for irrigators to select water-intensive crops, resulting in high total water use. Some provincial governments, have recently recognized the transfer rights to provide incentive for efficient use of water.

Since 1995, The independent pricing and Regulatory Tribunal (IPART) has determined bulk water for irrigators and major urban users, employing a prices which is both transparent and independent. The tribunal advocated five principles to be used in establishing bulk water prices. First, water charges should be based on the efficient provision of water services. Second, financial stability and sustainable service delivery should be achieved. Third, pricing should encourage the best overall outcome for the community. Fourth, costs should be borne by the specific beneficiary. And finally pricing should promote ecologically sustainable water use (Crase et al. 2000).

VIII. Empirical Analysis :

1) The effect of the price on the use of irrigation water: An Empirical example

As indicated before, unlike many inputs and commodities, water does not posses all properties for exchange. Except some local markets for ground water, trading groundwater is not common in Iran. Hence, demand for irrigation water is commonly estimated using a normative approach or functional analysis.

In this study, a "normative" mathematical programming approach was used. A normative model is one that finds a profit maximizing mix of enterprises, given a set of input prices and constraint. For each water price, the model shows the activities that farmers would likely select, under the constraint and price information assumed in the model, and hence, the amount of irrigation water they would use. The approach facilities examination of the consequences in economic, and institutional constraint within a consistent framework.

To this end, a random sample of about 200 farmers were selected in a typical irrigated area in Fars province of Iran (located in the South of Iran). Data were abtained from sample farmers through questioner and interview. Farmers were grouped into four Homogenous classes and for each group a representative farm were constructed. Liner programming model was estimated for each representative farm separately. To determine, the normative demand for irrigation water price per unit of water (Cubic meter) was changed and for each price, water consumption was computed. Consequently, the needed observation for estimating Normative demand and price elasticity of irrigation water for each season of the year were obtained.

Results and discussion

Table 2, and Figure 2 show the relation between the price and consumption (demand) of irrigation water in the region,. Using price versus quantities shown in table 2, demand function were derived using ordinary least square techniques (OLS). Estimating function are:

1) Water demand function for winter:

$Q = 20140.611 - 3011.734\ P$

(8.616)

$F = 20.07 \qquad R^2 = 0.61$

2) Water demand function for spring:

$Q = 131160.302 - 20201.856\ P$

(10.681)

$F = 35.741 \qquad R^2 = 0.74$

3) Water demand function for summer:

$Q = 373962.716 - 45172\ P$

(22.146)

$F = 94.5056 \qquad R^2 = 0.89$

4) Water demand function for the whole season:

$Q = 526163.6297 - 68385.345\ P$

(24.766)

$F = 136.826 \qquad R^2 = 0.92$

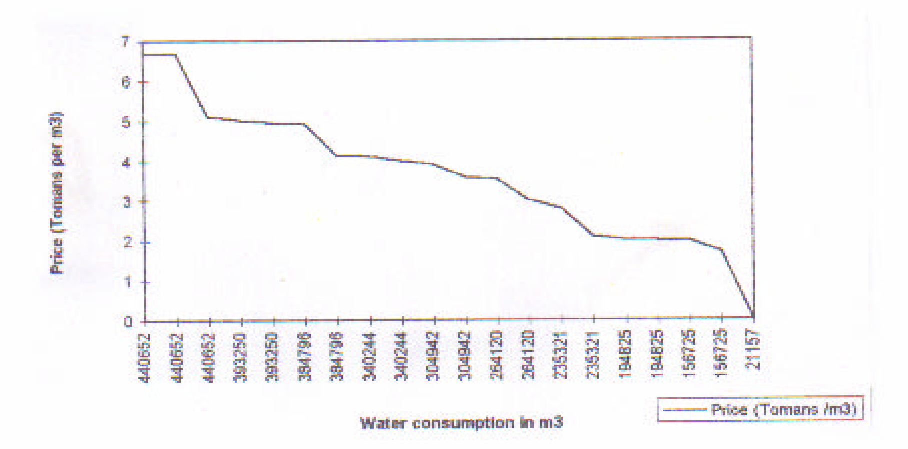

Fig 2. Demand curve for irrigation water in FIRUZ ABAD plain of Iran.

As indicated, demand for irrigation water varies with the season of the year. Elasticity of demand in winter and spring seasons are greater than summer. In other words, farmers are expected to be less responsive to water charges in summer than in other seasons. This appears to be a rational behavior, because summer is a hot season in the region. As such, reducing irrigation level and frequency would have negative and significant effect on crop yields. In addition, the findings of study, showed that raising water charges in an optimum cropping pattern , is likely to reduce water consumption given the irrigation technology and other related factors.

2) A pricing model based on the water nationalization act in Iran.

According to the water nationalization act in Iran, the ministry of energy is instructed to consider the current expenses for management, operation and maintenance and amortization of capital in determining irrigation water charges (full-cost beneficiary pricing). Since, water authority is a non profit organization, full-cost recovery may not be required in every instants. Any loss of a water authority in a river basin could be compensated by the surplus in other basin. In other words, irrigation revenue over the whole country must cover all costs, but, one water authority (or zone) may subsidize another.

A modified pricing model proposed by Gardener et al. (1974), was applied in an irrigation scheme, considering the above requirements. The model maximizes total economic rent, subject to the condition that the revenues collected by water charges do not exceed the cost of water supply. Since in large irrigation schemes like this, farm units are heterogeneous with respect to factors affecting crop income (such as soils, distance from irrigation canals, access to roads, etc.), they were classified into five homogenous groups (zones). In each zone, average total cost, average variable cost of irrigation water (O & M) as well as the average farmer's ability to pay (1 marginal value product of water) were computed.

In addition to setting an upper limit (marginal value product), a lower limit to water charge were considered. For efficient allocation of water, the lower limit is set at the O & M costs of the project. Since the upper and lower limits of water charges are determined independently in each zone, the upper limit in some zones may be less than the lower limit in the others.

In this case, water authority should decide whether it should delivery water to an inefficient zone. The decision to deliver water in this situation can be justified on criteria other than efficiency.

To determine water charge in each zone, water charge minus deliver cost in each zone were set at a predetermined percentage of water rent (the deference between the marginal value product and supply cost of water) in all zones. This percentage was set at 25 in this study. Hence, we can write :

$$1) \quad \left(\frac{P-C_t}{L_u-C_t}\right)_1 = \left(\frac{P-C_t}{L_u-C_t}\right)_2 = \left(\frac{P-C_t}{L_u-C_t}\right)_3 = \ldots = \left(\frac{P-C_t}{L_u-C_t}\right)_5 = X$$

Where : P = Water rate; C_t = Cost of delivering water; L_u = Value of marginal product or upper limit to water charge. Value of marginal product of water for each farm group were determined by a profit maximization mathematical programming model.

Results and discussion

Values of marginal product, and computed average total and variable costs for various farm groups in five homogenous zones are shown in tables 3 and 4.

1. The project is a diversion dam in Ghazvin area about 120 kilometers from Tehran. It is constructed to supply irrigation water to farmers and recharge the aquifers in Ghazvin plain.

Computing water rates

Using the equation 1 and the figures in Tables 3 and 4 , water rates in each of designated zones is computed : For example, water rate in zone one for the farm group having an average irrigated area of more than 10 Hectares would be :

$$\frac{P - C_t}{L_u - C_t} = 0.25 \Rightarrow \frac{P - 36.6}{208 - 36.6} \Rightarrow P = 79 \text{Rial} / m^3$$

Likewise, water rates computed for other farm groups in various zones are shown in table 5.

It should be indicated that average water rate for the whole irrigated area[3] was computed at 65 Rials per cubic meters. At present, irrigators are paying an average water charge of 15 Rials per cubic meter, covering about 23 percent of delivery and 86 percent of operations and maintenance cost.

The advantages of the above method for pricing irrigation water are:

1- Water charges are based on some percentage of " irrigation-induced ability to pay ", the cost of supply, and the condition that the cost must be covered by water charges. This percentage should be determined in such a way that all water allotment be demanded by the farmers. Since price of water is related to both the value and the cost of delivery, this is a positive point since it may encourage efficient farmers, provided right of water transfer is recognized.

2- The method allows management to use a portion of water rent in the low cost zones for subsidizing the zones where the farmers ability to pay is less than the cost of water. As a result total irrigated area would be greater than when the price of water is equal to its supply cost in all zones. Because, in the latter case, farmers would not be demanding water.

Disadvantages:

While the system can be criticized on the equity grounds, this is a price to be paid for the efficiency of water use.

Another disadvantage of the above method is its complication and relatively high implementation costs, because, the system requires controlled water delivery. Wholesale deliver is a remedy to be considered.

IX. Requirements of sustainable and effective pricing policy

Increasing difficulty in subsidizing irrigation schemes in many developing countries has resulted in a deterioration of O & M services and progressive deterioration of the schemes. The causes include poor institutional provisions for collection of water fees, lack of political will to support and enforce sound water pricing policy, and farmers, refusal to pay for the poor services.

Compared to farmers on rainfed lands, equity consideration implies that those benefiting from irrigation projects should be expected to contribute to the investment and O & M. Costs of these schemes. Nevertheless, they can not be accountable for faulty designs, inefficiency in the implementation, expensive construction activities and over manning of public agencies.

Irrigation water pricing is not likely to have any significant impact on the efficiency of water use, unless water deliveries to farmers are measured, and it has high private and social values.

Financial autonomy of the irrigation agency, that is , the extent to which the level of its operating budget is tied to the amount of revenues generated by its operation is essential for improving systems' efficiency and sustainability.

At the Marco-level, water pricing policy must be compatible with overall government policies for pricing both agricultural and non-agricultural services. The implementation costs of irrigation water pricing must be evaluated , and ways to minimize these costs relative to the revenues generated be sought.

The most critical factor affecting the sustainability of irrigation schemes is the participation and involvement of water users in the decision processes regarding the establishment of water rates and their implementation. There should be clear linkage between the financial responsibility of water users for irrigation costs and the accountability (to the water users) of those responsible for the operation and maintenance of the irrigation systems.

While, in principle, water charge should not exceed the typical water user's " irrigation-induced ability to pay ", in practice it should be lower that this, to provide incentive for the irrigators to engage in irrigated agriculture.

As indicated, collecting water charges from large numbers of small farmers in developing countries is an expensive and formidale task. A possible remedy would be to arrange for the bulk sale of water. This can be accomplished by delivering water to a group of farmers (water users Association) on a volumetric basis. The group would then be responsible for the distribution of water, levying and collection of charges and paying the cost of its local distribution as well as the purchased price to the irrigation agency. To make this work, strong water associations are needed with clearly defined responsibility and rights to contract for the distribution of irrigation water, and collection of payment from individual water users.

X - References

1. Arar, A. 1987. Short Report on cost of Irrigation Water and Irrigation Water Charges in some Arab countries. Report on the Export Consultation on Irrigation water charges, FAO, Rome, Italy.

2. Aryan, T. and SH. Zolfaghari, 1996. Economic and Fiscal tools for water management policies proceeding of regional water Resources Management conference, Isfahan, Iran.

3. Auty, R. M. and K. Brown (eds.). 1997. Approaches to sustainable development, Printer, London and Washington D.C.

4. Baumol, W. J. and D. F. Bradford, 1970. "Optimal Departure from marginal cost pricing. American Economic Review. 60: 256-83.

5. Bromley, D. W., D. C. Tylor, and D. E. Parker. 1980. Water Reform and Economic Development: an Institutional Aspects of water Development in Developing countries. Economic Development and cultural change, 28: 365 - 387.

6. Caswell, M., E. Lichtenberg, and D. Zilberman, 1990. "The effects of Pricing Polic ies on Water Conservation and Drainage". Amer. Jour. Of Agr. Econ. 72: 883-890.

7. Chaudry, M. A. 1986 Irrigation water charges and Recurrent cost Recovery in Pakistan. Report on the Expert consultation on Irrigation water charges, FAO, Rome, Italy.

8. Crase, L.; L. O'Reilly and B. Dollery, 2000. "Water markets as a vehicle for water Reform : The case of New Southwales" The Australian J. Agr. And Resour. Econ. 44: 299-321.

9. Dashti, GH. 1996. Water Pricing Policy and Demand for Irrigation Water in Iran. Proceeding of Regional Water Management Conference, Isfahan, Iran.

10. DeGroter, H. and Y. Tsur, 1991. Explaining Price Policy Bias in Agriculture: "The Calculus of support Maximizing Politicians." American Jour. Agricultural Economic s. 73: 1244-53.

11. Dinar, A., K. C. Knapp and J. Letey, 1989. "Irrigation water pricing policies to Reduce and Finance subsurface Drainage disposal" Agricultural Water Management. 16: 155-171.

12. Dubbourg, W. R. 1994a. Pricing for Sustainable water Abstraction in England and Wales. A comparison of theory and practice, Center for Social & Economic Research on the global Environment , London.

13. Fisher, B. S. and Thrope, S. 1990. Issues in Resources Management. The Australian Journal of agricultural Economics, 34: 87-102.

14. Gardener, B. D., Y. Madhi, S. Partovi, M. Hendizadeh, and M Saghatoleslami, 1974. " Pricing Irrigation Water in Iran. " Water Resource Research, 10: 1080-84.

15. Griffin, R.C., and G. M. Perru. 1985. Volumetric pricing of Agricultural Water supplies :

A case study, water Res. Research 21: 944-950.

16. Hayward, J. A., and K. S. Kumar. 1994. " Jordan Agricultural Sector Adjustment Loan: Water Component. " Middle East Department, World Bank, Washington, D.C. Processed (Cited in Tsur and Dinar).

17. Iranian national committee on Irrigation and drainage, 2000. Technical and Training workshop on Deficit Irrigation. May, 1, Tehran.

18. Kasnakoglu, H. and E. Cakmak. 1995. " Economic value and pricing of water in Agriculture ". Paper presented at the seminar Economic Aspects of water Management . CIHEAM. International Center for Advanced Mediterranean Agronomic Studies, Marrakech Processed (Cited in Tsur and Dinar).

19. Overseas Private Investment Corporation (OPIC) 1999. Environmental hand book. Washington, D.C.

20. Pasad, K. and P. K. Rae, 1991. On Irrigation water pricing in India. Water Resources Development. 1: 274-280.

21. Sampath, R. 1992. Issues in Irrigation water pricing in developing countries. World Development 20: 967-977.

22.Seagraves, J. A. and K.W. Easter. 1983. Pricing Irrigation water in Developing countries. Water Resource Bulletin, 19: 663-671.

23. Small, I. E. 1986. Water charges: A tool for Irrigation Performance. Report on Expert consultation on Irrigation water charges. FAO, Rome, Italy.

24. Soltani, G. R. 1995. Pricing and Optimal Allocation of Irrigation Water in Dorudzan Irrigation project. Research Rep. No. 44. Dept. of Agricultural Economics, Shiraz University.

25. Teerink, J. R. and M. Nakashima, 1993. Water Allocation, Rights and Pricing, Examples from Japan and the United states. World Bank technical paper no. 18.

26. Tsur, Y. and A. Dinar. 1997. " The Relative Efficiency and Implementation costs of Alternative Methods for Pricing Irrigation Water " the world Bank Economic Review. 11: 243-262.

Table 1 - Fees levied on groundwater

Crop	**Percent of crop's value**
Wheat	0.25
Rice	0.60
Dates, Citrus and summer crops	0.85
Almond and pistachio	1.0
Other fruit crops	0.8
Other crops	0.5

Source: Dashti, GH. 1996. Water pricing policy in Iran.
Proceeding of regional water management conference.
Isfahan, Iran.

Table 2. Water consumption (in 1000m^3) at different prices : FIRUZ ABAD plain.

Total Consumption	**Consumption in Summer**	**Consumption in Spring**	**Consumption in Winter**	**Price (Tomans/m^3) ***
440652	324049.66	101114.50	15488.02	0
440652	324049.66	101114.50	15488.02	1.7
440652	324049.66	101114.50	15488.02	1.99
393250.2	285554.91	91957.27	15738.03	2
393250.2	285554.91	91957.27	15738.03	2.01
384796.1	276152.0	93156	15488.02	2.1
384796.1	276152.0	93156	15488.02	2.80
340244.6	229981.2	93276.38	16986.99	3
340244.6	229981.2	93276.38	16986.99	3.54
304942	193378.04	93378.04	18185.92	3.6
304942	193378.04	93378.04	18185.92	3.9
264120.2	193052.23	59954.04	11113.92	4
264120.2	193052.23	59954.04	11113.92	4.1
235121.5	193052.23	34689.41	7579.86	4.15
235121.5	193052.23	34689.41	7579.86	4.93
194825.5	193052.23	1265.41	507.86	4.95
194825.5	193052.23	1265.41	507.86	5.01
156725.5	154952.23	1265.41	507.86	5.1
156725.5	154952.23	1265.41	507.86	6.68
21157.27	19384	1265.41	507.86	6.7
21157.27	19384	1265.41	507.86	∞

* Official exchange rate : One U.S. Dollar equals 185 Tomans.

Table 3- Value of marginal product of irrigation water in various farm groups (Rials/ m^3) *

Farm group	Zone	1	2	3	4	5
< 10 Ha.		65	148	190	230	102
> 10 Ha.		208	113	77	69	120

*Official exchange Rate : One U.S. Dollar = 1850 Rials

Table 4- Irrigation water delivery costs in different zones (Rials/ m^3)

Costs	Zone	1	2	3	4	5
O & M costs		16.7	17.1	17.3	17.7	18.2
Total costs		36.6	39.4	41.8	45.8	49.4

Table 5- Irrigation water Rates for various farm groups (Rials / m^3)

Farm group	Zone	1	2	3	4	5
< 10 Ha. Average Rate		44	66	79	92	62
Lower Rate		16.7	17.1	17.3	17.7	18.2
> 10 Ha. Average Rate		79	58	51	51	67
Lower Rate		16.7	17.1	17.3	17.7	182