PRICING IRRIGATION WATER IN MEXICO: EFFICIENCY, EQUITY AND REVENUE CONSIDERATIONS

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Abstract

The withdrawal of water for irrigation in the dryer regions of Mexico already accounts for some 91% of potential availability. Further expansion of irrigated acreage, therefore, must rely more on increased water use efficiency rather than increased supply from engineering works. A prime instrument to bring about such an improvement could be an appropriate water pricing structure. The first three sections of the paper present the conceptual issues involved, as well as the empirical findings which show that irrigation farmers pay, on average, less than 10% of actual water costs. Water use efficiencies are shown to be less than 50% but are markedly higher in irrigation districts with volumetric compared to those with fixed water charges. The fourth section develops some representative pricing structures that are designed to account for both efficiency and income distributional goals, while the last one addresses some of the likely implementation problems.

I. Introduction

Economists have long maintained that an efficient utilization of water resources could be brought about by the application of the principle of equi-marginal value in use; this means that in any given watershed the value of the last unit of water utilized in all competing uses should be equal (12, 20, 23). As other analysts have shown later, this principle can be extended, at least conceptually, to include non-monetary goals such as income distribution or environmental quality (4, 21, 32).

This paper first provides a brief overview of the water problem in Mexico. This is followed by a discussion of the conceptual issues related to the pricing of water. The third section discusses the results of an empirical investigation of irrigation water prices and irrigation water costs in public irrigation districts and projects. The fourth section reports the results of an analysis of estimated water use efficiencies in thirteen districts, and relates observed efficiencies to existing water pricing structures. The fifth section relates water costs to farmers' income and income-distributional objectives, and makes some

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suggestions how these objectives could be combined with efficiency considerations and appropriate tariff structures without sacrificing the important social goal of increasing the income of small-scale farmers. Finally, the last section briefly raises the difficult issues of implementing such pricing policies.

II. Problem Setting

Irrigation provides the productive backbone of Mexico's agricultural sector. In 1972/73, of a total of 16.8 million hectares (41.5 million acres) of harvested cropland, slightly less than 5 million (12.4 million acres) were irrigated (this includes double-cropping). While these 5 million represented only 35% of the total area harvested, they accounted for about 53 to 58% of the total value of output. Hence output from irrigated land is on average 2.6 to 3.2 times higher per hectare than that from non-irrigated land (13).

If we eliminate the generally humid tropical lowlands of the country in which irrigation plays little or no role at all but which account for about 85 percent of total run-off, agricultural water withdrawal and consumption in the remaining regions, in 1970, amounted to 91% and 74% of total potential availability; for 1980 these percentages are estimated to reach 106 and 84 respectively.[1] Since these non-tropical, non-humid regions are precisely those which contain the majority of Mexico's non-agricultural population and industry as well, it is not surprising that water use conflicts and over-exploitation of aquifers are starting to plague many of them.[2]

III. Water Pricing - Legal and Conceptual Bases

In Mexico the ownership of water rests unambiguously with the Federal Government,[3] and the pricing of water for any and all uses is a Federal responsibility. According to the 1972 Water Law, charges are to be levied against all users, whether they obtain water from a (Federally-financed) irrigation project,[4] or simply obtained a concession for the use of certain quantities of water.[5] Even the federally owned Electricity Commission is required to pay for the use of water.[6]

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[1]Calculated from: (26) tables 3A and 3B.

[2]See also (17).

[3](9) p. 456.

[4]Ley Federal de Aguas, 1972, articles 68, 69, 70, 71, 79, and 80.

[5]*Ibid.* Articles 114 and 134.

[6]Ibid., Article 106.

The law is much less specific about the bases and amounts of such water charges. For concessional uses, reference is made to the quantities used, the economic capability of the user, and the costs of conservation and protection of the water resource as such.[7] For irrigation water use, reference is made to the need to cover the costs of operation, maintenance and conservation,[8] and, on the basis of special socio-economic studies of the users' ability-to-pay, of the repayable portion of the (federal) investment costs of the respective project.[9] In other words, water charges for practically all uses are seemingly limited to the principle of cost, or partial cost recovery only.

From a conceptual point of view, a wider range of price bases could be taken into account. These could be grouped under:

(1) Economic rent
(2) Opportunity costs
(3) Cost recovery
(4) Income redistribution

In the utilization of almost all natural resources, the principle of charging "economic rent" for the right to use (or deplete) the resource is well established (14, various sections; 24, p. 517 ff.). Economic rent represents the differential between the maximum willingness to pay per unit of resources utilized (rather than to do without it), and the costs incurred in obtaining the resource.

Opportunity costs measure the net value of a resource in its next best alternative use (31). In the case of the future water supply for the City of Guadalajara, for example, one of the opportunity costs of the water of Lake Chapala that could be used to supply the city until the year 2000 would be the foregone net benefits from the irrigation of some additional 75,000 acres in the upstream reaches of the Lerma-Chapala system,[10] while in the case of the Valley de Mexico the opportunity costs of the 151,000 acre-feet of ground water presently used to irrigate about 82,000 acres of land within the basin[11] can be measured by the projected costs of transferring water into the basin from far-away sources.

The principle of cost recovery requires little elaboration. As we have seen above the existing Mexican Water Law established it firmly. In practice, as we will see below, full cost recovery is not practiced in public irrigation

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[7] Ibid., Article 134.

[8] Ibid., Articles 68 and 76.

[9] Ibid., Articles 70 and 97.

[10] (28). Vol. 1, p. 141.

[11] Ibid., p. 140.

districts or projects, although it necessarily occurs in privately financed irrigation (and other water) works.

Income redistribution is a major objective of agricultural development policies in Mexico. However, as will be seen below, the structure and level of irrigation water charges result in rather large subsidies towards beneficiaries of public irrigation works regardless of their income levels.

Neither the economic rent principle nor the opportunity cost approach have yet been applied in Mexico. Water charges based on the rent principle would maintain existing water uses, but would, in most cases, result in significantly higher revenues (and perhaps even a net surplus) for the government. Obviously, this would have significant income--distributional consequences for the affected farmers. The opportunity cost approach would result in the most efficient allocation of water resources among competing uses; in regions where higher-value uses (urban and industrial) are growing rapidly this pricing approach would tend to reduce water allocation and use in lower-value agricultural uses. Because of the very real social and political costs of such transfers from one user to another (see, for example, 22) forward planning of existing, not yet fully utilized water resources should take account of projected future higher valued demands before the limited water resources are allocated to the agricultural sector (with little realistic hope for recapture later).[12]

IV. Water Prices--Water Costs

For public irrigation districts, the legal basis for water pricing has been spelled out in article 70 of the 1972 Water Law as follows:

> The Secretariat (of Hydraulic Resources) in concurrence with the opinion of the Department of Agricultural Affairs and Colonization and the Directive Council will undertake the necessary socio-economic studies in order to determine the level of charges--in which they will take into account the recoverable portion of the investment costs, as well as the necessary expenditures for the adequate administration, operation, conservation and improvement of the district.

This wording clearly points out the present thrust of public irrigation water charges: (1) recovery of operating, maintenance and repair expenditures through user charges and (2) partial recovery of original investment costs on

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[12]However, "value" should not be measured simply in money terms, but in terms of a perceived socio-economic welfare function. Such a function, under present Mexican conditions, would undoubtedly place a heavier weight on benefits received by small-scale landholders and other low-income groups, than on those that would basically flow to higher income classes. For an interesting approach of how to handle this issue analytically in a benefit-cost study see (8), 1974, chapt. 4.

the basis of case by case decisions of "ability to pay." As we will see below, even these rather lenient principles are not adhered to in practice.

The following evaluation of existing tariff and cost structures are based on a sample of 16 irrigation districts serving a total area of 3,888,000 acres (1,570,000 hectares) in 1971; this represented approximately 60% of the total area of all public irrigation districts in the country.

Table 1 summarizes the findings of a survey of costs and tariffs in the 16 irrigation districts.[13] Line (A) indicates that the average district income from water and related charges paid by the beneficiaries amounted to $3.34 per acre of irrigated land per year, while annual operating, maintenance and repair expenditures as shown in line (B) per acre ranged from $7.41 at an 8% to $8.60 at a 15% rate of interest.[14] In other words, average user charges covered only 38-45% of total O.M. & R. costs, and only one of the districts surveyed was

TABLE 1

AVERAGE, SELF-GENERATED DISTRICT INCOME, OPERATING, MAINTENANCE & REPAIR EXPENDITURES, AND TOTAL COSTS PER ACRE FOR SIXTEEN IRRIGATION DISTRICTS[1]

	Interest Rate	U.S. $/acre Harvested	Relation A/B %
A. District Income (excluding subsidies)/ acre harvested		$ 3.34	
B. O.M. & R./ acre harvested (current	0%	6.18	54
expenditures plus amortization for	8%	7.41	45
multi-year conservation expenses)	12%	7.54	44
	15%	8.60	39
C. Total Expenditures/ acre harvested	0%	17.18	19
(includes the expenditures under (B)	8%	43.10	8
plus annuitized historical investment	12%	58.99	6
costs in 1971 dollars)	15%	71.42	5

[1]These 16 districts cover an area of 3,877,760 acres and represent approximately 60% of the total acreage of all irrigation districts in the country in 1971.

[13]District expenditures show wide year-to-year variations in their "conservation" and "equipment" expenditure categories. Since these frequently represent multi-year-life investment, rather than annual costs, all expenditures in excess of the mean averages were capitalized and annuitized over a 5-year time horizon at the rates of interest shown.

[14]Public subsidies towards O.M. or R. costs varied widely from district to district, ranging from a low of Mex. $5.80 (U.S. $0.46) per hectare ($0.19/ acre) to Mex. $408.30/hectare (US $13.22/acre) evaluated at an interest rate of 12%).

financially self-sufficient on a current account basis (i.e., excluding investment costs). Line (C) shows total annual costs per hectare including annuitized amortization costs of the capital investments.[15] Again, these costs have been shown for 4 different rates of interest, ranging from 0 to 15%. If we compare these total annual costs with total annual user charges we find that at interest charges between 8 and 15% the average contribution of the beneficiaries to the total costs of providing irrigation water is less than 10% (i.e., 5% at 15% and 8% at 8% interest). This means that more than 90% of the total costs are paid through public subsidies.

While the district by district analysis forming the basis for the data of Table 1 was undertaken only for the year 1971, a time profile of the annual revenue and expenditure flows (excluding capital cost charges for all districts) was undertaken for the period of 1950 to 1973. The results of this analysis are shown in Figure 1.[16] The figure shows self-generated district income, total income (including subsidies), actual annual expenditures and value of output per unit of land. The small difference between the total income and expenditures represents annual current account surplusses of the districts. As can be seen, in none of the years did the self-generated income reach total current expenditures. In addition, the actual level of the resulting subsidies, which from 1967 to 1971 remained relatively constant at between 30 to 35%, started to rise sharply thereafter, basically as a consequence of the rising level of district expenditures. This trend is probably a reflection of the high rates of inflation that began to mount after 1971.[17] On the other hand, self-generated revenue flows remained relatively constant during that period. In the same period the value of output per unit of land rose sharply, reflecting both the steep increases in world market prices as well as the repeated increases in government-controlled support prices for basic food staples. As a consequence, not only the net subsidies increased but the farmers' cost of water relative to the value of output declined even further, amounting to less than 2% in 1973. Obviously, greater flexibility is needed in irrigation water tariffs to respond more rapidly to such drastic changes in costs and prices over time.

V. Water Use Efficiency

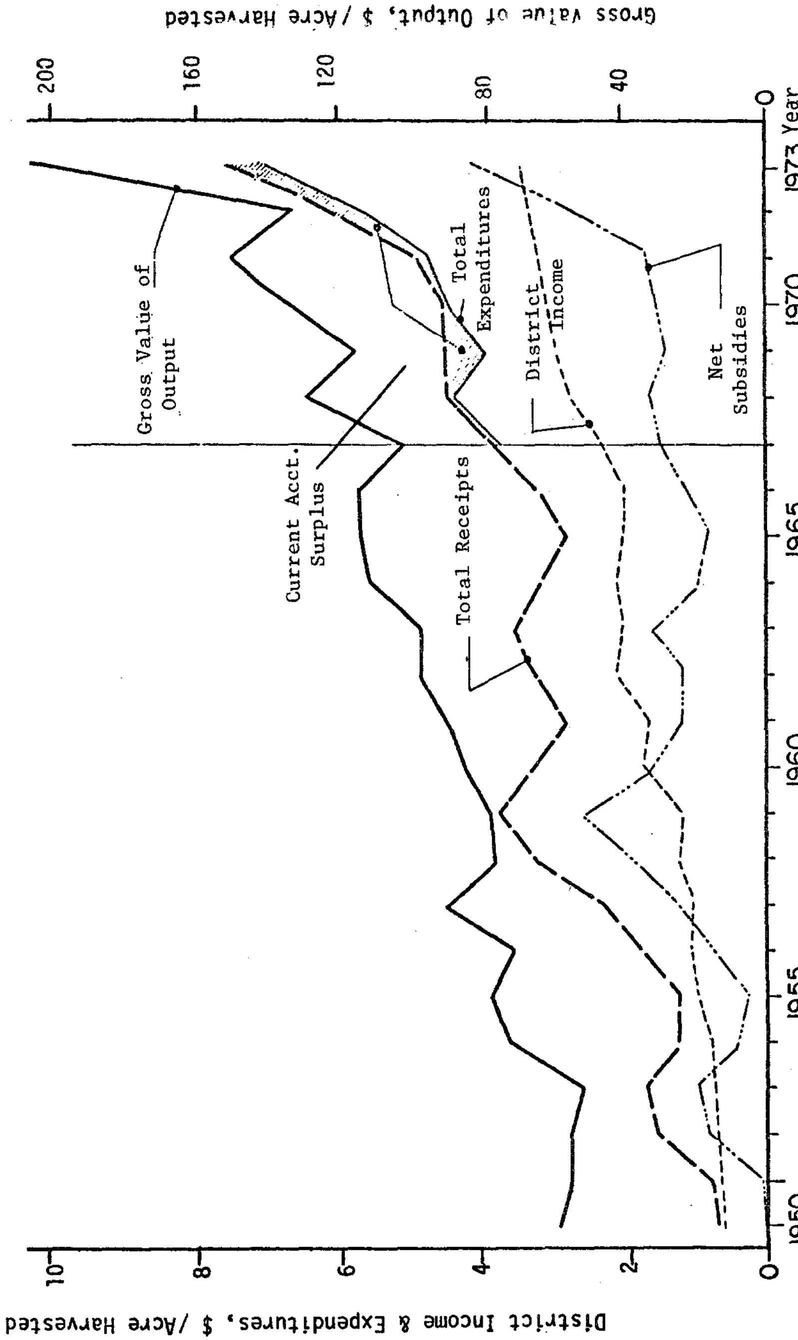
In its most comprehensive sense, water use efficiency is highest when the social value of the last unit of water utilized in any one of its alternative uses is

[15]Based on historic investment costs that were converted to a 1971 price basis by applying the Banco De Mexico Construction Cost Index. No attempt was made to capitalize the O.M. or R. subsidies paid from federal funds. Normal project life expectancy 40 years (15 years for pumps and motors).

[16]Because of certain data limitation in the 1950 to 1967 period, only the years from 1968 to 1973 are being discussed here.

[17]The National consumer price index rose from 116.6 in Dec. 1971 (1968=100.00) to 149.4 by December 1973, an increase of almost 32 points. From: (3), p. 54.

Figure 1



Gross Value of Output, $ / Acre Harvested
200
160
120
80
40
0
District Income & Expenditures, $ /Acre Harvested
10
8
6
4
2
0
1950
1955
1960
1965
1970
1973
Year
Gross Value of Output
Current Acct. Surplus
Total Receipts
Total Expenditures
District Income
Net Subsidies

equal. In this section, we will be concerned with a much more restricted meaning of efficiency, namely the technical efficiency of actual irrigation water use as compared to some theoretical water requirement function which considers only evaporation, temperature, rainfall and individual crop water requirements. For our studies the Blaney-Criddle formula was applied, to establish, on a district by district basis, water requirements for individual crops. "Efficiency" of water use was calculated by comparing these theoretically determined crop water requirements with actual estimated water use in the fields. A separate investigation evaluated the technical efficiency of the respective water delivery systems.

The results of these studies have been summarized for the 16 districts of our sample in Table 2. Efficiencies are stated in percentages from estimated optimum levels. As can be seen from the table, in 1971/72 delivery-system efficiencies ranged from a low of 47% in district 61 (Zamora) to a high of 100 percent in district 66 (Sto. Domingo).[18] More typically, delivery efficiencies ranged between 50 and 65 percent.[19]

Field efficiencies ranged from a low of 28% in district No. 61 to a high of 111 in district No. 20, Morelia and Queretaro. Basically, three groups of districts emerged from the study, those with high efficiencies of 80% or over, those with relatively low efficiencies of 45-60%, and those of very low ones in the range of 28-45%.

The results of these investigations must be interpreted with caution, however, as can be seen from the results for district 20, which shows efficiencies generally in excess of 100%. Water use efficiencies, as estimated by the Blaney-Criddle method, are, at best, first approximations of actual water requirements. These are significantly influenced by many factors that are not included in the B-C formulation. Examples are soil moisture absorption rates and soil moisture holding capacities, prevailing winds, vegetative ground cover, intensity and regularity of rainfall patterns, fertilizer applications, etc. Furthermore, the B-C formulation is strictly a physical one; it makes no attempt to relate crop water response functions to controlled reductions in water applications.[20] There exists scattered experimental evidence in Mexico and elsewhere that for some crops, in certain locations, water reductions of 20-50% from the pre-calculated theoretical water requirements result in negligible or only minor yield losses.[21] The results of theoretical efficiency calculations as

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[18] Sto Domingo depends entirely on ground water pumping, which drastically reduces the length of conduction canals and lines compared to surface-gravity systems.

[19] This is the general range of delivery system efficiencies observed in the United States. See (35), pp. 174-75.

[20] For a useful discussion of this issue see (1).

[21] According to a PLAMEPA study presented to one of the authors in Ciudad Obregon on February 4, 1972, irrigated maize yields remained constant at 6-7 tons per hectare when water applications were reduced from 60 to 42 cm. Further reductions to 21 cm resulted in a drop in yield to 5 tons/hectare.

TABLE 2

WATER CONDUCTION AND USE EFFICIENCIES
IN 16 IRRIGATION DISTRICTS
(percent)

District		Years	Conduction Efficiency	Field Use Efficiency
41.	Rio Yaqui	1971-1972	66	89
		1967-1972	64-70	85-98
75.	V. del Fuerte	1971-1972	55	80
		1967-1972	53-57	56-81
10.	Culiacan	1971-1972	48	91
		1967-1972	48-57	74-94
14.	Rio Colorado	1971-1972	50	65
		1967-1972	44-47	65-68
38.	Rio Mayo	1971-1972	67	84
		1967-1972	63-68	82-86
66.	Sto. Domingo	1971-1972	100	55
		1967-1972	100-100	48-54
05.	Cd. Delicias	1968-1969	52	59
		1967-1972	47-61	n.d.
11.	A. R. Lerma	1971-1972	68	66
		1967-1972	68-72	60-67
-	Tepalcatepec	1971-1972	60	38
		1969-1974	41-68	n.d.
		1969-1972		38-48
03.	Tula	1971-1972	51	45
		1967-1972	48-56	40-81
16.	Edo. de Morelos	1971-1972	60	82
		1967-1972	47-60	49-82
20.	Mor. y Quer.	1970-1971	58	111
		1967-1972	40-70	n.d.
		1967-1971		92-127
24.	C. de Chapala	1970-1971	58	98
		1967-1971	58-68	27-119
61.	Zamora	1971-1972	47	28
		1967-1972	44-70	23-32
19.	Tehuantepec	1971-1972	54	56
		1967-1972	35-54	56-77

those presented in Table 2, therefore, can only be used as first approximations of actual field conditions. These have to be established on the basis of actual empirical tests in a river region.

Some indirect evidence that there is, at present, little relationship between water use efficiency and crop yields can be gained from the data shown in Figure 2, which, for 13 districts, show the relationship between calculated water use efficiencies and the value of output per hectare. As can be seen, there appears to be no correlation between efficiency and the value of output[22] which seems to indicate that more careful use of water has no appreciable effect on yields. Apparently, then, measures to reduce irrigation water use, while certainly not costless, may well yield significant benefits in water savings without resulting in reduced agricultural production.

VI. The Effects of Tariff Structures on Water Use Efficiencies

While there exists a bewildering variety of several hundred different types and levels of irrigation water charges in the country's irrigation districts, it is nevertheless possible to group the various types into two major classes, namely those that are based on some form of volume charge and those that are fixed per time period (generally per crop cycle or per calendar year). The former are usually either charges per cubic meter of water or per irrigation application. Fixed charges per hectare per time period mean, of course, that marginal water costs are zero. As long as a farmer utilizes irrigation water at all, he has to pay the fixed charge regardless of the quantity that he uses. Variable charges by volume or number of application, on the other hand, create an incentive to reduce water usage because water costs then also are reduced.

In order to establish whether differences in the tariff structure affect water use efficiencies, thirteen districts were grouped according to their tariff structure into those with fixed and those with variable charges.[23] The results of this analysis are shown in table (3). In 1971/72, water use efficiencies in districts with fixed water charges ranged from 12% to 82%, resulting in an unweighted average of 51%. If the averages of the maximum and minimum efficiencies over a multi-year period are compared, the range is somewhat narrower, from 18 to 68%, with an overall unweighted average of 53% for all seven districts.

By comparison, districts with variable water charges show considerable higher rates of efficiencies. These ranged from 45 to 98% in 1971/72, with an unweighted average for all districts of 72%, and from 54 to 92%, and an unweighted average of 71% on the basis of the multi-year comparison.

These significant and consistent differences seem to suggest that tariff

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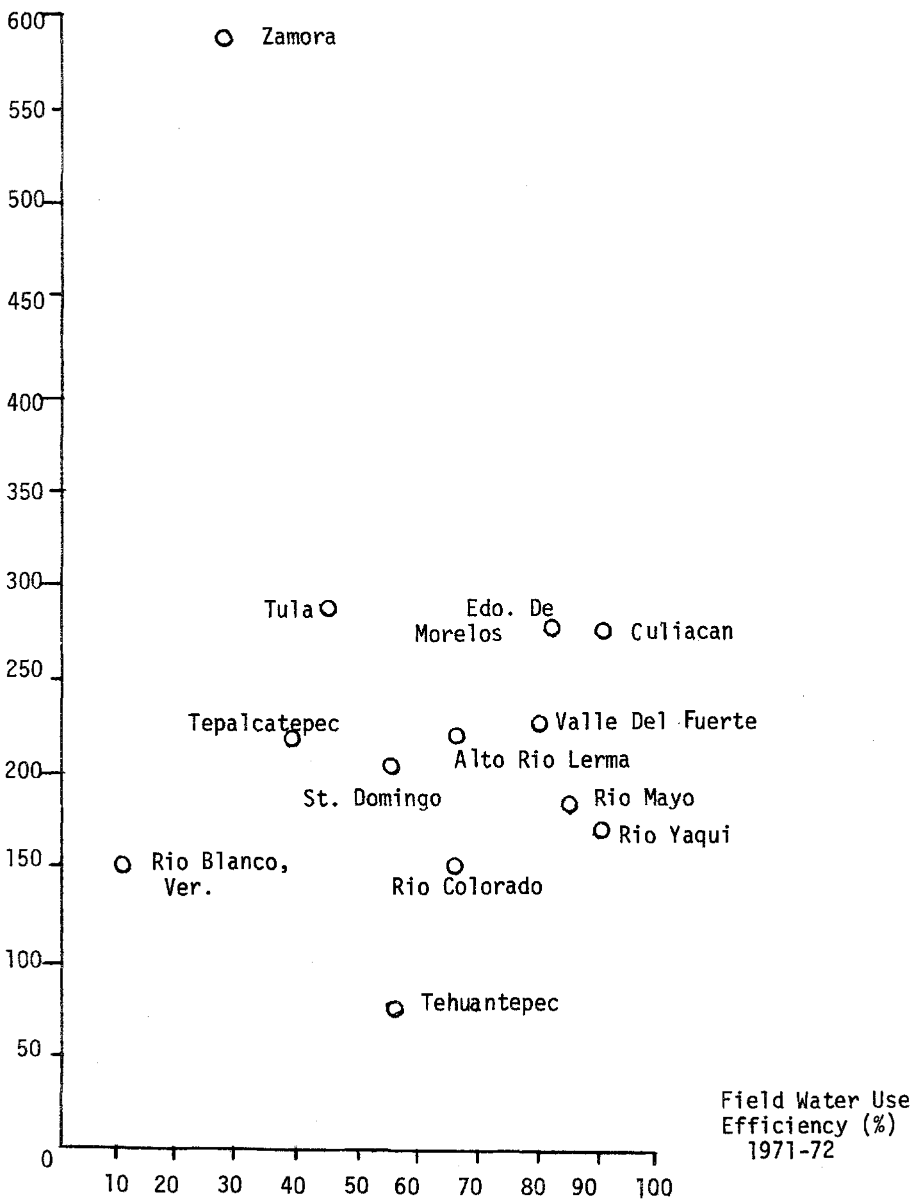
[22] This is true even if the extreme value of the Zamora district is disregarded.

[23] It was not possible to evaluate all 16 districts of the original sample since some of them applied more than one tariff structure.

Figure 2

Relation Between Field Water Use Efficiencies
and Value of Output Per Hectare



structures which penalize inefficient water users have a significant effect on farmers' behavior, and therefore can serve as an important policy instrument to bring about higher water use efficiencies.

If, for example, the districts with fixed water charges had applied variable rate structures instead, and if, as a result, water use efficiencies in these districts would have risen to those observed in districts with variable charges, then the resulting water savings would have been sufficient to irrigate some additional 1.5 million acres (623,000 hectares) on the basis of the 1971/72 data.

Obviously, the conclusions drawn from the above analysis must be interpreted with some caution. There may have been other factors than differences in tariff structures that could have explained the differences in efficiencies, as, for example, the existence of effective water rationing systems in water-short districts.[24] Furthermore, water savings, or higher water use efficiencies are of interest only if the water thus saved has value in alternative uses. This might not be the case in some of the districts which are located in areas with high rainfall or ample run-off, as for example in the area of district No. 82, Rio Blanco in the State of Veracruz. Clearly, the introduction of variable water charges is not costless, since it generally requires the introduction and operation of metering devices. Only if it can be shown that the net productive value of the water saved exceeds the additional investment and administrative costs would it be worthwhile to introduce and utilize more complex tariff systems.

Nevertheless, the findings of this investigation are encouraging and suggest that the use of variable, quantity-related water charges may represent a useful instrument for reducing waste and for increasing the effective water supply in many of the water- short regions of the country.

VII. Efficiency, Equity and Revenue Considerations

The question whether the present levels of subsidies to irrigation are justified or not is, obviously, a question of governmental policy and social choice. However, it is also a question that requires continued re-examination in the light of changing circumstances, as well as changes in public attitudes and policy goals. Nevertheless, as has been pointed out in a recent study of appropriate principles for the pricing of irrigation water:

> There is no prima facie reason why total recovery should not exceed the total financial costs incurred by the government for the project. Those beneficiaries whose incomes are above the exception level (i.e., the subsistence level) should be taxed as much as possible consistent with their continued participation in the project, and taking into account the adverse effects that the benefit taxes (i.e., water charges) may have on production and evasion incentives. If all beneficiaries have sub-exemption levels of income, the optimum

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[24]This is not uncommon in the relatively water-short districts in the Northwestern and northern regions of the country. See, for example (7).

TABLE 3

VARIATION IN FIELD WATER USE EFFICIENCIES BETWEEN DISTRICTS WITH FIXED AND VARIABLE WATER CHARGES

District	1971/72 Field Use Efficiency	Average of the Maximum and Minimum Annual Efficiencies shown in Table 3
Districts with Fixed Charges Per Hectare Per Time Period[1]	(A)	(B)
82 Rio Blanco, Ver.	12%	18%
61 Zamora	28	28
- Tepalcatepec	38	68
19 Tehuantepec	56	66
05 Cd. Delicias	59	59
75 V. del Fuerte	80	68
16 Edo. de Morelos	82	66
Unweighted Average	51	53
Districts with Charges that Vary with Quantity of Water Used[2]		
03 Tula	45%	60%
66 Sto. Domingo	55	54
14 Rio Colorado	65	68
11 A. R. Lerma	66	64
38 Rio Mayo	84	84
41 Rio Yaqui	89	92
24 C. de Chapala	98	73
Unweighted Average	72	71

[1] Including those tariffs that vary according to the crop planted.

[2] Including all districts that charge per irrigation per hectare or per unit of water supplied.

Sources: Table 3 and (33).

cost recovery will be zero. The lower limit of recovery should not therefore be set by the requirement that at least O. & M. costs be recovered (11).

Given the rather low water charges in Mexico and the widening spread between current district income and expenditures (See Table 1) various observors have suggested a revision of the existing tariffs so as to cover at least the annual O. M. & R. costs ((2), p. 62). The National Water Plan calls for the gradual increase in water charges to meet this goal including the costs of rehabilitation by the year 1982 (28, Vol. II, Chapt. V).

One of the issues that must be clarified with such an objective (or any other one in terms of overall revenue targets) is whether it should be achieved on an individual district and/or project basis, or by all districts and/or projects jointly. The first alternative would make each administrative unit self-sufficient in terms of current-account revenue and expenditure flows. This financial "independence" might be a worthwhile objective by itself given the expressed desire for more regional independence and decision-making. (28, Chapt. XVIII). However, offsetting this advantage would be the fact that beneficiaries in similar economic circumstances, but located in different districts or projects, would pay widely differing prices for irrigation water. Those supplied from gravity systems equipped with concrete-lined canals (characteristics that would result in low operating and maintenance costs) would pay least, while those supplied from deep-well pumps would likely pay most. For example, while the total annual costs of storage-dam-gravity projects were Mex. $2,639/hectare ($85.47/acre) and therefore somewhat higher than the Mex. $2,156/hectare ($69.82/acre) of groundwater projects, the former would pay only Mex. $300/hectare per year ($9.71/acre/year) to cover total operating and maintenance costs, while the latter would have to pay Mex. $833/hectare/year ($26.98/acre/year), or almost 2.8 times as much.[25] Since the substantial subsidies to irrigation farming are generally justified on income-distributional grounds, therefore, it would be more appropriate to set percentage revenue goals, such as the specific goal of covering O.M. & R. costs, on a country-wide basis, with specific water charges in each project and district then designed in such a way that districts or projects with low O.M. & R. but high capital costs would produce a current account surplus which would offset a deficit by high O.M. & R., low-capital cost projects elsewhere.

One pricing proposal which has found substantial support by some (see, for example (2), p. 62) is that of tariff schedules which would vary according to

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[25]Data from Table 2 and (25).

[26]Two complicating factors of such an assessment would be the problem of differing crop compositions (5, Table 4) and the rather significant economics of scale inherent in agricultural production techniques in Mexico and elsewhere. On the latter point see (8, Chpt. IV; 29, p. 248 ff; 6, p. 136ff).

the value of the crop produced. Under such a scheme, low-value crops would pay low, and high-value crops high charges. Such tariffs are actually in force in a few districts in Mexico. On equity grounds, such proposals seem to have much appeal, considering that an acre of irrigated maize in 1971/72 prices for example, may have yielded at the most some $175 worth of output, while an acre of export-quality tomatoes may have brought $1300, and an acre of strawberries as much as $3000. However, on efficiency grounds such water pricing differentials are not to be recommended since they create disincentive effects for planting higher-value crops. This is exactly the opposite of avowed Mexican agricultural policies. Differentiated water charges by crop, therefore, should be limited to the differences in actual water uses, i.e., to the difference in the volume of water required for growing each crop. Such a volumetric differentiation would also be a useful tool to prevent or reduce the growing of high water-using crops such as rice, sugar cane, alfalfa, etc. in regions with limited water supplies.

Figure 3 shows two examples of water tariffs that are patterned in such a form as to take account of income distributional objectives. It is clear that there are an infinite number of different tariffs that could be implemented. Therefore, these two examples are strictly illustrative and should not be interpreted as representing recommendations by the authors. As has been emphasized above, the issue of income distribution is one that only a government, or a society collectively can decide for itself; a professional analyst can do no more than to indicate the possible ranges of alternatives and to evaluate their likely consequences in terms of the various stated societal goals.

To simplify the exposition, the charges have been shown in terms of dollars per acre. As will be argued below, whenever possible charges should be based on volumetric charges instead.

Given average water use rates in Mexican irrigation districts, the equivalent charges per acre-foot would amount to roughtly 30 percent of the charges per acre shown in Figure 3.[27] In example A, charges for the first five hectares would amount to $3.24/acre, or about the existing average water charges per acre in all districts in 1971/72 (see Table 1). Charges would double for the next five hectares (about 25 acres). From 20 to 50 hectares, charges would be $32.38/acre, and $48.56/acre (or about $14.60 per acre-foot) for all land in excess of 50 hectares.[28] The latter charge would roughly reflect the average total annual cost of irrigation water supplied, given an approximate 10% rate of discount (see Table 1). All rates below $48.56, therefore, contain a net subsidy to the beneficiary. The average annual revenue, given the farm size distributions in all districts which are shown in Figure 3, would amount to $13.98/acre, or roughly double the average current expenditures of all districts in 1971/72. While under such a scheme all farmers would receive a subsidy regardless of

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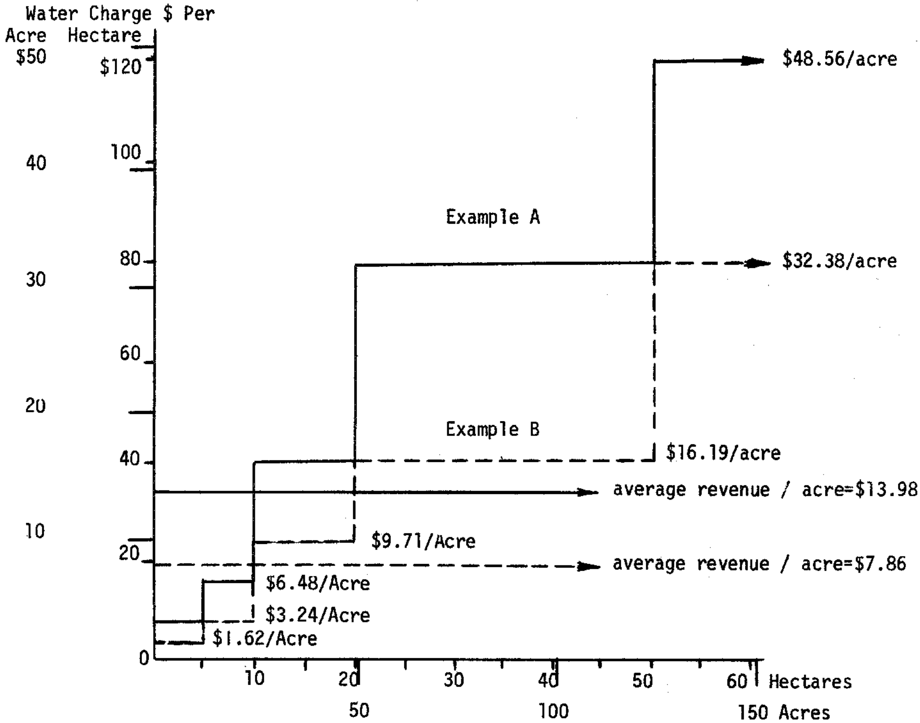
[27]Average field use in the 16 districts amounted to 108 cm, or 3.54 feet.

[28]In terms of 1971/72 average district yields, this charge would represent approximately 35% of the value of output per acre.

FIGURE 3

Two Illustrative Examples of Differentiated Water Tariffs Expressed in $/Acre.

Farm Size Distribution, All SRH Irrigation Districts, 1971/72			
Size			Percent of Total Revenue
HA	Acres	% of Farms	Contributed
0- 5	0- 12	17.5	4
5-10	12- 25	20.5	6
10-20	25- 49	22.8	14
20-50	49-124	16.3	22
50+	124+	22.9	54



the size of their holdings, the increasing steps of the tariff would avoid the disincentive effects of uniform tariffs that were based solely on farm size.[29]

Example B shows a similar tariff structure at considerable lower rates. The lowest bracket of $1.62/acre would represent approximately 50% of the average district charges in 1971/72, while the overall average district revenue per acre would just suffice to pay the current district expenditures in 1971/72. Example B therefore, as applied in 1971/72, would have fulfilled the revenue goal stated in Plan Nacional Hidraulico for the year 1982.[30]

As has been pointed out above, flat per acre water charges are generally undesirable in all regions in which water has alternative uses, whether in irrigation or elsewhere. Volumetric charges should be used instead, However, while it is relatively simple to install metering devices in irrigation districts that rely on ground-water, this is much more difficult and costly in gravity systems (2, p. 62); some observers claim that metering in canal systems is impractical because of cost and the problem of bribery and theft ((11), p. 14 & 15). However, in Mexico a number of gravity canal systems actually are operating with metering devices,[31] although both capital as well as O.M. & R. costs are significantly higher than those in un-metered districts.

Because of the added cost of metering, therefore, it should be introduced only in those regions in which studies can show that the water saved has alternative uses, either in irrigation, or elsewhere.[32] Only in regions where it can be shown that the net value of the water saved is likely to exceed the added costs of metering is the latter warranted. Some measures short of metering that would have a somewhat similar effect would be to charge users per irrigation application. If the latter were to vary systematically by crop (i.e., more water applied to one crop than another per application) then crop-specific water charges should be used as well.

Such pricing schemes would have the further advantage that they might induce farmers to systematically introduce water-saving technologies. In Mexico

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[29]For example, if all holdings with less than, say, 5 hectares were charged $2.00 per hectare, but those with more than 5 hectares $4.00 for all, then a farmer with a holding of 6 hectares would face a marginal water charge for the sixth hectare of $14.00. This could well persuade him to operate only on 5 hectares.

[30]Given the substantive rates of inflation that have occurred since then, as well as the much higher unit costs of new irrigation projects, 1982 tariffs will have to be significantly higher than those shown in our example.

[31]In the Rio Mayo irrigation district, for example, introduction of metering and volumetric charges led to an increase in water use efficiency of 15%. (28, Vol. II, Chpt. XI).

[32]A special case is given by regions with groundwater overdrafts where alternative uses have to include the evaluation of the effects and costs of ultimate exhaustion of the acquifer storage.

some 15,000 hectares of irrigated land in various regions are utilizing sprinkler irrigation systems instead of the usual gravity type. Average irrigation efficiencies with sprinklers are about 90% compared to the present national average of 46% (28, Vol. II, chapt. XI). Some 540 hectares (1350 acres) are equipped with drip-irrigation systems, and in one experimental plot, in the Rio Yaqui District, which uses drip irrigation, corn yields increased to 140% of normal, while water use declined by 38%. Similar results, some even more startling, are known from many areas around the world.[33] Installation of such equipment would appear much more attractive to a farmer who faces volumetric water charges, particularly if the latter, at the margin, reflect high opportunity costs. In addition, it might be desirable for the government to actually subsidize the installation of such equipment in lieu of the presently employed subsidies which are provided only through the construction and operation of conventional irrigation works. Obviously, the installation of water-use-reducing devices by farm-would act as a direct substitute for the need to constructing additional irrigation facilities and, if costs per unit of water saved were to be less than the costs of additional irrigation works, genuine savings would result from such a policy.

VIII. Some Problems of Implementations

While the foregoing discussion clearly indicates the desirability of both increasing and restructuring the existing water tariffs, implementation of such a policy faces formidable obstacles. The major one will be the reluctance of the present beneficiaries of the existing tariffs to vote voluntarily for higher ones. According to articles 68 (for irrigation districts) and 76 (for irrigation units of the rural development program) of the 1972 Water Law, the determination of water tariffs and their revision is the responsibility of the respective Directive Councils (Comité Directivo) of the units.[34] But the Directive Councils consist basically of elected user representatives who will not consider it to be in their interest to vote for higher rates, even though the wording of the law emphasizes the coverage, through user charges, of all current operating costs.

Even less clear is the limiting effect of articles 70 and 97, which require the Secretary of Hydraulic Resources to undertake socio-economic studies which are to determine the ability of the respective beneficiaries to contribute to the recovery of investment costs. These studies, and their recommendations, require the participation and opinion of the Department of Agricultural Affairs and Colonization (i.e., the Department in charge of the Agrarian Reform Laws) as well as that of the District Committees (for Districts) or user representatives (for Rural Development Projects).

Given these political, institutional and legal obstacles it appears much more likely that the introduction of new and generally higher water charges will

[33] See, for example, the five papers grouped under the sub-title "Water Use" in (10), pp. 322-356.

[34] I.e., it is their responsibility to "revise and propose periodically to the Secretary (of Hydraulic Resources) the service quotas and budget tariffs for administration, operation and conservation" (Paragraph 62).

be much easier in new projects, or in rehabilitation projects that provide benefits not only for new farmers but also for those already established in the district.[35] With public irrigation works expected to more than double within the next 25 years, and with rehabilitation projected for close to 25 percent of existing districts, this may bring about a gradual change to more appropriate pricing structures in the majority of public irrigation works in the country. However, such an incremental approach, while politically probably the only feasible one, inevitably will also mean that the goals of horizontal equity between economically equally situated beneficiaries living in different districts will remain an elusive goal for quite some time to come.

Taking these issues into account, the espoused and seemingly modest goal of Mexico's National Water Plan to bring about no more than full coverage of district O.M. & R. costs by 1982 looks much more realistic than any alternative objectives that might call for more refined and drastic changes in existing water pricing structures in the already operating districts and projects.[36]

However, quite apart from these implementation difficulties, it must be concluded that present water pricing practices in Mexico are inadquate, and that actual tariff levels are lower than necessary to meet the stated goals of both efficiency and equity. Changes in these tariffs, with major emphasis on volumetric charges in those areas that face alternative or additional water needs, are likely to bring about a much needed increase in the efficiency of water use, which in turn could substantially increase effective water availability in many areas. A restructuring of water tariffs, in addition, could bring about greater income-distributional equity between irrigation water users, without requiring a sacrifice of efficiency in turn. On the contrary: equity and efficiency goals could be incorporated in the tariff structure so that both would be enhanced.

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[35] Frequently, the goal of rehabilitation is simply to extend water supplies to new, adjacent areas and new farmers, rather than to those already established. In such situations strong resistance to increased tariffs by the latter group is to be expected.

[36] This would, on an average for all districts, require a doubling of existing tariffs in terms of 1973 district income and expenditure data (see Fig. 1). For some districts, such as No. 16 (Edo. Morelos) or No. 24 (C. de Chapala), for example, tariffs would have to be increased almost fivefold to meet the same goal.

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