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OPERATION AND MAINTENANCE COSTS

by

Juan A. Sagardoy

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1. INTRODUCTION

In the irrigation sector, the 1980s have been characterized by a marked interest in the performance of existing irrigation schemes. Although in most of the evaluations the considerable contributions made by irrigation in economic terms and welfare obtained by the benefitted farmers are recognized, there is also a general concensus on the need for improving irrigation performance. Often, deficient operation and maintenance of the system are identified as a major reason for poor performance, and insufficient financial resources are given as a chief reason for the improper service provided.

Consequently, the notion seems to have spread that substantially increasing the water rates will automatically result in a better operation and maintenance service and thus the overall performance of the scheme will improve.

Although we recognize that suitable operation and maintenance services require considerably higher water rates than those existing in many instances, there is no guarantee that higher water rates will automatically improve the operation and maintenance and the overall performance. In other words, increased water rates are often necessary but must be accompanied by suitable institutional changes and improved management capabilities in order to upgrade the standards of the O&M Service.

A further consideration is that before attempting to increase water rate serious consideration must be given to the possibilities of reducing actual O&M costs. This is often a much more viable alternative. In order to visualize some of these possibilities the paper analyses the influence of the different components of the O&M costs and their corresponding weight in some selected cases.

The other point to be examined in detail is that the improvement of the O&M Service does not necessarily mean that the overall performance of the irrigation scheme will improve in a noticeable way. Again, a number of additional measures or services are often needed - particularly in the early years of the life of an irrigation scheme - to guarantee a proper functioning of the scheme. The financial implications of these additional services cannot be ignored.

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Finally, in order to have an insight into the possibilities for the farmers to pay water charges, their effect on the production costs of some selected crops is analysed.

However, before entering into the discussion of some of the mentioned issues it seems necessary to review certain concepts associated with operation and maintenance.

2. WHAT IS ACTUALLY MEANT BY OPERATION AND MAINTENANCE COSTS?

The concept of O&M costs is often used in a loose manner meaning the sum of all costs associated with the distribution of water and maintenance of the irrigation infrastructure. However, large differences exist among the irrigation/drainage infrastructures to be covered by O&M activities in different projects and also in the activities which are considered as O&M by the management of the scheme. These two factors alone are already responsible for wide variations in O&M costs among irrigation schemes even within a given country. These factors are reviewed below.

2.1 Physical Systems of an Irrigation Project Needing O&M Activities

An irrigation project may include several or all of the following systems:

a. Water distribution system, made up of several or all of the following elements: (i) dam; (ii) diversion dam; (iii) pumping stations; (iv) main canal or conduit; (v) secondary canals or pipes; (vi) tertiary canals (watercourses); (vii) well and pumping units.

b. A drainage system, comprising some/all of the following elements: (i) farm drains (pipes or canals); (ii) secondary drains (pipes or canals); (iii) primary drains (canals); (iv) collectors; and (v) pumping stations.

c. A road system, for servicing the water distribution and drainage systems and facilitating access to farms.

d. Buildings (offices, stores, workshops, etc.) necessary to undertake the activities regarding the functioning of the above mentioned systems.

The question arising here is whether O&M costs should cover the expenditures related to the 4 systems (water distribution, drainage, roads, buildings) or only those directly related to water distribution. It is believed that most of the countries reporting on O&M expenditures refer to those arising from the water distribution system and the buildings. However, we feel that the drainage system is an inseparable component in the management of water and should also be included as part of the O&M costs.

As to the road system, the roads which are used specifically to service the canals should be maintained by the project, but those of multipurpose use should be excluded from the O&M costs.

The subject is further complicated by the fact that some of the elements of the water distribution system, like dams, can be of multipurpose use and the distribution of O&M costs among the different uses may be rather arbitrary.

2.2 O&M Activities

A number of activities are required to allow physical systems to perform their functions adequately and these are listed below:

(i)	Overall Management	-	Directing and supervising all activities
(ii)	Planning	-	Matching supply and demand (yearly crop plan)
		*	Matching financial resources and expenditures (annual budget)
(iii)	Implementation	*	Handling of structures to deliver water requirements
		*	Processing information to meet water needs
		*	Maintaining all the physical systems for which the O&M units are responsible
		-	Enforcing the rules and regulations of the system
(iv)	Monitoring	-	Recording water deliveries and effected maintenance
		-	Recording irrigated areas, crops, yields
(v)	Administrative Control	*	Financial control of revenues and expenditures
		*	Personnel management
		*	Purchasing of supplies
		-	Control of stocks (in stores)

The above list of activities should be undertaken in all cases but unfortunately this is more the exception than the rule. In most instances only the activities marked with an asterisk are carried out.

Assistance to farmers to improve farm irrigation is an activity sometimes carried out (Mexico, Spain, Cyprus), but in spite of its importance this is frequently

2.3 Working Resources

In order to carry out the activities, the management of the schemes needs the usual working resources:

- personnel (management, professional, technical, clerical, skilled labour, unskilled labour);
- materials and supplies;
- equipment (heavy, medium and light equipment);
- energy and public utilities (telephone, water);
- buildings (offices, stores, workshops, etc.);
- financial resources to cover other expenditures, like rentals, loans, indemnities, etc.

Some of the costs inherent to the working resources are fixed (independent of the volume of water supplies) and others are variable (depending of the amount supplied).

A breakdown of expenditures into fixed and variable is given below:

		Fixed	Variable
Personnel			
1.	Salaries and fringe benefits	X	
2.	Travel and subsistence	X	
Materials and supplies			
3.	Materials (wood, cement, etc.)	X	X
4.	Supplies (tyres, fuel, stationery, food, etc.)	X	X
Equipment			
5.	Depreciation cost	X	
6.	Spares	X	
7.	Repairs	X	X
8.	Hire of equipment		X
Energy and public utilities			
9.	Electricity/petrol for pumping stations		X
10.	Water (purchased)		X
11.	Telephone	X	
Offices, stores, workshops and other buildings			
12.	Amortization cost	X	
13.	Repairs/maintenance	X	X
14.	Rents	X	

Others

15.	Indemnities	X
16.	Payment of loans	X
17.	Contributions	X

It is interesting to note that most of the expenditures belong to the fixed category - or at least those having a greater weight in the total expenditure. This is one of the reasons why a considerable reduction/increase in the water diverted is likely to have a reduced effect on the overall O&M costs, except in cases where the water is pumped and therefore the energy component is very important.

2.4 Functional Units

The activities, together with some of the working resources, are often grouped in functional units in order to have a better organization of the work to be done. The most common grouping is indicated below.

Operation and Maintenance Service	- Director/Manager's Office - Water Distribution Unit - Maintenance Unit - Administration Unit

For medium-sized irrigation schemes these units are not clearly differentiated and the staff of the O&M Service perform functions pertaining to both water distribution and maintenance.

Often, the irrigation schemes of a given area - generally within a river basin - are too small to justify such organization. In these cases a central O&M Service is established - often called "Irrigation District"[1] - which provides common services for all the irrigation schemes of the area (basin), although small water distribution units exist in every scheme. This type of "Irrigation District" not only carries out the functions that are inherent to the O&M Service but often it also performs some watershed conservation works in order to maintain favourable conditions for the off-the-river diversions. This type of work is sometimes considered part of the O&M expenditures. The corresponding organization appears quite suitable for small watersheds but it certainly implies higher expenditures than those which, strictly speaking, are considered as O&M costs.

The picture emerging from the former review of the elements integrating the O&M Costs is that of a great diversity of physical systems covered by this concept and a variable number of activities undertaken in some cases but not in all. Therefore the need for some standardization in the concepts appears necessary, or at least the need for describing which system and activities are covered by the reported O&M costs, so that their exact meaning can be understood.

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[1] This concept of an irrigation district is entirely different from that commonly accepted in the USA where irrigation district is synonimous with irrigation schemes.

3. O&M COSTS AND WATER CHARGES

The working resources mentioned before, i.e. personnel, equipment, material and supplies, energy, transport and others, have some inherent costs, the determination of which is rather straightforward, except in the case of equipment. In this case, the annual costs, corresponding to the depreciation of the equipment or replacement costs, are rarely included; only those necessary for operation are considered. The implication of this policy is that at the end of the working life of the equipment there is no capital for replacement, and since governments are under financial constraints they cannot provide it either. At this time, the consequence is that the maintenance of the scheme is not effected properly, as most of the equipment is used for this purpose. Here again the need for some standardization as to how to calculate the costs of equipment appears useful.

In principle, the O&M costs should be more or less equal to the corresponding part of the water charges[1] imposed on the farmers for this concept, but often there are large differences, the water charge being considerably lower than the actual costs (see Table 2). In particular, the salaries of government staff engaged in the O&M Service are often not charged. As farmers are mostly not charged for the personnel cost component, this represents a large subsidy. If they are eventually going to take up this responsibility they must be prepared to face a considerable rise in water charges by this mere fact.

In theory, the water charges corresponding to the O&M costs should be somewhat higher than the O&M costs, the reason being that this policy will allow the building up of a "reserve fund" to cover any expenses for unexpected failures/damages in the physical systems or to carry out some improvements.

Another factor contributing to the disparity between costs and charges arises from the fact that expenditures incurred in one given year are not recovered through water charges until the following year or the year after. In countries with substantial inflation this means a considerable reduction in revenues for the scheme. Adjustment of the water rates to inflation is an issue that requires attention.

There are other issues related to repartition of the costs to be charged to farmers, such as which bases should be utilized for charging: command or irrigated area; hectare; amount of water diverted or delivered per cubic metre; a double (fixed and variable costs) or a simple charge (fixed + variable costs), but they belong more to the domain of other papers to be presented at the Consultation.

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[1] Here the water charge is understood as the amount paid by the farmer to cover the recovery of the investments - although in most cases this is a small contribution or even non-existent - and the O&M costs.

4. WATER CHARGES OR SCHEME RUNNING CHARGES?

With the present concern for water charges, the notion seems to spread that if proper funding is available for O&M activities the overall performance of the scheme will automatically improve and farmers will utilize the water better and increase their production. Although we do not deny that this may be the case in areas where farmers have great experience with irrigation water, there are many other instances - particularly in relation to new schemes - where this is not the case. In fact, even projects with a long life, when evaluated, prove that they have been suffering chronically from deficiencies which require major changes in the organizational structure and have substantial implication in the costs of running the scheme.

This may be better illustrated by the example of the Pisque Irrigation Scheme of Ecuador where a substantial effort has been made to prove that it is necessary to coordinate a large number of activities which go far beyond the operation and maintenance of the scheme in order to produce an authentic agricultural development in the project. In fact, in addition to strengthening the O&M Service the project has implemented the following services: (a) three workshops on mechanization, metalwork and woodwork; (b) a social department for implementing and encouraging the establishment of water users' associations; (c) an agriculture development department aimed at providing advice to farmers on irrigated agriculture; (d) a mechanization unit to rent services to farmers; (e) a revolving fund for fertilizers; (f) a fruit nursery; and (g) a reforestation service (the area is affected by serious erosion problems). The services for mechanization, fertilizers, the fruit nursery and reforestation have an autonomous management but all are coordinated within the "overall management of the scheme" where each of these units/departments is represented.

The total investment costs necessary to develop these services and to rehabilitate the irrigation system were US$ 1 087 per irrigated hectare (see Table 1) but 90 percent of these costs were invested in the rehabilitation of the irrigation scheme and only 10 percent in the facilities/equipment needed for the above described services. This indicates the importance of taking an integrated approach when attempting rehabilitation of an irrigation network, since the basis for suitable agricultural development can be established with relatively small additional investments.

Table 1 also describes the foreseen average annual expenses for a five-year period (1983-87) of each of the services provided and the expected revenues at the rates prevailing in 1983 and illustrates that some services are nearly self-financed (mechanization, fertilizers, fruit nursery, O&M) but others have large deficits, as they do not generate a visible income. The expected total deficit (12.1 million sucres) represents an increase of about 100 percent over the existing payments but amounts only to US$ 52/ha (at values of 1986). This increase in the rate permits the small deficit of the autonomous services to be absorbed, the financing of some rehabilitation works

and the financing of those services which are necessary but do not generate direct income.

The government had two alternatives, either to subsidize this deficit or increase the water charges to make up the difference. In this latter case, the water charge is no longer a charge for water but for running the scheme and providing some services which are indispensable to produce the expected agricultural development. This is particularly relevant when considering that more than 50 percent of the farmers have less than 1 hectare and therefore a reduced capacity to invest and improve their productivity.

The question raised here is whether it is more important to have "running of the scheme charges" or "water charges" when the overall final objective is to improve the performance on the entire scheme. The advantage of such rates is that a redistribution of the income takes place within the scheme, as all the farmers (small and large) pay for the services but the ones benefiting more directly should be small ones. Another advantage is the considerable employment generated (3 times more than for O&M activities, see Table 1), of people requiring a certain degree of technical specialization.

As to the farmers' capacity to pay for these additional services, the analysis of the margin (gross income less direct cost) indicated that the increase of the rate will only reduce the margin by 4 to 2 percent for the tomatoes and avocados and by 10 to 8 percent in the case of potatoes, maize and beans, which are the predominant crops of the scheme, and therefore the implementation of the suggested charge appears quite feasible.

5. RELATIVE IMPORTANCE OF THE WORKING RESOURCES IN THE AGGREGATION OF O&M COST

In order to analyse the possibilities for reducing O&M costs it is necessary to have a clear notion of the corresponding weight of the working resources in the aggregation of O&M costs. For this purpose their importance is analysed in the light of two examples (Tables 2 and 3) corresponding to the experience of selected irrigation schemes in Jamaica and the USA respectively.

5.1 Personnel Costs

For gravity irrigation schemes (RCIW[1] in Jamaica and all of them in the USA), this component is by far the largest, ranging in value from 63 to 71 percent of total expenditures[2]. Our experience from other countries is consistent with these figures and rarely goes below 50 percent of costs.

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[1] RCIW = Rio Cobre Irrigation Works.

[2] Much lower values are given for the Tulare and Lower Tule irrigation projects in Table 3 but these values are distorted by the high value of the "others" component under which large amounts of water have been purchased from other districts.

It is interesting to note that there is not much difference between the figures for developing and developed countries. Apparently the greater efficiency in the use of personnel in a developed country is offset by the greater salaries and travel costs.

As personnel is the largest component of the costs, the greater opportunity for reducing the O&M expenditures is in this item. Therefore particular attention should be paid to using staff in the most efficient manner. This indicates the importance of dedicating greater effort to determine manpower requirements for the major O&M activities so that overstaffing and related deficiencies can be more easily identified.

The other interesting implication is that personnel is a fixed cost (not depending on the amount of water used) and therefore greater or smaller efficiency in water distribution is bound to have a limited effect on the overall O&M costs. In other words, the water distribution efficiency is less important than the efficient use of the staff as far as costs are concerned in gravity irrigation systems. However, there are other technical considerations (shortage of water resources) which can invalidate or reverse this argument.

For irrigation schemes requiring pumping of all the water used the personnel component immediately loses its primary importance. In fact, Table 2 illustrates that in pumping schemes (SDIS, MCIA and HIA[1]) the personnel component is down to percentages that range between 13 and 23. This fact is analysed in more detail in the next section.

5.2 Energy Costs

The importance of energy costs in the total O&M expenditure is highly dependent on the total lift and the volume of water pumped. Therefore great variations in costs can be found. In the case of Jamaica, where the lift ranges between 15 and 35 metres and the amounts pumped are very large (see Table 2), the energy cost ranges from 61 to 73 percent of the total. Of course, the type of energy used (electricity or fuel oil) and the respective prices have a significant impact on the energy cost.

Not only do the energy costs represent an important component but they tend to increase the overall O&M costs. In the case of Jamaica, the O&M cost for the pumping schemes is more than 10 times that of gravity (RCIW). This may be an exaggerated difference due to some inefficiencies but costs are considerably higher.

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[1] SDIS = St. Dorothy Irrigation Authority
MCIA = Mid Claredon Irrigation Authority
HIA = Hounslow Irrigation Authority

As energy costs are highly dependent on the volume of water pumped, the most immediate way to reduce them is to minimize the water pumped. This can be achieved by maximizing the efficiency of the water distribution system as well as that of the water used on the farm. Contrary to what happens in gravity systems, the efficiency of the water distribution and use becomes the highest priority, if costs are to be reduced. Increasing the overall efficiency may require some efforts in terms of investment to improve the irrigation infrastructure as well as in farmers' training to reduce water use at farm levels. The trade-offs between these investments and the saving on energy costs need to be analyzed in each case.

5.3 Materials and Supplies

The weight of this component in the total O&M cost ranges from 10 to 22 percent for the surface irrigation schemes of Tables 2 and 3 (exceptions are made of Tulare and Lower Tule in which values are distorted by the "other" component). It is much smaller (4 to 8 percent) in pumping schemes. Therefore their impact on the overall O&M is in any case limited and savings/reductions made in this component are liable to have a limited effect as far as costs are concerned.

However, in some developing countries it may be important to use local materials and national supplies rather than imported ones, which are often not easily available or their importation requires long periods. These delays may have a more detrimental effect on the undertaking of certain activities than the greater or smaller cost of the item.

5.4 Equipment

The cost of equipment is made up of several components: depreciation, operating costs and repairs. The first item, as mentioned earlier, is rarely considered when reporting about equipment costs. In any case, the weight of this component appears surprisingly small for the two cases analysed, with values below 4 percent in most cases for gravity schemes. It is somewhat higher (9-12 percent) in the case of pumping schemes, which is logical as the amount of equipment (particularly pump-sets) is considerably larger.

If the above pattern is a generalized one it could be concluded that equipment has little impact on the overall costs and therefore offers little room for reducing costs. However, this apparent conclusion will need a more in-depth analysis to be generalized. To add complexity to this component, one has to realize that labour is often used to undertake some works that could be effected by equipment. The costs inherent to this labour may appear under "personnel", further distorting the weight of the two components.

5.5 Others

This is often a very small component but there are a few cases (Table 3, Tulare and Lower Tule scheme) when it can assume large values (over 50 percent of the total). This corresponds to the fact that sometimes a project has to buy water from another project where there is a surplus. As this water is often acquired at a high cost, the opportunity for reducing this purchase should be carefully studied.

6. RELATIVE IMPORTANCE OF O&M ACTIVITIES IN THE TOTAL O&M EXPENDITURE

Another way to look for possibilities of reducing O&M costs is to break down the total costs into major activities and analyse their weight in the total costs. This has been attempted in Table 4 and the following average distribution can be observed:

Operation	45%
Maintenance	24%
Monitoring/Supervision	6%
Administration	12%
Others	13%

Basically all the expenditures made for Operation correspond to personnel emoluments, therefore the remarks made earlier apply here.

The question can be raised here if the operation costs can be reduced by implementing an automatic system of water distribution (on demand). Although this appears possible, experience with "on demand" irrigation systems in developing countries has proved quite troublesome and perhaps the reduction in the operation cost has been largely compensated by an increase in repairs and the need for maintenance.

With regard to maintenance costs, the issue arises as to what extent it is worthwhile to line canals in order to reduce maintenance costs. To illustrate this, Table 5 shows that maintenance of lined canals or pipes is 34 percent cheaper than that of unlined canals. However, this lower cost has sometimes no apparent effect on the total maintenance costs. The Tulare scheme has a maintenance cost of US$ 20/ha (see Table 4) and 88 percent of the total length of the irrigation network (462 km) comprises unlined canals, while the San Joaquin scheme has 94 percent of the total length (560 km), is made of lined canals or pipes and has a maintenance cost of 23 US$/ha. On the other hand the Merced System has a lot of unlined canals and yet the maintenance cost is 35 US$/ha. These indicates that lining of canals tend to produce lower maintenance cost but there are other factors that may alter this conclusion.

Another important issue is the trade-offs between maintenance machinery and labour with particular reference to developing countries. Questions like what type of maintenance works can be more effectively carried out by labour or machinery have not been satisfactorily answered.

Monitoring and supervision costs are only 6 percent of the total but represent a very important activity. Rather than reducing this cost, efforts should be undertaken to make it really effective.

The administration cost is made up essentially of personnel. The reduction of this cost can be obtained by using simple operative procedures which will eventually require less staff. Complex administrative procedures and scarce automation of offices produce unnecessarily heavy administration costs. The use of personal computers with their reduced price could really help to reduce administration costs.

Finally, the question arises whether the above-mentioned distribution would be entirely different in a developing country. We have little information on this issue but indications are that the distribution is rather consistent, with a tendency to have greater values for O&M and much lower for the remaining components. This may be clarified by the country reports presented at the Consultation.

7. DELEGATING TO FARMERS THE RESPONSIBILITY FOR OPERATING SOME PARTS OF THE SYSTEM

If the governments of the developing world are forced to reduce public expenditures, it is likely that their contributions to O&M expenditures will be reduced in the future. In practice, this means that either the farmers will take over the entire responsibility for managing the irrigation, and this will certainly imply much higher water rates, or the farmers will take responsibility for only some parts of the water distribution system while governments keep the remaining part. This latter alternative seems to be logically preferred as delegating the responsibility for running a large scheme to farmers is not only a financial question but also a matter of having people suitably prepared to take up this difficult and complex burden.

In fact, in several Asian countries the operation and maintenance of tertiary and quaternary canals have already been transferred to farmers, as for example in Indonesia. What is the financial implication of this transfer of responsibility? Very little information is available on the topic but in order to have a first approximation of the cost involved, a theoretical calculation has been made in Annex 1 to evaluate the O&M costs of a tertiary canal under the Indonesian conditions.

The O&M costs for a certiary canal irrigating 150 ha are distributed as follows:

	Rp	%
Operation	81 000	9
Maintenance	735 000	80
Others	100 000	11
Total	916 000	100

The total expenditure represents a cost of Rp 6 106/ha (US$ 5.47/ha). This value is about 50 percent of the total government allocation for the O&M activities in the period 1984/85 (Rp 11 512/ha). This illustrates the importance of delegating the management of this part of the system to farmers under the Indonesian conditions. Another way to visualize this importance is that the mentioned cost per hectare is equivalent to 8/9 mandays/ha.

Indeed, a major effort is needed for evaluation under other conditions so as to see the consistency of these results. It is, however, interesting to note that in developed countries the tertiary canals are often lined or replaced by pipes requiring very little maintenance. Under these circumstances the transfer of this responsibility does not appear economically significant.

If farmers can operate tertiary canals satisfactorily, the question arises why not secondary, primary and eventually the whole water distribution system. This involves two sets of questions: one is the technical capability to do the work and the other is the economic advantage of doing so.

Experience elsewhere (Spain, Korea, Italy, USA, etc.) proves that farmers can run very large irrigation schemes but often long periods are needed for this complex activity to be fully transferred to them.

The economic advantage of this transfer to the farmers is not so clear, as for large irrigation systems a considerable number of professional and technical people are always needed and cannot be replaced by farmers. The advantage may be that these people, being responsible to farmers, are likely to perform more efficiently than the public servants but on the other hand in government-run schemes there are hidden subsidies for which the farmers do not pay. In our opinion the economic advantage is more for the government which divests itself of a heavy annual expenditure. The farmers gain is more in terms of self-reliance and independence to solve their own problems within a fully democratic system.

8. HOW TO INCREASE REVENUES TO FINANCE O&M COSTS?

In the former sections of this paper, we have been particularly concerned with the possibilities of reducing O&M costs but is there any chance of increasing revenues which can be utilized to finance these costs? Here are some ideas:

a. The irrigation water can be utilized for other purposes which can generate important revenues. In Thailand, for example, the small dams are utilized for fish production with considerable success. The revenues arising from this activity are distributed among the benefitting community and cover some costs of the O&M.

b. Maintenance machinery is often underutilized as it is dedicated only to the maintenance activities of the scheme. In some cases (Peru) the establishment of a machinery pool that also provides services to private people outside the system has proved a highly viable enterprise, reducing maintenance costs.

c. Can the irrigation system generate part of its energy requirements? Burning some agricultural residues (rice husks, straw, etc.) has proved a viable alternative in some cases. Some of the canals occasionally offer good conditions for mini-hydropower stations.

d. Why should farmers pay for all the irrigation costs when a much larger community benefits from the irrigation system? It is conceivable that any person trading with the irrigation scheme could pay a sort of "value added tax" that would be reverted to the scheme.

e. The value of irrigated land is much higher than the non-irrigated and, in many parts of the world, farmers do not reimburse irrigation investment costs. Therefore, when it becomes irrigable because of new irrigation systems and this land is later sold, the seller makes a large profit (since he has not returned the investment). It would be fair in such cases to impose a tax on the seller that could be reinvested/reused in the irrigation system.

There are certainly other possibilities but too little attention has been dedicated to them. It would be important to analyse and collect at least the existing successful experiences.

9. IMPACT OF IRRIGATION COSTS ON THE FARMER'S INCOME

It seems socially and economically correct that farmers pay for the services associated with the distribution of water, provided that these services are effective and there are no substantial mistakes in the design of the system which can take a heavy toll on the O&M costs. Nevertheless, this sound policy cannot be implemented in an indiscriminate manner, as there are many instances in which some of the farmers of a given irrigation system may not have the capacity to pay for the real O&M costs. Therefore it is always important to check the farmers' repayment capacity - particularly of those having smaller financial capacity - before proceeding to the implementation of water rates.

In order to better visualize the effect of irrigation costs on the income generated by crops, an example has been worked out in Table 6. All the data are taken from a detailed study of the crop production costs undertaken by the FAO/UNDP project "Development of Irrigated Agriculture Production" (PAN/81/011). The data correspond to the Herrera Region where average precipitation is 514 mm/year and temperature throughout the year is 26°C. Two different seasons can be differenciated: the wet season from May to November concentrates 95 percent of the rainfall and the dry season (December to April) the rest. Crop production is possible in both seasons provided the water requirements can be satisfied.

Three scenarios have been elaborated in order to see the effect of different water charges policies. The first scenario corresponds to a water charge of US$ 0.01/m³ which is considered a "fair charge" and includes a partial recovery of the investments. The second is considered as a "high price" (US$ 0.02/m³) and corresponds to the total recovery of investments in addition to O&M costs. Lastly, a flat rate per hectare and season of US$ 30 has been applied, which represents the present rate paid in some schemes. The conclusions for each scenario are discussed below.

i. First scenario (US$ 0.01/m³)

a. All the wet season (WS) crops have a higher income than the same crops grown in the dry season (DS). This appears logical as the DS crops have much higher irrigation requirements than the WS crops. This indicates that the O&M costs together with the labour irrigation costs heavily penalize the DS crops.

b. The impact of total irrigation cost on net income or on total production costs is very important for rice and maize while it is negligible for horticultural crops. This indicates that horticultural crops are only marginally affected by irrigation costs and therefore farmers using water for these crops are not likely to react to moderate changes in the charges for water. This raises the question of why to charge water per m³ in the case of horticultural crops if farmers are not financially motivated to save water.

c. Table 6 shows that the labour irrigation cost[1] is a very small component of the total costs. Therefore, the opportunity for replacing labour by some modern irrigation

[1] This refers to the cost of labour utilized for applying the irrigation water on the farm.

methods (localized, sprinkler, etc.) is very small. This is particularly relevant in developing countries where the cost corresponding to amortization of the equipment is likely to be higher than the labour irrigation costs. However, there may be other important reasons (limited water supply, unavailability of labour, reduction of effort, etc.) which may lead to the adoption of modern irrigation techniques.

ii. Second scenario (US$ 0.02/m³)

a. The application of this water charge implies that DS rice is uneconomical (negative net income) and DS maize generates a net income of only US$ 84/ha. The practical implication is that rice and maize cannot be grown economically during the dry season. The problem of what to grow instead becomes a serious one, since soils used for rice cannot be utilized for many other crops. Therefore a change in the water charge should not be implemented without carefully studying its effect on the crop pattern of the irrigation scheme.

b. This scenario stresses some of the conclusions (a and b) already described in the first scenario. It is interesting to note that at this price, there is no point in trying to become more efficient in the use of water for rice: a reduction of 40 percent of the irrigation requirements would still give a negative income.

iii. Third scenario (US$ 30/ha/season)

a. Under this hypothesis the total irrigation costs tend to augment for the wet season crops and decrease for the dry season crops. The result is that the net income of the wet season crops tends to be smaller (compared with the first scenario) while that of the dry season crops increases substantially. In fact, this alternative has some equilibrating effect on the irrigation costs between the wet and dry season crops, and also among the crops with high and low water requirements.

b. Under this alternative the dry season rice and maize again become profitable, while the income from horticultural crops is hardly affected. If the government policy is to produce rice and maize - as it was in the past in Panama - this water charge represents a viable alternative to increase, or at least not to reduce, the areas dedicated to their production.

This last scenario points out an interesting solution to the problem mentioned earlier of some farmers not having enough payment capacity to afford the real O&M cost. It would be conceivable that these farmers pay a much lower water charge than other farmers being in a better financial position. In a way this solution implies that

the "better-off" farmers to some extent subsidize the irrigation expenditures of the poorer farmers. For this purpose a flat rate per hectare appears a more useful tool than payment per cubic metre.

Although the above conclusions apply to a particular region of a given country, it is believed that similar important conclusions can be derived from the study of the production and irrigation costs of the different irrigated crops in other countries. This information would be extremely valuable when trying to determine suitable water charges.

TABLE 1

INVESTMENTS AND RUNNING COSTS OF THE PISQUE IRRIGATION PROJECT
(ECUADOR)

	Investment Rehabilitation & Improvement	Average annual expenditure (1983/87)	Average annual revenue (1983/87)	Financial Deficit	Number of persons employed
	.....	1 000 Sucres	.....		
1 General Administration	4 240	2 225	–	2 225	11
1 Topographical Surveys Unit	445	463	–	463	4
2 Workshop	2 981	1 753	–	1 753	13
3 Social Department	393	325	–	325	2
1 O&M of Irrigation Network	225 621	5 229	4 803	426	35
2 Agriculture Development Dept.	4 185	2 983	105	2 878	17
1 Agriculture Mechanization Dept.	4 491	1 393	1 168	225	6
2 Revolving Fund for Fertilizers	2 473	2 391	2 391	–	–
2 Fruit Development Programme	1 291	470	394	76	5
2 Reforestation Programme	5 539	4 261	2 882	1 379	18
1 Rehabilitation of canals (investment)	–	2 205	–	2 205	n.a.
3 Purchasing of land for nursery (investment)	–	190	–	190	n.a.
TOTAL	251 669	23 888	11 743	12 145	111
Average total cost per ha (Sucres)[1]	47 937	4 550	2 237	2 313	
Average total cost per ha (US$)[2]	1 087	103	51	52	
Actualized average cost per ha (US$)[3]	1 380	131	64	67	

Source: Nagant D "Organización y significación económica de un proyecto de riego - caso del proyecto Pisque Tropicultura, 1984, 2, 2, 60-66.

[1] Irrigated area: 5 250 ha
[2] At a rate of 1 US$ = 44,1 Sucres prevailing in 1983
[3] Actualized to 1983 with the US Bureau of Reclamation Index (1.27)

TABLE 2

O&M COSTS FROM SELECTED IRRIGATION SCHEMES
(JAMAICA)

	Unit	RCIW 1/	SDIA 1/	MCIA 1/	HIA 1/
Irrigable area	ha	14 200	1 900	4 500	800
Irrigated area	ha	9 400	1 130	2 830	670
Total water diverted/pumped	10 m³	111	20	75	7
Average water use	m³/ha	11 808	17 785	26 501	11 046
O&M Cost per Irrig. hectare:					
1. Personnel 4/	US$/ha,(%)	17 (71)	42 (13)	64 (16)	87 (23)
2. Material & supplies	US$/ha,(%)	4 (17)	15 (4)	31 (8)	16 (4)
3. Energy	US$/ha,(%)	1.5 (6)	230 (73)	281 (70)	233 (61)
4. Maint. of equipment	US$/ha,(%)	1 (4)	28 (9)	25 (6)	44 (12)
5. Others	US$/ha,(%)	0.5 (2)	-	4 (1)	-
6. Total O&M costs/ha	US$/ha	24	315	405	380
7. Total O&M costs/m³	US$/m³	0.2	1.8	1.5	3.6
Present water charge 3/	US$/m³	0.03	0.08	0.13	0.13

Source: Irrigation Water Pricing Policy and Tariffs, FAO, Oct. 1985 (ULG Consultants, Report)

1/ RCIW = Río Cobre Irrigation Works
SDIA = St. Dorothy Irrigation Authority
MCIA = Mid Claredon Irrigation Authority
HIA = Hounslow Irrigation Authority

2/ 1 US$ = 5.78 J$

3/ Irrigation water is sold by yd³/hour at following pices (1983 rates, still apply):
Río Cobre: 12J$/hour
Opens canals: 30 J$/hour
Pressure pipes: 50 J$/hour

4/ Includes travel and subsistence allowances.

TABLE 3

BREAKDOWN OF ANNUAL EXPENSES BY WORKING MEANS IN SELECTED IRRIGATION SCHEMES (USA)

	South San Joaquin		Merced		Tulare		Lower Tule	
	US$	%	US$	%	US%	%	US$	%
Personnel[1]	722 000	63	1 457 000	71	371 000	37	300 000	29
Materials	251 000	22	204 000	9,9	80 000	8,2	53 000	5,2
Equipment	10 000	0,8	46 000	2,2	17 000	1,7	91 000	9
Energy	49 000	4,3	188 000	9,2	0	0	0	0
Others	101 000	8,9	151 000	7,4	511 000[2]	52	567 000[2]	56
TOTALS	1 133 000		2 046 000		2 011 000		1 011 000	

Source: Operation, Maintenance and Repair of Selected Irrigation Systems, WB, AGR, Technical Note No.1, 1977

[1] Includes fringe benefits
[2] Includes costs of purchasing water from other districts

TABLE 4

OPERATION AND MAINTENANCE COSTS FROM SELECTED IRRIGATION SCHEMES
(USA)

	(1)	(2)		(3)		(4)		(5)		(6)		(7)	(8)	(9)	(10)
	Irrigated Area	O&M Costs per irrigated hectare											Water Diverted	Water Use/ha	O&M Cost per m³
		Op.[1]		Maint.		Sup. Eng.		Adm.		Others		TOTAL			
	(ha)	$	%	$	%	$	%	$	%	$	%	$	(10^6m³)	m³	(US$/m³)
South San Joaquin	26 308	46	46	23	23	12	12	20	20	-	-	100	394	15 000	0.7
Merced	46 676	27	26	35	34	5	5	9	9	25	25	102	849	18 200	0.6
Tulare	25 253	49	54	20	22	3	3	6	7	12	13	90	286	11 300	0.8
Lower Tule	35 490	42	64	12	18	2	3	8	12	3	2	66	331	9 300	0.7
TOTAL	133 727														
Mean Value	33 431	41	45	22	24	6	6	11	12	14	13	90		13 450	0.7

Source: Operation, Maintenance and Repair of Selected Irrigation Systems, WB, AGR, Technical Note No.1, 1979.

Notes

- Column (2): includes costs for water development (Pumping), purchased water and transmission and distribution.
- Original values were updated using the O&M index cost (1975 to 1986 = 2.33)

MAINTENANCE COSTS OF SPECIAL WORKS

	(1) San Joaquin		(2) Merced		(3) Tulare		(4) Lower Tule		(5) Size Range	(6) Mean Value
	Km[1]	$/Km	Km	$/Km	Km	$/Km	Km	$/Km	m³/s	US$/Km
Maintenance of unlined canals	32	1 085	812	1 113	411	1 361	326	1 511	1.5-28.0	1 267
Maintenance of lined canals	64	724	222	954	-		-		0.4-2.6	839
Maintenance of pipelines	464	897	171	894	56	642	-		0.2-0.7	811
Total lengh of canals/ pipes (Km)	560		1 195		467		326			
Total assets[2]/km	24 526		19 425		4 817		7 039			

Source: Operation, Maintenance and Repair of Selected Irrigation Schemes, WB; AGR, Technical Note No.1, 1979. Figures updated to 1986 using O&M index (2.33)

[1] Km refers to total length of canal/pipelines.
[2] Values of 1975

TABLE 6

IMPACT OF IRRIGATION COSTS ON TOTAL PRODUCTION COSTS AND INCOME
(Selected crops, Panama)[3]

	Rice		Maize		Horticulture Crops					
					Water melon		Peppers		Industrial tomato	
	W[1]	D[1]	W	D	W	D	W	D	W	D
First Scenario										
Water charge = 0.01 US$/m³										
1. Irrigation labour costs	31	90	15	53	16	53	5	42	7	44
2. Water charge	44	128	22	78	22	77	8	61	10	63
3. Total irrigation costs	75	218	37	161	38	130	13	103	17	107
4. Irrigation requirements	4 417	12 759	2 221	7 763	2 228	7 646	777	6 049	999	6 281
5. Total Production costs	986	1 129	520	644	1 558	1 636	3 226	3 316	2 631	2 721
6. Gross income	1 208	1 208	775	775	2 862	2 862	6 360	6 360	3 710	3 710
7. Net income	222	79	255	131	1 304	1 226	3 134	3 044	1 079	989
8. Total Irrig. costs/Tot. Prod. Costs (%)	8	19	7	25	2	8	1	3	1	4
9. Total Irrig. costs/Net income (%)	34	(-275)	15	(-123)	3	11	1	3	2	11
Second Scenario[2]										
Water charge = 0.02 US$/m³										
3. Total irrigation costs	119	345	59	208	60	206	21	163	27	170
5. Total production costs	1 030	1 256	542	691	1 580	1 712	3 234	3 376	2 641	2 784
7. Net income	178	(-122)	234	84	1 281	1 150	3 126	2 983	1 068	926
8. Tot. Irrig. Costs/Tot Prod. Costs (%)	12	27	11	30	4	12	1	5	1	6
9. Tot. Irrig. Costs/Net income (%)	67	(-283)	25	(-247)	5	18	1	5	3	19
Third Scenario[2]										
Water charge = 30 US$/ha/season										
3. Total irrigation costs	61	120	45	83	46	83	35	72	37	74
5. Total production costs	972	1 031	528	566	1 566	1 589	3 248	3 285	2 651	2 688
7. Net income	236	177	247	272	1 296	1 273	3 112	3 075	1 059	1 022
8. Tot Irrig. Costs/ Tot prod. Costs (%)	8	12	9	15	3	5	1	2	1	3
9. Tot. Irrig. Costs/Net income (%)	34	63	18	31	5	7	1	2	3	7

Source: Banco de Datos de Cuentas Normativas de Actividades Agropecuarias (Programa P.A.C.C.A.), Documento Técnico No.9. Proyecto de Desarrollo de la Agricultura bajo Riego (FAO/UNDP/PAN/81/011), Marzo 1985, Panamá.

[1] W = Wet Season; D = Dry Season

[2] For the second and third Scenario only horizontal lines that are different from the first scenario are reported

[3] All data from Herrera Region, Panama

ANNEX - I

ESTIMATED O&M COSTS FOR A TERTIARY CANAL (Indonesia)

1. DESCRIPTION

The total length of the tertiary canal is 2.5 km and that of the quaternary canals (field canals) is 12.5 km. The area served is 150 ha distributed in 175 farms. The average trapezoidial section of the tertiary canal is 0.7 m^2 capable of carrying a maximum flow of 0.5 m^3/s. The average section of the quaternary canals is 0.05 m^2 and they carry flows in the order of 20 l/s.

2. OPERATION COSTS

One ditchrider ("ulu-ulu") together with one helper can manage the water distribution within the area as it has suitable operating structures. The related annual cost is:

	Rupees
1 ditchrider (120 kg rice x 150 Rps/kg x 3 seasons)=	54 000
1 helper (60 kg rice x 150 Rps/kg x 3 seasons)=	27 000
	81 000

3. MAINTENANCE COSTS

The tertiary canal needs weed clearance every three months to keep it in proper working order. One man can clean 25 m/day of one side of the canal; therefore the labour required for one cleaning is:

$$\frac{2\ 500}{25} \times 2 = 200 \text{ mandays; for 4 times/year} = 800 \text{ mandays}$$

Quaternary canals also need four weedings per year and one worker can undertake 200-250 m/day. Therefore the labour requirements are:

$$\frac{12\ 500}{200} = 62.5 \text{ mandays/weeding; for 4 times/year} = 250 \text{ mandays}$$

The estimated maintenance cost is therefore:

1 050 mandays x 700 Rs/day = 735 000 Rps/year

4. OTHER COSTS

The undertaking of the above-mentioned O&M activities requires the existence of a water users' organization which has some costs in terms of supplies and material. Theses are estimated at 100 000 Rps per year.

5. TOTAL O&M COSTS

Operation:	81 000
Maintenance	735 000
Others	100 000
Total	916 000

This represents a cost per hectare of 6 106 Rps. (5.47 US$/ha) or approximately 8/9 mandays per hectare.

The allocation for O&M activities from the central government for the period 1984/85 was 11 512 Rps/ha, therefore the O&M costs of tertiary canals represent an important part (35%) of the total expenditure (176/8 Rps/ha).