Assessing Water Charges under Changing Institutional Irrigation Management in Pakistan: A Methodological Framework

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The Government of Pakistan has opted for institutional reforms for canal irrigation system of the country with a view to undertaking efficient operation and maintenance of the system and improving cost recovery. In the new reforms, the Farmers' Organisations will manage distributaries and minors and pay the cost of upstream water in full. The complex hierarchy of the system poses serious challenges for working out the cost of water delivery for various channels. The paper presents a methodological framework for assessing the recoverable O&M costs from the farmers benefiting from an irrigation network. Hakra 4-R Distributary in the Eastern Sadiqia Canal serves as an illustration. The methodology shows how the beneficiary farmers can share the costs of the system. Simple methods are provided for working out water rates on the basis of volume of water received, commanded area, and duration of the irrigation turn. Out of the three methods, the area-based and time-based water rates have comparative advantage over the volumetric water rates owing to the resource endowments of the farmers.

1. INTRODUCTION

In view of the rising costs, irrigation water in Pakistan has come to be heavily subsidised. Under the conditionality clauses of World Bank's structural adjustment programme, curtailment of all kinds of input subsidies was essential to reduce budgetary deficits and to ensure a sustainable development process in agriculture. As a consequence, cost recovery of irrigation system became an integral part of government policy in Pakistan in recent years.

To bridge the gap between revenue from irrigation and the outlays on system operation and maintenance (O&M), the Government decided to introduce institutional reforms. The reforms aim at restructuring the water delivery and cost recovery systems so that the Provincial Irrigation Departments (PIDs) would become Provincial Irrigation

and Drainage Authorities (PIDAs)[1] with full financial autonomy. The PIDAs will perform, *inter alia*, the tasks of receiving irrigation supplies at the barrages falling within the province and from inter-provincial sources or link canals. They will deliver the received water in agreed quantities to the various Area Water Boards (AWBs) and Farmers' Organisations (FOs).

The AWBs and the FOs have to become self-sustaining and self-sufficient to the extent of recovering full funding for maintaining canals and subsidiary drains within a stipulated period [Punjab (1997)]. The AWBs will be responsible for payment to the PIDA for the water received and for supply of water to the FOs. The expenditures incurred by the AWBs on purchase of water from PIDAs and the costs incurred on delivery of water to the FOs will be fully recovered from the FOs. Besides, FOs will also operate and maintain their distributary/minor at their own cost. They will need to assess and collect water charges from their member farmers for meeting their financial obligations to AWBs.

The financial obligations associated with cost of water delivery for the FOs will depend on the amount of expenditure incurred on the network upstream and locally at the distributary, and thus may vary from year to year. The FOs will need to assess the water charges every year and collect the same from farmers benefiting from the system. Besides, the administrative costs involved in assessment and collection of water charges will deserve consideration. The new mechanism of levying water charges may contrast sharply with the one currently in vogue.

How the Area Water Boards, FOs, and the benefiting farmers will share the O&M costs is an important issue that needs special attention in the changing context of irrigation management in the country. Each FO may decide to assess and levy water charges in accordance with the best-suited method in terms of its resource endowment, both human and financial.

The purpose of this paper is to present a methodological framework for assessing costs to be shared by AWBs and water charges for the farmers considering the monetary obligations. In order to achieve this objective, this paper spans over six sections. Section 2 gives a description of Pakistan's canal irrigation system. What costs are relevant and how they should be shared by FOs and the benefiting farmers are the issues underlying the methodological framework laid out and discussed in Section 3. An assessment of various methods of levying water charges is provided in Section 4. While Section 5 discusses data needs of effective estimation of water charges, the final section (Section 6) has a basis in the conclusions of this study.

The institutional reforms under consideration, however, are still in the inception phase. This constrains availability of the important information needed for working out water charges. Information regarding the area of operation of an AWB, its mechanism

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[1]For details, see the Provincial Irrigation and Drainage Authority Acts of Sindh, Punjab, and the NWFP provinces promulgated in 1997. [Sindh (1997); Punjab (1997); NWFP (1997)].

for incurring costs, distribution of staff time among various parts of the system, etc., is crucial for such an exercise but is not available yet. Therefore, an important underlying assumption of this paper is that each canal network emanating from a barrage will only share the costs incurred on that particular network. This also implies that the beneficiaries of public tubewells will pay for all the costs for the tubewells and the canal network will not be taxed for expensive O&M of the SCARPs. For each distributary/minor, the costs are considered in view of the irrigation network feeding that particular distributary/minor. In this paper, 4-R Distributary off-taking from the Hakra Branch Canal of the Eastern Sadiqia Canal is used as the reference distributary for an illustration of the methodology.

2. CANAL IRRIGATION SYSTEM OF PAKISTAN

Starting from the catchment areas of the Indus Basin and its tributaries, the irrigation system of Pakistan has three large reservoirs, namely Tarbela, Mangla, and Chashma. According to the Indus Water Treaty with India, Pakistan is not entitled to the waters of the Ravi and the Sutlej rivers. Therefore, several links canals have been constructed to divert supplies from upstream to downstream rivers. A network of ten link canals at present is in operation to ensure regular water supplies in the downstream rivers. The Chashma-Jhelum and the Taunsa-Punjnad link canals connect the Indus and the Jhelum rivers. The Upper Jhelum and the Rasul-Qadirabad link canals connect the Jhelum and the Chenab rivers. Likewise, the Marala-Ravi, the Upper Chenab, the Qadirabad-Balloki, the Trimu-Sidhnai, and the Haveli link canals attach the Chenab and the Ravi rivers. The Ravi and the Sutlej rivers are connected to each other by the Balloki-Sulemanki link canal.

There are forty-five main canals in the country which off-take from various barrages and feed various branch canals. The branch canals feed several distributaries and minors connected to farmers' watercourses through irrigation structures called *moghas.* The farmers' fields are supplied with irrigation water by following a fixed roster of turns or *(warabandi)*[2] agreed upon by the shareholders of the concerned watercourse. These warabandis also establish the water rights for the farmers who have managed to register the warabandi with the respective office of the Irrigation Department.

Several researchers have explained the different levels of the canal irrigation system of Pakistan. The most commonly used is that by [Uphoff (1986)]. Tailoring the hierarchy of the canal irrigation system to suit the new institutional structures of PIDAs, AWBs and FOs, the irrigation costs that need to be recovered can be studied functionally at the three socio-technical levels of the canal irrigation system.

[2]A comprehensive discussion on warabandi, its principles, and the actual situation in the field can be found in [Malhotra (1984); Makin (1987); Chaudhry and Young (1989); Bhatti and Kijni (1990); Merry (1990); Qureshi *et al.* (1994), and Bandaragoda and Saeed (1995)].

(1) The macro level comprises the irrigation system of the entire country. Nevertheless, irrigation is a provincial subject and, thus, needs to be studied for each province separately, including storage reservoirs, or dams which feed the downstream link canals, barrages, river headworks, main canals, and branch canals. This level is only meant for delivery of water to the distribution network and as such is not to be used for direct abstraction of water for irrigation purposes. Nevertheless, some outlets directly emanate from a few of the main and branch canals. Under the proposed reforms, the PIDAs will receive irrigation supplies at the barrages falling within the province and from inter-provincial sources or link canals and deliver the same in agreed quantities to the various AWBs in the province.

(2) The meso level involves the distribution system of distributaries and minors/sub-minors that are connected to the farmers watercourses through moghas or outlet structures. The FOs will manage the meso level of the irrigation system in the forthcoming reforms.

(3) The micro level refers to watercourses connected to field channels and ditches to irrigate the farmers' fields. Farmers are already managing their watercourses individually or jointly.

Using this functional description, the recoverable cost of irrigation water for a distributary would include the proportionate share of the distributary in the amount of water received or area served multiplied by the costs incurred at the macro level of the irrigation system during a given time-period, say a year. Besides, the FO will also incur costs on the O&M of the distributary.

Adopting this approach, the costs incurred on the entire canal irrigation network from above the watercourse to the catchment area of the river will be considered for recovery from the farmers who are entitled to use water from a watercourse. Such a cost-sharing principle would ensure equity in the sense that the water charges proposed at a specific macro, meso or micro level of the irrigation system would only include those costs that were somehow incurred to supply water to that particular irrigation system.

The Hakra 4-R distributary is one of the seventeen distributaries/minor channels off-taking from the Hakra Branch Canal, which itself is the tail of Eastern Sadiqia Canal emanating from Sulemanki Barrage at the Sutlej river. From this barrage, two other canals, namely, Fordwah and Pakpattan, also off-take. Besides the Sutlej river, the Sulemanki Barrage receives water from the Balloki-Sulemanki Link Canal that emanates from the Balloki Barrage at the Ravi river. Three link canals, i.e., the Marala-Ravi Link Canal, the Upper Chenab Link Canal, and the Qadirabad-Balloki (Q-B) Link Canal feed the Balloki Barrage. The Q-B link canal also feeds the Lower Chenab Canal through the LCC Feeder. The Chenab River at Qadirabad Barrage is fed by the water from the Khanki Barrage,

located upstream at the river, and the Rasool Qadirabad (R-Q) Link Canal, which off-takes from the Rasul Barrage at the Jhelum river. From the R-Q Link Canal, two other canals, the RP and the Lower Jhelum, also receive water. All the water stored at the Mangla Reservoir is distributed among three off-takes, i.e., the Upper Jhelum Link Canal (to Chenab), the R-Q Link Canal, or downstream in the Jhelum.

3. METHODOLOGY FOR CALCULATING COST OF WATER DELIVERY

The O&M costs for any particular canal or distributary comprise essentially two parts. One part of the costs is incurred locally and the other part is the contribution in the costs incurred upstream of the canal to deliver water or the price of upstream water. Adding up these two cost components, one can know how much the beneficiaries need to pay for irrigation water.

The O&M costs are generally categorised into the following elements by the Punjab PID [Ahmad (1996)].

> (a) Establishment charges, comprising salary and allowances of the staff; (b) Petrol, Oil, and Lubricants (POL) expenses include all kinds of expenditures needed to run the official vehicles; (c) Maintenance and Repairs (M&R) expenses include all public works expenditures incurred on the irrigation structures, except those for flood control; (d) Flood Control is the expenditure on strengthening of embankments of rivers, link canals, barrages, headworks, etc.; and (e) Others, including expenses on hospitals and clinics, small dams, excavator store division, research institute, hill torrents, waterlogging and salinity, administration, special revenue establishment, and the Punjab engineering academy establishment.

The cost of irrigation water has been worked out at the provincial level by using the financial allocations to the PIDs. Chaudhry (1986) has proposed the desirable cost recovery targets for Punjab and Sindh provinces on this basis. He has proposed the target level water charges, based on actual water applied to various crops, differentiating between the SCARP and Non-SCARP areas.

There is an inherent danger of levying water charges inequitably for cost recovery if the water applied is considered as a basis for levying water charges. In fact various distributaries draw water from different irrigation networks and have different water duties,[3] implying that the cost of delivery of water will differ from distributary to distributary. The actual amount of water applied to various crops may differ even within the same distributary command area because of soil and watercourse characteristics,

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[3]Water duty indicates the water allowance per thousand acres of culturable command area and varies between 2.84 cusecs/1000 acres for the Rohri Canal (Sindh) to 10 cusecs/1000 acres in case of the Lower Swat Canal (NWFP) [Bandaragoda and Rehman (1995)].

location of the watercourse at the distributary, location of the farm at the watercourse, topography of the area, etc. Thus, the amount of water applied would not be a good measure for estimation of water rates even for the farms located at various watercourses within the command area of the same distributary. As managing the available water efficiently is the responsibility of the users, the users should also share the conveyance losses. The amount of water supplied should serve as the basis for cost-sharing instead of the amount of water applied.

For estimating water charges for a specific distributary canal, all the costs need to be considered, starting from the reservoir and its catchment area. The sections below entail a model for working out the costs and contributions for various off-takes of a typical canal irrigation system fed by a reservoir built on a river.

Cost of Water Delivery for Link Canals and Barrages

PIDAs will receive water from barrages falling within the provinces and link canals [Punjab (1997)]. The summation of all of the O&M costs for the Mangla reservoir and its catchment area that feed the Jhelum river upto the Rasul Barrage will yield the total recoverable costs for the network fed by the reservoir. Apart from a contribution in the total costs up to the Rasul Barrage, the costs for the Chashma-Jhelum and the Taunsa-Punjnad link canals, which are located downstream of the Rasul Barrage, will be borne by the canal network located on the river downstream from this point.

The costs that accrue to the R-Q Link Canal will thus be distributed among the LJC, the RPC, and the Qadirabad Barrage proportionate to the amount of water received or area served. The total recoverable costs at Qadirabad Barrage will consist of the share in costs for water delivery from the Chenab river plus the share in the R-Q link canal's O&M. The recoverable costs at the Balloki Barrage will consist of the share of the barrage in upstream costs of the Ravi river plus the costs that accrue to the Q-B link canal net of the contribution by the LCC feeder. The downstream Ravi, the LBDC, and the B-S link canal will share these costs. At the Sulemanki Barrage, the cost of water (Cs) will consist of the upstream costs incurred to supply water through the Sutlej plus the costs of the B-S Link Canal.

The costs incurred at the Sulemanki Barrage ($Co\&m_s$) also need to be added in the cost of water delivery. Thus the total costs recoverable from the beneficiary canals of the Sulemanki Barrage (Ct_s) will be

$$Ct_s = Cs + Co\&m_s \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad (1)$$

Cost of Water Delivery for Canals

All the off-takes will have to share Ct_s in proportion to the amount of

respective water withdrawals from the barrage. Thus, the conveyance losses will be shared among the off-taking canals proportionately as well.

The cost of water delivery for ith canal (Cu_i) can be obtained by Equation 2.

$$Cu_i = Ct_s * (Qc_i \div \Sigma\, Qc_i) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

where

Cu_I is the upstream Q&M cost for the ith canal;

Ct_s is the total Q&M costs of the Sulemanki Headworks including cost of water delivery;

Qc_I is the total amount of water diverted to the ith canal during the period; and

$\Sigma\, Qc_i$ is the total amount of water diverted from the headworks to i number of canals during the period.

Tailoring Equation (2) for Eastern Sadiqia Canal, we get

$$Cu_{es} = Ct_s * (Qc_{es} \div Q_s) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

where

Cu_{es} is the cost of water delivery for Eastern Sadiqia Canal;

Ct_s is the total O&M costs at Sulemanki Headworks including cost of water delivery;

Qc_{es} is the amount of water diverted to Eastern Sadiqia Canal during the period; and

Q_s is the total water delivered from Sulemanki Headworks to its off-taking canals.

The total O&M costs for the Eastern Sadiqia canal would then be

$$C_{es} = Cu_{es} + Cl_{es} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

where

C_{es} is the total O&M cost for the Eastern Sadiqia canal;

Cu_{es} is the contribution of the Eastern Sadiqia canal in upstream O&M costs; and

Cl_{es} is the O&M costs incurred locally at the canal.

Cost of Water Delivery for Branch Canals

The cost of water delivery for ith branch canal (Cu_{bi}) off-taking from the Eastern Sadiqia canal can be obtained by Equation 5.

$$Cu_{bi} = C_{es} * (Qb_i \div Q_{es}) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

where

  Cu_{bi} is the upstream cost of water delivery for the ith branch canal;

  C_{es} is the total cost of the Eastern Sadiqia canal;

  Qb_i is the total amount of water diverted to the ith branch canal during the period; and

  Q_{es} is the total amount of water diverted from Eastern Sadiqia Canal to its off-takes during the period.

Tailoring Equation 5 for the Hakra Branch Canal, we get

$$Cu_h = C_{es} * (Q_h \div Q_{es}) \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (6)$$

the total O&M costs for the Hakra Branch Canal would then be

$$C_h \;=\; Cu_h \;+\; Cl_h \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (7)$$

where

  C_h is the total O&M cost for the Hakra Branch Canal;

  Cu_h is the contribution of the Hakra in upstream O&M costs; and

  Cl_h is the O&M costs incurred locally at the canal.

Cost of Water Delivery for Distributary Canals

The contribution in upstream O&M costs for ith distributary canal (Cdu_i) off-taking from the Hakra Branch can be obtained by Equation 8.

$$Cud_i \;=\; C_h * (Qd_i \div Qn) \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (8)$$

where

  Cud_i is the upstream O&M cost for the ith distributary canal;

  C_h is the total O&M costs of the Hakra Branch Canal;

  Qd_i is the total amount of water diverted to the ith distributary canal during the period; and

  Q_h is the total amount of water directly diverted from the Hakra branch canal to various distributries/minors/outlets during the period.

For 4-R Distributary, the above equation can be written as

$$Cu_{4\text{-}R} \;=\; C_h * (Q_{4\text{-}R} \div Q_h) \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (9)$$

where

Cu_{4-R} is the upstream O&M cost for the 4-*R* distributary canal;

C_h is the total O&M costs of the Hakra Branch Canal;

Q_{4-R} is the total amount of water diverted to the 4-*R* Distributary Canal during the period; and

Q_h is the total amount of water directly diverted from the Hakra branch canal to various distributaries/minors/outlets during the period.

The total O&M costs for the 4-*R* Distributary Canal would then be

$$C_{4-R} \ = \ Cu_{4-R} \ + \ Cl_{4-R} \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (10)$$

where

C_{4-R} is the total recoverable costs for the 4-*R* Distributary Canal;

Cu_{4-R} is the cost of water for the 4-*R* Distributary Canal; and

Cl_{4-R} is the O&M costs incurred locally at the distributary canal.

Thus the amount that needs to be translated into the water charges (desired level of cost recovery) would be C_{4-R} which is illustrated empirically in the following sub-section.

Empirical Estimation of the O&M Costs of Irrigation System

The Punjab Irrigation Department (PID) maintains statistics of the canals and distributaries regarding water supplies during various months to various channels, and annual maintenance costs incurred therein. However, the information is generally inaccessible as the Department has stopped publishing this information since 1988 owing to unknown reasons. The water supplies and costs for the link canals, in any case, are not available in such publications. It is, therefore, extremely difficult to calculate these costs. Due to the paucity of information, the analysis in this paper is restricted to the Eastern Sadiqia Canal and downstream, assuming that the O&M costs of the link canals are to be borne by the users other than agricultural irrigation.[4]

The total O&M costs of the Eastern Sadiqia Canal, the Hakra Branch Canal and the 4-R Distributary are presented in Table 1. The O&M expenses, as already defined, have been done in Section 3. Since the PID record keeps account of expenditures on the basis of irrigation administrative units (divisions/sub-divisions), it becomes well nigh impossible to isolate the costs for a typical irrigation channel. Therefore, for obtaining the cost estimates, the allocative ratios have been used for minors, distributaries, branches, and the main canals.

[4]The canal water is also used for power generation, aquaculture, and industrial and domestic purposes.

Table 1

Average Annual O&M Costs for Various Components of
the Eastern Sadiqia Canal System

Level of the System	Total Designed Outflow (cusecs)	Total Culturable Command Area (ha)	Total Annual O&M Cost* (Rs)
Eastern Sadiqia Canal	4,547	386,917	2,270,553
Hakra Canal	2,351	212,228	3,836,701
4-R Distributary	193	17,575	1,948,318

Source: Authors' calculations based on Annexes ii, and ix of Mudasser (1997).
        *Average of expenses for 1994-95 and 1995-96.

The total cost that has to be borne by the users located at the Hakra 4-R Distributary would comprise the O&M costs incurred at the distributary, and a part of the costs incurred at each of the Eastern Sadiqia Canal and the Hakra Branch Canal. The costs can be added using our definitional Equations.

Under our assumptions, the value of C_{es} in Equation (4) is around 2.3 million rupees. Replacing the value of C_{es} in Equation (6), we get

$$C_{uh} = 2270553 * (2351 \div 4547) = 1,173,976 \text{ rupees.}$$

For the Hakra Branch, the total cost of water delivery, according to Equation (7) would then be

$$C_h = 1173976 + 3836701 + 5,010,677 \text{ rupees.}$$

Similarly, the value of upstream costs for the 4-R Distributary (C_{u4-R}) can be calculated by Equation (9) as given below:

$$C_{u4-R} = 5010677 * (193 \div 2351) = 411,340 \text{ rupees.}$$

The total recoverable cost from the farmers can be calculated by employing Equation (10) as below:

$$C_{4-R} = 411,340 + 1,948,318 + 2,359,658 \text{ rupees.}$$

4. ESTIMATION OF WATER CHARGES

At least three structures for levying water charges can be identified in the context of Pakistan's canal irrigation system. The water charges can be based on the volume of water supplied to various farms, the duration of the irrigation turn, or the commanded or cropped area. Each of these structures is discussed in the following sub-sections. The

underlying principle is that to share the costs of delivery of water, the farmers should pay in proportion to the amount of water they receive from the irrigation network.

Volume-based Water Rates (metred rates)

The volumetric water rates represent the direct relationship between irrigation water received (and thus applied) and its prices [Chaudhry *et al.* (1993)]. It is due to the direct relationship that many researchers [Gotsch and Falcon (1970); Hufbauer and Akhtar (1970); Lewis (1969); Sampath (1992) and Swendsen (1986)] have highlighted the need for imposing volumetric rates.

The water received by the *i*th farm can be assessed by multiplying the inflow received (q_i) at the particular farm with the duration (t_i) for which the water application was carried out. Thus the total volume of water at the *i*th farm (V_i) during a particular period would be:

$$V_i = q_i * t_i \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (11)$$

The total volume of water received by the farm during the entire period under consideration (*Vi*) can be obtained by summation of all the v_is. If there are *N* farms at the distributary, the total amount of water supplied to all the farms during the reference period can be obtained by multiplying *Vi* with *N*. The average water charge per unit of water received by the farmers in the distributary command area can then be calculated by Equation 12.

$$R_v = C_{4\text{-}R} \div (N * Vi) \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (12)$$

where

R_v is the water rate per unit of water supplied;

Vi is the total amount of water supplied to the *i*th field during the reference period;

N is the total number of farms irrigated from the distributary; and

$C_{4\text{-}R}$ is the total recoverable cost for the distributary.

This rate can be applied at a flat rate; at a flat rate but differentiated by peak and low demand periods or seasons; and at a block rate, which results in a rate change when water is used beyond a certain amount.

This structure of water rates ensures a high degree of equity for levying water charges but it also demands regular monitoring of every farm in terms of duration of irrigation application and discharge of water. Estimation of the actual amount of water input, for different crops under extremely variable discharges at the distributaries and within watercourses, needs enormous financial and human input. One needs to monitor

the discharges regularly. The discharge monitoring is an expensive exercise. Since the irrigation system at the distributary level is more sensitive to upstream water levels [Mahbub and Gulhathi (1951)], it will need to be carried out at the distributary and outlet head, and at the farmgate. This option, being expensive and laborious, thus, would not be cost-effective due to high investment costs involved in equipment and manpower.[5]

The construction of the outlet structures allows only for a fixed discharge of water per unit of time as observed by Wolf (1986). Therefore, it can be assumed that all the farmers at a watercourse will be equally affected by any variation in the distributary water flow. Thus, the water charges can be based on the design of various outlets, if these are calibrated. If the outlet structure of the ith watercourse allows qi units of volume of water per unit of time, the amount of water charges to be paid by all the farmers on that watercourse can be calculated by Equation 13. This amount can then be shared as proportionate to the landholdings of the farmers within the watercourse command.

$$Rv_i \; = \; C_{4\text{-}R} \; * \; (q_i \div \Sigma \; q_i) \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (13)$$

where

Rv_i is the total amount of water charges to borne by the farmers of the *i*th watercourse;

q_i is the design discharge of the *i*th outlet; and

Σq_i is the sum of design discharges of all the outlets emanating from the *i*th distributary.

Area-based Water Charges

Water charges can also be levied based on the area since the water allowance for a specific distributary and its watercourses is based on the culturable area within the command area. The farmer's landholding is regarded as the Gross Command Area (GCA). After subtracting the uncultivable area from the GCA, the Culturable Command Area (CCA) is obtained and it forms the basis for fixation of the water rights for a specific farmer. The summation of CCA of all the shareholders of the watercourse forms the CCA of the watercourse, and the design discharge for the watercourse is fixed in accordance with the total CCA on that watercourse. The authorised discharge of the distributary channel is based on the sum total of CCA of the individual watercourses of the distributary, after adjusting for the seepage losses. The average water charges per

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[5]The estimated costs of water installations are not available but there is consensus in Pakistan that the installation and maintenance of meters will be a costly affair [Lewis (1969); Hufbauer and Akhtar (1970) and Chaudhry (1986)]. This would be especially true as meters could be easily stolen and tempered in the far-flung rural areas.

unit of culturable command area (R_{cca} can be calculated by using Equation (14).

$$R_{cca} = C_{4\text{-}R} \div \Sigma \; CCA_i \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (14)$$

where

$\Sigma \; CCA_i$ is sum of total culturable command areas of all the outlets emanating from the distributary.

Similarly, water charges per cropped acre of crop c (R_{ca} can be calculated by Equation (15).

$$R_{ca} = C_{4\text{-}R} * (P_c \div \Sigma \; CA) \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (15)$$

where

P_c is the proportion of the distributary command area planted with crop c out of the total area planted during the reference period; and

$\Sigma \; CA$ is the total command area of the distributary planted with crop c during the period.

The crop-based water charges are already being criticised on several grounds, such as fostering under-assessment owing to under-reporting of crop and area statistics by assessment officials [Johenson *et al.* (1977); Pakistan (1990); Mudasser (1997)]. Lack of a direct relationship between the crop-based water charges and the use of water constrains efficient use of water. Therefore, the crop-based water charges can not be expected to perform rational allocative functions.

The water rates based on culturable command area have been advocated as a close proxy for volumetric charges [Chaudhry *et al.* (1993); Pakistan (1988)]. They are believed to encourage an efficient use of land and water since they would leave the decision regarding crop choices with the farmers based on a fixed water supply. Besides, the administrative costs involved in assessment would decrease substantially. Levying the water charges on commanded area will, nevertheless, require reconsidering the current allocational rules for double-cropped areas, additional supplies to orchards, etc., as these areas will obviously use more water but will pay charges equivalent to a single crop area. There is also a strong implicit assumption in levying area-based water rates that the water availability is normal and constant temporally and spatially. This assumption in practice does not hold as there are frequent variations in discharges received even within a day. Besides, there is usually inequity in distribution of water at and among distributaries. The proposal, therefore, will have economic feasibility only if water supplies per unit of command area on average are equitably distributed across various distributaries and water courses.

Time-based Water Rates

In the given warabandi system of water allocation, it is possible to charge for canal irrigation water in terms of duration of the irrigation turn. This is close to a flat rate water charge based on a culturable command area because the time allocation is also based on area. Besides, the additional irrigation time given for orchards can also be charged through these water charges.

Depending on the design discharge of an outlet and the number of shareholders, each shareholder of land has been allocated an irrigation turn in proportion to his commanded area. The roster of irrigation turn completes one cycle from head to tail in 168 hours (one week) in some parts and 252 (10.50 days) hours in other parts of the country. The allowances for watercourse filling and draining times are specified for deserving shareholders in the irrigation rosters. In an experiment for levying time-based water charges in Haryana [Malhotra (1980)] the net irrigation turn (of watercourse draining and filling time) was used to levy the water charges.

Ideally, the supply of water should be monitored with respect to discharge and duration, as there are frequent variations in the flow pattern due to upstream disturbances. Ignoring these variations by assuming that all the users are affected equally across the entire distributary, water charges per hour of currently allocated net irrigation turn (Rt_j) on a particular watercourse j with a design discharge Q_{oj} can be computed by Equation (16).

$$Rt_j = C_{4-R} * (Q_{oj} \div \Sigma W_o) * (1 \div k) \quad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (16)$$

Where

ΣW_o is the total authorised withdrawal (sum of design discharges of all the outlets drawing water from the distributary);

k is a constant number and is equal to the total length of the rotation cycle of the net irrigation turns on the particular watercourse in hours.

The administrative costs involved in this method are obviously very low, as is the case with commanded area-based water charges. This method also has similar advantages in inducing efficiency in use of water by the users, as is the case with water charges based on commanded area.

5. DATA REQUIREMENTS AND CONSTRAINTS

The data requirements for the purposes of estimation of water rates for a particular distributary are not too demanding. What is needed is an account of costs apportioned separately for all levels of the irrigation system. Similarly, an account of the amount of water deliveries from the source to various off-takes would be needed.

Yet, availability of the required data may be constrained due to a number of reasons. First, a number of canals are managed by the same administrative unit such as an irrigation division, which may continue for quite some time in the future as well, thus making it impossible to identify costs associated with a single off-take [Mudasser (1997)]. Only a few of the maintenance costs that are directly incurred on the physical improvement of a part of the system can be identified as direct costs. Similarly, the PID staff of an administrative unit can not explicitly distribute its time among various off-takes. The best possible option would be to divide the total O&M costs among various off-takes in proportion to the amount of water withdrawals. This method, nevertheless, has its own limitations. For instance, if an off-take is inundated during a flood to save other off-takes and structures, the water will not only be charged but also will have negative benefits for the farmers on that channel. Likewise, the account of water flows into various channels is not recorded with great accuracy. A number of irrigation structures in the canal network had been calibrated quite some time. Their respective discharge tables have now become almost obsolete due to continuous silt deposition in the parent and off-taking channels. It can be argued that the installation of volumetric devices up to the distributary headworks will be useful for keeping the procedures transparent. The individual FOs may decide for themselves about the structures for levying the water charges.

6. CONCLUSIONS

The role of institutional reforms in improving irrigation cost recovery is crucial. However, the success of the reforms largely depends on the future roles assigned to the FOs and AWBs. The equity considerations stress that the farmers be charged only for the costs incurred to supply water to them, but the apportionment of O&M costs among various distributaries and minors poses a great challenge to the researchers. Among the three structures presented above, the volumetric method of assessing water charges is the most efficient but not convenient owing to the heavy technical and investment requirements. Crop-based water charges have already been experienced and not found suitable. There is little justification for retaining this method which requires intensive crop surveys and induces personal biases in assessment. The water rates based on commanded area and duration of irrigation turn seem to be best suited. The groundwork for data collection about the commanded areas and irrigation turns can be done relatively easily by processing the already existing official records or field reconnaissance surveys. Due to simple arithmetic calculations, these can easily be undertaken by the farmers' organisations as well. Use of the commanded area method certainly looks more productive as farmers are usually aware of each other's commanded area and thus will keep a check on each other.

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