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Privatizing Public Irrigation Tubewells in Pakistan: An Appraisal of Alternatives

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As part of its broader groundwater privatization programme, the Government of Pakistan is seeking to transfer to the private sector the management, operation, and maintenance functions of the system of public tubewells (called "SCARPs") which were installed to control waterlogging and salinity. This paper presents a micro level analysis of alternative privatization strategies. Linear programming models of representative farms in SCARP I area of Punjab Province were developed to explore the efficiency and equity implications of various transition options. Net benefits of supplemental water available from SCARP tubewells were estimated at about Rs 800 per acre, which are about three times higher than the existing level of O&M expenditure. Even without considering the long-term benefits of waterlogging control, this result implies that the SCARP programme has a high social rate of return. For particular SCARP tubewells which are uneconomical to repair and operate, replacing these tubewells with farmer-owned small tubewells appears likely to improve agricultural productivity and reduce government outlays. Operable SCARP tubewells should be kept in service unless they are replaced by equal or greater alternative pumping capacity in the private sector to prevent waterlogging. Rural institutions should be strengthened to ensure efficient local level groundwater management.

INTRODUCTION

Most of Pakistan's food and fibre are produced from the Indus irrigation system developed over the last century. Lack of appropriate drainage facilities has caused severe waterlogging and soil salinization over large areas, particularly in Punjab and Sind provinces. This problem was addressed beginning in the early 1960s by a vertical drainage programme called the Salinity Control and Reclamation Project (SCARP). Presently, about 12,500 SCARP tubewells (having a capacity of 3–5 cubic feet per second) are serving about 7.4 million acres, which is about 20 percent of the Indus Basin's cultivable area. Almost all of the completed projects are located in fresh groundwater (FGW) areas, implying that provision of supplemental water has emerged as a primary objective of these tubewells in addition to

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meeting drainage requirements. Estimated cost of completed and under-construction SCARP projects is US $ 5.5 and 1.2 billion in current prices [World Bank (1986)].

Although the water-table has been successfully lowered by public tubewells and private groundwater development, only a small fraction of the salt-affected soils has been completely reclaimed [Government of Pakistan (1988)]. Nevertheless, crop productivity has improved.[1] Bokhari (1980) noted that the waterlogging relief provided by SCARP tubewells seemed to vanish whenever a tubewell had to be abandoned (such as from high salinity or mechanical break-down). However, water-table decline and agricultural production improvements which have occurred in SCARP areas cannot be attributed only to installation of public tubewells, as significant growth in private tubewells has taken place and the production technology has improved as well [Johnson (1982)].

A number of reports attest to the falling productivity of SCARP tubewells. Several technical, financial, institutional, and management reasons have been put forth. Evaluations based on technological considerations indicated that inadequate design, construction, and maintenance of screens and gravel packs have resulted in low capacity utilization rates [HARZA (1978); WAPDA (1979)]. Inadequate funding for tubewell replacement and O&M have also hampered the performance of SCARP tubewells. A tight budget is the principal reason for inadequately funded tubewell maintenance, a situation not improved by the policy of not charging the producers the full cost of water. However, even when funds were available, a slow, cumbersome, and centralized decision-making process often caused unnecessary delay in returning inoperative wells to service [Ali *et al.* (1981)].

The public tubewells take up about 60 percent of the country's irrigation operation and maintenance (O&M) budget. Most of this is for electrical energy. Subsidies on SCARP tubewell water have been a source of major concern in recent years. Allocating more funds for O&M of SCARP tubewells means availability of less money for O&M of the country's vast surface irrigation system. The resulting deferred maintenance has a very high social cost [Chaudhry and Ali (1989)].

Throughout the world, governments are turning increasingly to private provision of services previously performed by the public sector. Privatization is expected to yield a more efficient way of achieving public objectives and to reduce the outlays made by the central government. Roth (1987) broadly surveys the issues facing developing countries as they surrender to decentralization programmes. Hanke (1987) provides an optimistic assessment of the prospects for privatization.

The pronounced success of private tubewells in FGW zones, serious O&M

[1] How much of the increase in crop yields is a function of new high-yielding varieties and what percentage is a function of additional groundwater supplies are unknown [S. H. Johnson III (1982)]. Moreover, the contribution of waterlogging and salinity control is also unknown.

problems associated with public tubewells, severe budgetary constraints, and failure of SCARP tubewells to provide reliable supplemental irrigation at a sustainable cost have been the important factors in the emergence of "SCARP privatization concept". The proposal suggests gradually shifting the responsibility for groundwater extraction from government to farmers. The economic rationale behind this policy objective is to maximize social benefits from conjunctive groundwater use while at the same time reducing the government outlays for O&M. The commendable role played by private tubewells in controlling the water-table and providing supplemental water for irrigation purposes lent further support to the privatization concept.

Against this background, the GOP initiated a SCARP Transition Project in Khanqah Dogran unit of SCARP I in 1986.[2] In the absence of prior experience, it was not known exactly how the farmers and institutions would participate in or respond to this concept, or what would be the impact of this transition on the farmers' income, or how this transition would affect the water-table. Therefore, the project was designed on a pilot basis to assess its replicability in other SCARP areas having FGW supplies. The pilot project cost Rs 380 million for the replacement of 213 tubewells. According to a government report, this cost is exorbitantly high and includes a high foreign exchange component which is unnecessary [Government of Pakistan (1988)]. At this rate replacement of 7500 useable groundwater SCARP tubewells would cost about Rs 13,500 million. Therefore, replicability of this approach to other areas is highly doubtful, which underscores the need to examine alternative options.

The purpose of this study is to develop a farm model and to explore the allocative efficiency and equity implications of various SCARP transition options at the farm level, considering the altered water supply that would be available under each option. Efficiency is measured by an approximation to producer's surplus. Our analysis does not directly deal with waterlogging and salinity benefits, but assumes that profitability of groundwater use serves as a lower bound on collective profitability.

ALTERNATIVE APPROACHES TO PRIVATIZATION

Various options evaluated in this study are discussed below. Macro-level possible outcomes which may follow as a result of implementing these options are also mentioned. We summarize the water supply and institutional attributes of the various options in Table 1. The distributional effects of the various options depend,

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[2] The project aims to replace 213 SCARP tubewells with 1050 small capacity, farmer-owned tubewells in the project area. The World Bank is providing financial and technical assistance for the project.

Table 1

Water Supply and Institutional Assumptions used in the Analysis of Various Transition Options

Transition Option	Source of Water Supply[a]	Annual Water Availability (Acre Inches)	Cost Bearing Agency (Government or Farmers or Private Groups)	Possible Changes in Institutional Arrangements	Probable Impacts on		
					Water-table	Agric. Output	Govt's O&M Budget Deficit
Continuation	CN, GT, PT	284.47	Government for CN and GT; and Farmers for PT.	No Change in Existing Institutions.	b	b	Increase
Termination							
Case 1	CN, PT	173.63	Government for CN; and Farmers for PT.	No Change in Existing Institutions.	Rise	Decrease	Decrease
Case 2	CN, PT	201.06	Government for CN; and Farmers for PT.	No Change in Existing Institutions.	Rise	Decrease	Decrease
Transfer							
Case 1	CN, GT, PT	346.43	Government for CN and Rehabilitation of GT; Private Groups for O&M of GT; and Farmers for PT.	Local Level Groups are Formed to Take up O&M Functions of GT.	Drop	Increase	Increase
Case 2	CN, GT, PT	346.43	Government for CN; Farmers for PT and Private Groups for Rehabilitation and O&M of GT.	Local Level Groups are Formed to Take up Rehabilitation and O&M functions of GT.	Drop	Increase	Decrease

Continued –

Table 1 – (*Continued*)

Replacement							
Case 1	CN, PT	449.72	Government for CN; and Farmers for PT.	No Change in Existing Institutions.	Drop	Increase	Decrease
Case 2	CN, PT	1357.72	Government for CN; and Farmers for PT.	Water Markets would Develop Permitting Frequent Sale and Purchase of Groundwater in Study Area.	Drop	Increase	Decrease
Case 3	CN, PT	447.33	Government for CN; and Farmers for PT.	Water Markets would Develop Permitting Frequent Sale and Purchase of Groundwater in Study Area.	Drop	Increase	Decrease
Improvement							
Case 1	CN, GT, PT	295.54	Government for CN and GT; and Farmers for PT.	Management Improvements in O&M of GT through Better Economic Incentives to PID Staff.	Rise	Increase	Increase
Case 2	CN, GT, PT	320.69	Government for CN and GT; and Farmers for PT.	Physical Improvements in Water Delivery System.	Rise	Increase	Increase

Continued –

Table 1 – (*Continued*)

Transition Option	Source of Water Supply[a]	Annual Water Availability (Acre Inches)	Cost Bearing Agency (Government or Farmers or Private Groups)	Possible Changes in Institutional Arrangements	Probable Impacts on Water-table	Probable Impacts on Agric. Output	Probable Impacts on Govt's O&M Budget Deficit
Case 3	CN, GT, PT	334.18	Government for CN and GT; and Farmers for PT.	Management Improvements in O&M of GT through]Better Economic Incentives to PID Staff; and Physical Improvements in Water Delivery System.	Rise	Increase	Increase

[a] CN = Canal, GT = Government Tubewell, PT = Private Tubewell.

[b] Existing situation.

of course, on the working rules (including water prices) adopted by those sharing the water. Numerous such rules could be envisioned, each with specific impact.

Continuation of Existing SCARP Programme ("Continuation")

This option assumes that SCARP tubewells would continue to operate. Further, no change in existing institutional arrangements is assumed. Farmers would continue to receive water from SCARP tubewells, canals, and private tubewells already installed in the project area. The government would bear the cost for supplying water from public tubewells and canals. Farmers would bear the cost of private tubewell water, whether pumping it themselves or purchasing from neighbours. As a result of this option, not only would O&M subsidies continue, but the canal system would be undermaintained since a higher proportion of the total O&M budget would be diverted towards the maintenance of the public tubewells.

Complete Termination of SCARP Programme ("Termination")

SCARP tubewells in this scenario are considered to be terminated or abandoned. The farmer would receive only the amount of water provided by canals and by those private tubewells operating at the time when SCARP tubewells are terminated. There would be no change in the existing institutions. Under this scenario, crop production is likely to be effected adversely due to inadequate water supply. The government would be relieved from heavy financial strains and, as such, relatively more funds would be available for O&M of the canal system.[3] As a result of the decline in groundwater pumpage, the water table will be expected to rise, which in turn will cause damage to the land and to crop production. We have analyzed two cases under this option. Case 1 assumes no change in the existing utilization rate of the private tubewells (12 percent). Since the demand for supplemental water is likely to increase in the absence of SCARP tubewells, the annual utilization rate of private tubewells was raised to 15 percent in case 2.

Transfer to Private Ownership ("Transfer")

Management and operation functions regarding SCARP tubewells are assumed to be transferred to some private entity, such as an individual farmer, farmer associations, a village-level cooperative, or a commercial firm. Practically, it is very unlikely that an individual farmer would choose to own a SCARP tubewell because of its large capacity and location (SCARP tubewells having a capacity of 3 to 5 cfs are mainly located at the head of a watercourse). However, it may become a beneficial

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[3] Chaudhry and Ali (1989) estimated that a 10 percent real increase in O&M expenditures on canal system in one year would increase agricultural productivity by 30 percent in six years.

venture if a group of farmers located on the same watercourse takes it up for operation. Nevertheless, Pakistan's experience in organizing such farmer groups has not been very encouraging.[4]

Whatever is the structure or form of the group, the productivity of tubewells now publically owned and operated can be expected to increase for two interlinked reasons: (a) the profit motive would guide the private sector to pump and sell more water to needy farmers; and (b) there will be much less deferred maintenance or undue break-downs due to non-availability of funds. With the private sector taking up the management and operation functions of SCARP tubewells, one can definitely expect an increase in the annual utilization rate. We have analyzed two cases under this option. Case 1 assumes that the government would rehabilitate or replace the deteriorated tubewells and then transfer them to private groups for regular operation, management, and maintenance. In this case, water would be priced on the basis of O&M costs of the tubewell. Case 2 assumes that SCARP tubewells are transferred to private groups in their present form, who would repair the tubewells and then operate them. The social cost of water in this case would include O&M costs and annualized capital costs.[5]

As a result of increased groundwater pumpage, the water table will be lowered. Agricultural production is expected to increase due to less waterlogging and the availability of more supplemental water. The government would be relieved of heavy financial strains, implying that more funds would be available for O&M of the canal system.

Replacement with Smaller Private Wells ("Replacement")

This option portrays a situation where SCARP tubewells are terminated and replaced by small farmer-owned tubewells, (rather like the SCARP transition approach presently being followed in the pilot project area). Benefits demonstrated by SCARP and private tubewells, as well as water shortages caused by the termination of SCARP tubewells, are expected to induce some farmers to invest in small tubewells. However, the government may have to make strenuous efforts to provide credit and energy to the farmers to speed up the implementation process. In the

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[4] This is not to say that such groups cannot be formed to function on a long-term basis. As a matter of fact, such groups have proven to be successful in various parts of the world having a similar irrigation system and other similar socio-economic factors. More serious research efforts are needed to study the causes restricting cooperation among the farmers and to devise policies which can bring them together for their common cause.

[5] Total and O&M costs of water pumped from SCARP tubewell were estimated to be Rs 108 and 72 per acre-foot, respectively. See Chaudhry and Young (1989) for detailed cost estimates.

absence of these facilities, private investment in small tubewells may be slow to take off, causing the water table to rise and thus damaging the land and crop production.

Since every farmer in the project area is not expected to own or have a share in a tubewell, the benefits of groundwater development would be shared mainly through the water markets. Three possible cases reflecting different water market conditions are evaluated under this option. The first case considers a situation where the farmer owns a tubewell but pumps the water only to meet his own farm needs. The second case assumes that the farmer sells any surplus water to the neighbouring farmers. The third case assumes that the farmer does not own a tubewell but purchases the water at the market rate. In general, this option would result in the availability of timely water to the farmers. In the very short-run, the water table may rise as a result of inadequate pumping. On the other hand, because of the termination of SCARP tubewells, more funds would be available for O&M of the canal system.

Improved Management of SCARP Tubewells ("Improvement")

This option analyses the impact of management and operational improvements in various components of the public irrigation system. We have considered three cases under this option. The first case assumes improvements in the management and operation of SCARP tubewells. These improvements can be realized by providing better economic incentives to the field staff (particularly tubewell operators) of the irrigation department; more careful and intensive monitoring; and developing procedures for quick repair and maintenance of the tubewells. Indeed, some of these improvements would not be possible without some additional cost. In the absence of prior information on this issue, we have assumed a 10 percent increase in the water pumped from SCARP tubewells with similar increases in the cost of water.

The second case considers improvements in the delivery efficiency of the watercourse. The process of waterlogging and salinization is slowed by any reduction in seepage losses such as those that occur as a result of watercourse improvements [USAID (1982)]. Therefore, in recent years, most of the irrigation development programmes in Pakistan have focused their attention on reducing the large water losses from the irrigation system. The watercourse improvement programme has been one of the most successful programmes implemented in this context; perhaps the only programme that received great appreciation from the farmers. Clyma and Corey (1974) estimated average water losses from watercourses located in SCARP areas to be around 40 percent; approximately 15 percent due to seepage and 25 percent due to spills. About 75 percent of the spillage losses can be controlled with simple routine maintenance of the earthen watercourse main channel and major branches at the cost of Rs 9.82 per acre [Eckert *et al.* (1975)]. We have used the same assumptions in our analysis, expressing the cost estimates in 1986-87 prices. The third case is a combination of both management and operational improvements considered under cases 1 and 2.

Under this option, agricultural production is expected to rise due to increased availability of water. As a result of the watercourse improvement programme and increased pumpage from SCARP tubewells, one expects the water table to go down. Higher O&M subsidies are likely to continue, and no change in existing institutions is expected.

SCARP TRANSITION MODEL

In general, the water availability under each option, coupled with its price and timing, would determine the micro level feasibility of these options. A long tradition of economists has been able to deal with water allocation in largely conceptual terms, usually concluding that exchangeable property rights would improve economic welfare. Johnson *et al.* (1981) and Young (1986) are representative examples. Young and Bredehoeft (1972) adapted the standard linear programming (LP) format to a conjunctive ground and surface water management problem. We have also used the LP formulation for the present study because the technique is widely understood, and could readily incorporate alternative water sources with differing costs and (or) timing of availability. The productivity and profitability of a wide range of water shortage patterns could also be readily reflected.

Structure of the Model

The LP model was developed to simulate farmer choice of crop mix and irrigation water allocation in response to changes in water supply and price structure in the Khanqah Dogran unit of the SCARP I area in Punjab province. A standard form of the model in matrix notation is:

$$\begin{array}{llll} \text{Max (or min)} & Z & = & CX' \\ \text{Subject to:} & AX' & \leqslant & B \qquad \ldots \qquad \ldots \qquad \ldots \qquad (1) \\ \text{and} & X & \geqslant & 0 \end{array}$$

The four basic elements of the model are: objective function (CX'); activities (X); constraints (B); and matrix of technical coefficients (A). The schematic presentation of the model developed for the project area is given in Table 2. The objective function is designed to maximize returns to water as shown in Equation (2), subject to the technical constraints of the production function and the level of resource

Table 2

Schematic Representation of Linear Programming Model

Raw Identification[a]		Unit	Activities and Column Identification						Right-hand Side
			Crop Production (90)	Livestock Production (4)	Sales or Final Consumption (11)	Livestock Feeding (5)	Input Purchases (4)	Water Purchase (12)	
			Acre	Animal	Kg	Kg	Nutrient-kg or Man-hour	Acre Inches	
			X_{ik}	X_j	X_j	X_j	X_j	X_j	
Objective Function	(2)	Rs	$-C_{jk}$	C_j	C_j	0	$-C_j$	$-C_j$	*Max*
Crop Outputs	(11)	Kg	$-A_{jk}$		0, 1	0, 1			$= 0$
Livestock Outputs	(4)	Animal		0, 1					$= 0$
Livestock Inputs	(5)	TDN		A_{ij}		$-A_{ij}$			$= 0$
Monthly Land	(12)	Acre	0, 1						$\leq B_i$

Continued –

Table 2 – (*Continued*)

Raw Identification[a]		Unit	Activities and Column Identification						Right-hand Side
			Crop Production (90)	Livestock Production (4)	Sales or Final Consumption (11)	Livestock Feeding (5)	Input Purchases (4)	Water Purchase (12)	
			Acre	Animal	Kg	Kg	Nutrient-kg or Man-hour	Acre Inches	
			X_{ik}	X_j	X_j	X_j	X_j	X_j	
Fertilizer	(3)	Nutrient (kg)	A_{ijk}				–1		$= 0$
Seasonal Labour	(2)	Man-hour	A_{ijk}				–1		$\leqslant B_i$
Monthly Water	(12)	Acre Inches	A_{ijk}						$\leqslant B_i$
Monthly Pumping[b]	(12)	Acre Inches						–1	$\leqslant B_i$
Production Limits	(4)	Acre	A_{ijk}						$>\!< B_i$

[a] Number of activities (columns) and constraints (rows) given in parentheses. i indexes inputs; j indexes products; k indexes water stress levels.

[b] Maximum water available from public or private tubewells. Separate constraints for these sources are added because water from private tubewells has a price tag attached to it.

availability.

$$\max z \quad = \quad \sum_{j=1}^{m} \quad Y_j P_{yi} \quad - \quad \sum_{i=1}^{n-1} \quad X_i \; P_{xi} \quad \ldots \qquad (2)$$

where Py_j and Px_i are prices of products and inputs, respectively, X_i (i = 1,2,..,n) refers to quantity of input i; and Y_j (j = 1,2,..,n) is quantity of product j. X_a denotes the irrigation water resource and z is the net benefit imputed as the value or shadow price of irrigation water. Net benefits are defined as revenues (including imputed home consumption) minus cost of cash inputs, wages, and land. The labour charge reflects local wage rates, while the opportunity cost of land is measured as the net returns to non-irrigated (rainfed) wheat. The model is formulated so as to find a selection of crops and the irrigation level for a specified water supply, as well as an irrigable land limit which maximizes net returns to water.

The model incorporates four types of activities: production, sales, feeding, and purchasing. The production activities represent 11 crops and 5 types of livestock. Crop production was assumed to take place over a broad range of irrigation regimes, ranging from non-stressed production to highly stressed production in response to evaporation deficits. For some major crops, production activities representing different planting dates and possibilities of substitution between fertilizer and irrigation water were also incorporated. Sales activities cover the disposition of output from primary crops and livestock. Intermediate activities represent the feeding of fodder and residue of primary crops to the livestock. Purchasing activities are incorporated for those inputs where pricing is an issue.

The constraints faced by the cultivator can be categorized into fixed resources (land, canal water, and family labour); resource augmenting constraints, which limit the amount of purchased inputs and special crop rotation constraints, which restrict the range of feasible cropping patterns. Land and water are basic constraints, and these are expressed on a monthly basis. The present model represents a farm size of 10 acres, which is the average farm size in the project area. The model assumes that water supply in each month is fixed and it cannot be transferred among months. Labour is valued at prevailing market rates, and this constraint is expressed on a seasonal (*rabi* and *kharif*) basis, assuming that a total of 1686 hours of family or hired labour is available to the farm in each season.

A special set of constraints restricts the range of feasible solutions. The acreage of certain perishable, risky and therefore high-valued crops (vegetables, orchard, and pulses) have been limited to the average regional level. Similarly, the number of livestock on the farm is restricted to the typical existing holding of a pair of bullocks, two sheep, and one each of buffalo and cow. Explicit constraints were not placed on the acreage under fodder. The model provides the required amount of nutrients to these animals via production of seasonal fodder, wheat straw, sugar-cane tops, and rice straw.

Two basic types of entries are found in the technical coefficient matrix of the model. The first category represents the quantities of resources required to produce an acre of a crop or a unit of livestock. The values of these coefficients are found in their respective resource constraint rows. These resource-use constraints are monthly for land and water, seasonal for labour, and annual for fertilizer. Labour requirements for crop production activities were designed to reflect irrigation and harvest workloads for each water-yield combination. The other major category includes the transfer coefficients, which convert per acre activities into outputs, which can be either sold, consumed on farm, or used as intermediate goods for input into livestock production activities.

Water Response Activities

For each crop, seven production activities were developed, each representing a different level of water stress. Stress conditions ranged from a minimum of 10 percent to a maximum of 50 percent, distributed equally throughout the growing period. According to FAO (1979), the effect of water stress can be quantified by solving the relationship between relative yield decrease and relative evapotranspiration deficit[6] given by the empirically derived crop-yield response factor (*ky*), as given below:

where: $$Ky = [1 - Y_a/Y_m] \,/\, [1 - ET_a/ET_m] \quad \ldots \quad \ldots \quad \ldots \qquad (3)$$

Y_a = Actual harvested yield;

Y_m = Maximum harvested yield;

ET_a = Actual evapotranspiration;

ET_m = Maximum evapotranspiration; and

Ky = Yield response factor for crop of y.

The yield response factor for various crops, the estimation of the actual yield in response to water deficits, the water-use coefficients, and the labour requirements for stressed production activities used here are described in Chaudhry and Young (1989). For some major crops, in addition to the stressed production activities

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[6] Because of data limitations, the relationship between ET_a/ET_m was approximated using the ratio of actual water applied to maximum water required for a particular crop.

developed by us, we used experimental data of PARC (1982) reflecting yield response to different moisture and fertility levels.

Data Base

Most of the crop productivity and resource endowment assumptions used in this research were taken from the data collected and compiled by local consultants (ACE-SGI) for the Government of Pakistan and the World Bank as part of the feasibility study on "SCARP Transition and Improvement Project" (1984). The farm management survey represents interviews with 493 farmers located on 67 public tubewells in SCARP I.[7] The survey provided detailed information about cropping pattern, water use, and input-output matrix of various crops grown in the area. The results of the survey, particularly with respect to fertilizer use and crop yields, were updated in 1985 by the same consultants for a subsequent feasibility study on "SCARP Transition and Pilot Project". Revisions were stated to be based on indications from local agricultural extension agents, interviews with farmers, and data obtained from the crop-cutting experiments of the agriculture department. The data with respect to input-output coefficients were further validated by us after discussion with a panel of experts and local extension agents. Data used to develop crop budgets, per acre production costs and income of various crops, and water requirements of various crops are shown in the Appendix.

The data with respect to input-output prices were taken from government documents and the World Bank (1986). The data on TDN requirements for livestock were taken from the Indus Basin Irrigation Model developed by the World Bank. Additional secondary data were obtained from published government documents. Further details with respect to activities, constraints, and technical coefficients used in the programming model can be found in Chaudhry and Young (1989).

RESULTS AND DISCUSSION

For each transition option, the model uses the estimates of water supply available from different sources for the farm and selects the cropping and water use pattern which will yield the highest expected net benefits. As such, the available water is allocated to high-valued crop activities for the given set of physical and technical constraints.

The model's reliability was tested by comparing its predictions with respect to the cropping pattern and cropping intensity against two sources of data on the study

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[7] SCARP I is located in Central Punjab covering an area of 1.14 million acres in the districts of Sheikhupura, Gujranwala, Faisalabad, and Jhang. A total number of 2073 tubewells, with pumpage capacity of 6041 cusecs, were installed under SCARP I.

area. One source was the cropping pattern for the pilot project area reported by the Irrigation Department, while the other was a survey of 493 farmers in the SCARP I area. The cropping intensity predicted by the model was almost the same as shown by the records of the Irrigation Department, but about 20 percent less than the survey results. This later discrepancy could be explained by the fact that the model used current water supply levels reported for the pilot project area which are lower than the water supply to the entire SCARP I area. Rice and wheat were the dominant crops in the model's cropping pattern, which is consistent with observed behaviour. Forecast acreages of these crops were in between those reported in comparable sources. In general, the model represents farmer land and water allocation decisions within a satisfactory degree of accuracy.

Evaluation of Performance: Efficiency Criteria

The allocative efficiency measure used in this study to evaluate the performance of various transition options is annual net returns to water, a measure approximating producer surplus. The most efficient option is the one that would yield the highest net returns to irrigation water. Cropping intensity, while not a major criterion, is of interest, and is also displayed. Table 3 summarizes these evaluations.

The first comparison we highlight is between continuation of SCARP tubewells and termination. The difference between these two cases measures the net economic contribution of SCARP wells to agricultural productivity, assuming the investment in well and pump to be written off. The net benefits to water supplied by SCARP tubewells were Rs 806 per acre. Comparing these benefits with the incremental costs of pumping (measured by existing O&M costs) gives a benefit-cost ratio in the neighbourhood of 3 : 1. This clearly suggests that SCARP tubewells are economically efficient and can continue to play an important role in increasing agricultural productivity. Accounting for drainage benefits, which we have not attempted, would further improve the benefit-cost ratio. This role, however, has been underrated so far in the water management agencies. From our analysis, the SCARP programme does not appear to be overly expensive, particularly when the government is extracting a large portion of potential producer surplus via underpricing of some of the agricultural outputs.

Among all the remaining options, the cases considered under the replacement option yielded the highest net benefits and cropping intensity. Although the cropping intensity was the same (193.5 percent) for each of the cases considered under the replacement option, the net benefits were different. The net benefits of case 2 were higher than the net benefits of case 1 because the well-owner had the opportunity to sell surplus supplemental water in the former case. On the other hand,

Table 3

Comparison of Various SCARP Transition Options using Different Performance Measures

Transition Option	Water Supply (Acre Inches)	Net Benefits (Rs per Acre)	Cropping Intensity (Percent)
1. Continuation	284.5	1560.1	108.0
2. Termination			
Case 1	173.6	754.5 (–52)	73.0 (–32)
Case 2	201.1	982.1 (–37)	74.0 (–32)
3. Transfer			
Case 1	346.4	1973.7 (27)	143.0 (32)
Case 2	346.4	1798.2 (15)	143.0 (32)
4. Replacement			
Case 1	449.7	2451.0 (57)	193.5 (79)
Case 2	1357.7	2692.5 (73)	193.5 (79)
Case 3	447.3	2252.3 (44)	193.5 (79)
5. Improvement			
Case 1	295.5	1606.8 (03)	113.4 (05)
Case 2	320.7	1753.1 (12)	124.2 (15)
Case 3	334.2	1815.9 (16)	130.7 (21)

Note: Figures in parentheses indicate the percentage increase from the baseline case.

the net benefits of case 3 (purchaser) were lower than the net benefits of case 1 (owner) because the price of supplemental water was higher in the former case.[8]

The transfer option was ranked as the next best alternative followed by the improvement and continuation options. However, case 3 of the improvement option yielded almost the same net benefits as case 2 of the transfer option, but the cropping intensity was lower under the former case. This discrepancy can be attributed to different cost-sharing arrangements assumed for various cases. The termination option performed poorest among all the options.

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[8] Only variable pumping costs were used as price of supplemental water in case 1, while the market rate for supplemental water (which was 15 to 20 percent higher than the variable pumping costs) was considered in case 3.

Evaluation of Equity Concerns

To explore some important equity aspects of the various transition options, farms of the project area are classified by size (small vs. large) and tenancy (owner vs. tenant) categories. The basic model was first adjusted so as to reflect the farming systems and institutional constraints faced by these farm categories. The model was then solved for assumptions representing the transition options to capture the income distribution effects. The equity of various transition options is examined by using two measures. The first measure – Land Income Ratio (LIR) – is defined as the ratio of the per acre net income of small (or tenant) farmer to the per acre net income of large (or owner) farmer. The second measure – Farm Worker Income Ratio (FWIR) – is defined as the ratio of the income per farm worker on small (or tenant) farms to the income per farm worker on large (or owner) farms. Under both measures, the ratio equals to one in the case of perfect equality, and decreases as inequality increases.

Results, as in Table 4, with respect to small versus large farms indicated that case 2 of the replacement option performed best while case 1 of the termination option was ranked lowest under both equity measures. In other words, termination of SCARP tubewells would further aggravate the income distribution gap between small and large farmers. The replacement option, however, would significantly narrow the income distribution gap between these farm categories. (This conclusion assumes effective initiation of markets for pumped water). The LIR ranged between 0.78 to 0.86 for most of the cases, except for the cases considered under the termination option. The FWIR for these farm categories ranged from a minimum of 0.16 to the maximum of 0.49. For the continuation option, the LIR was 0.78 and FWIR was 0.33.

Rankings of the various transition options changed when equity implications of these options were analyzed for farmers with different tenurial status. According to both equity measures, the termination option was ranked best while case 2 of the replacement option performed poorest. The LIR ranged from 0.46 to 0.61 for various transition options, with a ratio of 0.58 for the existing case. The FWIR for the continuation option was 0.52, and ranged between 0.41 to 0.55 for various transition options.

The Preferable Option

One's judgement regarding which of these options is to be preferred depends upon value judgements as to how efficiency and equity considerations are to be balanced off against each other. It also depends on whether or not a specific SCARP well possesses any remaining economically useful life.

Our analysis suggests against terminating (closing down) any well which is

Table 4

Comparison of Various SCARP Transition Options using Different Equity Measures

Transition Options	LIR[a] Small vs Large	LIR[a] Tenant vs Owner	FWIR[b] Small vs Large	FWIR[b] Tenant vs Owner
1. Continuation	0.78 (7)	0.58 (3)	0.33 (4)	0.52 (4)
2. Termination				
Case 1	0.37 (9)	0.61 (1)	0.16 (6)	0.54 (2)
Case 2	0.54 (8)	0.61 (1)	0.23 (5)	0.55 (1)
3. Transfer				
Case 1	0.86 (2)	0.56 (4)	0.36 (2)	0.50 (5)
Case 2	0.85 (3)	0.59 (2)	0.36 (2)	0.53 (3)
4. Replacement				
Case 1	0.86 (2)	0.51 (6)	0.36 (2)	0.46 (7)
Case 2	0.92 (1)	0.46 (7)	0.49 (1)	0.41 (8)
Case 3	0.86 (2)	0.53 (5)	0.36 (2)	0.47 (6)
5. Improvement				
Case 1	0.79 (6)	0.58 (3)	0.33 (4)	0.52 (4)
Case 2	0.81 (5)	0.58 (3)	0.35 (3)	0.52 (4)
Case 3	0.83 (4)	0.58 (3)	0.35 (3)	0.52 (4)

[a] LIR = Land Income Ratio.
[b] FWIR = Farm Worker Income Ratio.
Rank is given in parentheses.

functioning or can be economically returned to service. Given the nation's shortage of capital, and the comparison between continuation and termination, any such well should be permitted to operate so long as it is economical. The transfer option appears to be the best choice for such tubewells. With the change in management, these tubewells can still play an important role in controlling the water table and increasing the agricultural productivity. In this context, the practicability of different transfer models should be tested on a pilot basis; for instance, transfer to individual farmers, to farmers' groups, and to commercial firms. If the tubewells cannot be sold, these can be gifted to groups such as water-users' associations (WUAs). The transfer of SCARP tubewells would mean a shift in the burden of costs since the new private owners would pay the electricity bills and meet maintenance expenses. Moreover, since SCARP tubewells provide water equitably to all water-users, they offer an important political advantage. As SCARP tubewells become inoperable, they should be allowed to die a natural death and farmers should be encouraged to replace them with smaller wells located where they are needed.

For tubewells which are completely worn out, the replacement option appears to be the best choice. This approach yielded the highest net income and cropping intensity, and is found to be relatively more equitable for the farmers who differ by farm size. However, benefits of this option were skewed relatively more in favour of owners as compared to the tenants. Differences in initial resource endowments and assumptions with respect to the market price of tubewell water are the factors responsible for making tenants relatively worse off under this option.

Note, however, that the replacement option assumes smooth functioning of the water markets, i.e., farmers without their own tubewells would be able to buy as much water as required for their crops at the prevailing market price. In practice, this condition not only requires installation of sufficient number of tubewells but also calls for proper locational distribution of these tubewells to ensure effective working of the water markets.[9] The former requirement would not be difficult to meet because, with the termination of SCARP tubewells, the demand for supplemental water would definitely encourage more farmers to instal their own tubewells. Meeting the latter requirement, however, will be more critical since the rigidity of the *warabandi* system greatly affects the economics of private tubewell installation because of a fewer number of potential users and purchasers of tubewell water.

During the replacement process, emphasis should be more on diesel-powered tubewells rather than electric tubewells because electricity is highly subsidized and thus has a high social opportunity cost than does diesel fuel [Chaudhry and Young (1989)]. Moreover, diesel tubewells tend to be more reliable as they are not subject to the risk of load-shedding and outages that frequently occur in the electrical system.

Related work in progress suggests that macro-level government policies tend to inhibit the incentives for private individuals to invest in tubewells. Commodity price policies, designed to capture a part of the producers' net income, lower the expected

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[9] The present *warabandi* system of water allocation (under this system farmers take the full supply of water flowing in the watercourse for a period of time fixed in proportion to the size of their landholding, at a fixed time once a week) does not allow the farmers to supplement canal water supplies with tubewell water unless they have an uninterrupted right to the total discharge and flow in the watercourse or if the main watercourse length between their *nakka* location and the tubewell location is unused or empty of water [Renfro (1982)].

return to additional water supplies [Chaudhry and Young (1990) (in press)]. Subsidies to electricity and the taxes on diesel fuel distort the social cost of energy, and send inappropriate signals to the farm sector [Chaudhry and Young (1989)].

Finally, public sector agricultural extension programmes should be developed to educate farmers about various technical and financial aspects of groundwater management. More particularly, these programmes should include information and advice on installation and maintenance procedures which may help to reduce the cost of supplemental water at the farm level. In addition to the structural and engineering emphasis for water management, the rural institutions should be strengthened to ensure successful implementation of any specific groundwater privatization programme. Water allocation and distribution policies should be tailored so as to encourage exchanges and marketing of water.

SUMMARY AND CONCLUSIONS

The SCARP tubewells have played a critical role in slowing waterlogging and salinity over vast irrigated areas of the Indus Basin. However, in recent years, these tubewells have become increasingly expensive to operate. The GOP is, therefore, seeking to transfer most of the SCARP tubewells to the private sector, in addition to the privatization of the entire groundwater development programme. A SCARP Transition Pilot project was implemented to assess its replicability in other SCARP areas, but enormously high costs associated with the ongoing programme suggest a search for other approaches.

Linear programming models of representative farms in the study area (SCARP I) are developed to simulate the farmer's response to various transition options considering the altered water supply available under each option. These options are: continuation, termination, transfer, replacement, and improvement. A wide range of possible cases were evaluated under these options within the context of efficiency and equity objectives. In general, the SCARP programme does not appear to be overly expensive – given its high rate of return in crop productivity and, further, if viewed as an insurance policy to prevent deterioration of an important irrigated land asset.

The replacement option appears to be the best choice for tubewells which are judged uneconomical to repair. This option would encourage installation of farmer-owned small tubewells. The success of this approach, however, depends upon the nature of the economic incentive package provided to producers. Since every farmer in the project area is unlikely to own a tubewell, benefits of groundwater development under this option would be shared mainly through water markets. In practice, this option not only requires installation of sufficient number of tubewells but also calls for proper locational distribution of these tubewells to ensure effective working of the water markets. During the replacement process, emphasis should be on diesel tubewells because these are more reliable and socially less expensive to operate. The government incentives should be tailored to encourage installation of tubewells under joint ownership. At the same time, the public sector agricultural extension programmes should educate farmers about efficient installation and maintenance procedures which may help to reduce the cost of supplemental water.

The management and operational functions of SCARP tubewells which can be continued to be operated economically may be transferred to private groups. In addition to having the political advantage of providing water equitably to all water-users, this option would help in reducing government's O&M budget deficits. However, since Pakistan's experience in organizing such groups has not been very encouraging in the past, it is important to examine the practicability of various forms of private groups (such as individual farmers, farmer's groups like WUAs, and commercial firms) on a pilot basis. The operable SCARP tubewells should be kept operational until they can be replaced by equal alternative pumping capacity in the private sector. As aging SCARP tubewells become uneconomical to operate, they should be allowed to die their natural death, and the farmers should be encouraged to replace these with smaller wells in the areas where they are needed. Successful implementation of the privatization programme requires that local-level rural institutions should be strengthened, and institutional rigidities implicit in the water allocation and distribution system should be removed.

Throughout the world, it is increasingly recognized that a centralized management of economic processes is less productive than the organizational arrangements making use of private property rights and selected incentives. While the SCARP programme has continued to perform an enormously valuable service in protecting the soil and water resources of the Indus Basin, and in enhancing farm productivity, the full evidence suggests that the performance could yet be enhanced. Privatization of the groundwater programme holds a great promise to accomplish this. Much research, however, remains to be done. It would be useful to know what sort of organizational arrangements would most effectively facilitate the equitable and efficient distribution of private tubewell water. Another important issue warranting study is the economic benefits of waterlogging control.

Appendix

Per Acre Resource-use, Yield, Production Cost, and Income of Major Crops in the Study Area

Parameters	Units	Cotton	Rice *Basmati*	*Kharif* Fodder	Wheat	Pulses	Oilseed	*Rabi* Fodder	Sugar-cane
Manual Labour	Hours	176	176	96	112	48	64	160	336
Bullock Labour	Hours	84	60	24	48	32	24	36	84
Fertilizer									
Nitrogen	Nutrient. Kgs	18	25	9	23	3	9	3	32
Phosphate	Nutrient. Kgs	6	16	4	11	6	5	5	16
Pesticides	Rupees	100	50	0	0	0	50	0	100
Farm Manure	Cart Load	1	1	1	1	1	1	2	3
Water Requirement	Acre Inches	27	35	16	16	10	11	31	60
Yield	Kilograms	340	920	12000	900	360	320	20000	14930
Production Costs*	Rupees	1490	1408	783	1147	630	673	1153	2951
Gross Income**	Rupees	1751	2300	1560	1854	1868	1184	3150	4404
Net Income	Rupees	261	892	777	707	1238	511	1997	1453

Source: (a) Feasibility report on "SCARP Transition Project", Vol. 5, Annex 15;
(b) Feasibility report on "SCARP Transition Pilot Project" Vol. I & II; and
(c) Personal interviews with local extension agents.

*Includes cost of manual and bullock labour, seed, fertilizer, pesticides, farm manure; interest rate on working capital; payments made to artisans; fixed taxes; and opportunity cost of land.

**Value of by-products is also included.

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