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WATER MARKETS
IN THE FORDWAH/EASTERN SADIQIA AREA

An Answer to Perceived Deficiencies
in Canal Water Supplies?

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Abstract

THIS PAPER PRESENTS the results of a study on water markets in the Fordwah/Eastern Sadiqia Irrigation System, which is located in the southeastern portion of the Province of the Punjab, Pakistan. Based on primary data collected by IIMI-Pakistan, the study stresses and quantifies the importance of water markets in the area. The sale and purchase of groundwater pumped by private tubewells are the major activities in these markets. Other forms of water transactions are the exchange of full or partial canal water turns, the exchange of canal water for tubewell water, and the sale and purchase of canal water.

Canal water supply, seasonal variations in crop water requirements, groundwater quality and tubewell operation costs (related to the source of power) are important factors influencing the type and level of water transactions. Farm characteristics (for example, holding size and tenure status) influence the participation of farmers in water trading activities as well.

A first attempt is made to evaluate the impact of water markets on the quality of irrigation services. Via surface water and groundwater markets, the flexibility and adequacy of the irrigation water supply are improved. The purchase of groundwater enhances the equity in access to irrigation water, increasing the quantity of water supplied to non-tubewell owners who are mainly small farmers and tenants. At the same time, it makes a more efficient use of the existing tubewell capacity. Tubewell owners, however, retain the largest share of the groundwater pumped, which is translated into a higher cropping intensity and larger areas under wheat and rice. The analysis of crop yields, however, did not show any clear difference between groups of farmers characterized by different degrees of control on the irrigation water supply.

Policymakers and funding agencies are currently advocating the privatization of the water sector and the development of water markets in Pakistan. However, further research is a prerequisite to any institutionalization and further development of water markets in Pakistan, to fully understand the impact of water markets on the quality of irrigation services, agricultural production and environmental sustainability.

Introduction

WITH MORE THAN 15 million hectares (ha) annually irrigated, the Indus Basin represents one of the largest irrigation systems in the world. Built by the British during the second half of the 19th century, the system was designed to spread the scarce available water over as large an area as possible on an equitable basis. The irrigation system was not designed for flexibility in operation. A constant discharge at the main and secondary levels of the irrigation system was to be distributed proportionally to tertiary offtakes (watercourses), according to the officially commanded area.

Within the watercourse command areas, farmers receive water for a specific period of time (water turn), following a weekly or ten-day schedule referred to locally as *warabandi* (*wahr*=turn, *bandi*= fixed). With this system, each farmer's turn is roughly proportional to the area of his land (Bandaragoda and Firdousi 1992). The actual crop water requirements were not accounted for in this supply-driven distribution system, thus reducing the managerial input. A hundred years later, the main operational objectives of this vast surface water irrigation network are still directed towards an equitable and supply-based distribution of water among farmers.

At present, system reality is at variance with these policy objectives. Research undertaken by IIMI on several canals in the Punjab has highlighted two important features of the current canal water supply: inequity and unreliability. The quantity of canal water distributed decreases from the head to the tail of both secondary canals (distributaries) and watercourse commands, while the unreliability in the water supply follows the opposite pattern, increasing from the head to the tail of both the distributary and watercourse command areas (see for example Vander Velde and Kijne 1992 or Kuper and Kijne 1993). These problems are well recognized by officials and policymakers, as evidenced by motions no.75 and no. 174 presented before the Punjab Provincial Assembly in October 1992, *regarding tail shortage and depressed feelings of the farmers about the actual performance of the (irrigation) system.*

Farmers have reacted to the perceived deficiencies of the surface water irrigation system by investing in tubewells to tap groundwater resources, thus augmenting their water supply and enhancing the flexibility in their irrigation application. Conservative estimates indicate that 40 percent of the total irrigation water supply at the farm gate in Punjab is derived from private tubewell supplies (Vander Velde and Johnson 1992).

A few groups of small farmers have invested commonly in tubewells, sharing the operation and maintenance costs and managing their tubewells jointly. However, tubewells have mainly remained an attribute of larger farms (see WAPDA 1980; Johnson 1989; GOP 1991). Small farmers have been mostly involved in the use of groundwater through water transactions. Water markets, which involve an important part of the farming community (see for example Khan 1986, 1990), do not relate only to tubewell water but also to canal water, even though the Canal and Drainage Act of 1873 forbids farmers to trade their canal water turns.

Water markets in Pakistan are mentioned in several publications, but studies specifically focused on water markets in Pakistan are still rare (see Renfro and Sparling 1986; Bajwa and Ahmad 1991; Meinzen-Dick and Sullins 1993), in absolute terms as well as compared to the literature describing and analyzing water markets in other South Asian countries like India and Bangladesh (for a more comprehensive literature review, see Meinzen-Dick and Sullins 1993). Moreover, most of the studies focus only on groundwater markets and are based mainly on interviews obtained in farm surveys.

The main objectives of this paper are to describe water markets and estimate their importance in the Fordwah/Eastern Sadiqia area, and to correlate their characteristics and functioning with the main features of the irrigation system (surface water and groundwater). The impact of water markets on irrigation services and agricultural production is considered. Recommendations for policymakers as well as a methodology for further research are proposed and discussed.

Research Locale

GENERAL

THE FORDWAH/EASTERN Sadiqia Irrigation System is situated on the left bank of the Sutlej River and is confined by the Indian border in the east and by the Cholistan Desert in the Southeast (see map, Appendix I). It commands a gross area of 301,000 ha, out of which 232,000 ha are culturally commandable.

The climate is semiarid and the annual evaporation (2,400 mm) far exceeds the annual rainfall (260 mm). The area is located in the cotton-wheat agro-ecological zone of the Punjab, with cotton, rice and forage crops dominating in the *kharif* (summer season), and wheat and forage crops in the *rabi* (winter season).

The Fordwah Canal and the Eastern Sadiqia Canal both originate from the Suleimanki Headworks on the Sutlej River (see map, Appendix 1) and were developed under the Sutlej Valley Project (1932). This project was launched to increase the reliability of the water supplies, during the kharif season, to the lower areas along the Sutlej River that were already irrigated by inundation canals, and to supply water to the higher-lying lands towards the Cholistan Desert.

Low river flows in rabi limited irrigation supplies in this season to only part of the system. The area that was heretofore irrigated through inundation canals, where farmers had a right to water in kharif, was, for the largest part, labeled non-perennial (i.e., only served during kharif, from April to October). The higher lands were made perennial (with a year-round supply). Water duties for the non-perennial channels are higher (0.5 l/s/ha or 7.0 cfs/1,000 acres) than for the perennial canals (0.25 l/s/ha or 3.6 cfs/1,000 acres).

In the study area, located in the northwest of the Fordwah/Eastern Sadiqia Irrigation System, two transects were drawn going perpendicular from the Sutlej River towards the Cholistan Desert, cutting across the Fordwah, Azim and Fateh distributaries. The Fordwah and Azim distributaries both divert water from the tail of the Fordwah Branch of the Fordwah Canal, whereas the Fateh Distributary offtakes from the Malik Branch of the Eastern Sadiqia Canal. Along these three distributaries, five sample watercourses were selected, located along the transects. The main features of the three distributaries and the characteristics of the five sample watercourses are presented in Appendix II.

There are no public tubewells in this area, unlike in other parts of the Punjab. However, especially towards the river, a large number of private tubewells have been installed. The exploitation of groundwater in these command areas varies widely, influenced by the access to canal water supply, and limited by the quality of the groundwater.

The riparian tract, traditionally commanded by the inundation canals, was inhabited long before implementation of the Sutlej Valley Project. The farmers in this area, often referred to as "locals," can be categorized as having larger landholdings, a higher use of external labor and a more wheat-cotton-oriented farming system. The general perception of these locals is that they are noncooperative (see van Waijjen 1991). The command area of the Azim Distributary falls in this area. In the higher areas (the Fordwah Distributary and the Fateh Distributary), developed after the introduction of a more reliable irrigation water supply, farmers, locally known as "settlers," are usually viewed as being cooperative and more "progressive."

RESEARCH METHODOLOGY

The analysis is mainly based on a comprehensive set of primary data collected from June 1991 to June 1992 in the study area. Surface water flows were monitored by collecting daily stage readings at strategic locations in the canal distribution system from June 1991 onwards. Discharges were recorded at the main system level, at the head of the Fordwah and Azim distributaries, and at the tertiary intakes of sample watercourses. Cropping intensities and cropping patterns for the sample watercourses were obtained through crop surveys (one per season). The predominant role of tubewell water in water transactions warranted a focus on tubewell owners and their participation in water sales. A tubewell census in the 5 sample watercourses was first undertaken in 1990 and has been regularly updated since. Location, age, type of tubewell, operational status, ownership characteristics (single owner or shareholders) and other basic information were collected for all of the private tubewells. Information on tubewell operation and groundwater transactions has also been recorded since June 1991.

Sixty farmers (12 in each sample watercourse) were interviewed using a formal questionnaire during kharif 1991. The objective of this survey was to better understand the farming system and its socioeconomic environment. One section of the questionnaire focused on farmers' management of irrigation water and on water markets. Thirty tubewell owners, already monitored by IIMI for irrigation application data, formed the base of the sample. Thirty additional farmers were selected mainly within the non-tubewell owner population, according to their position along the watercourse (head, middle or tail). Out of 60 sample farmers, 41 are tubewell owners or tubewell shareholders, with direct access to groundwater for irrigation purposes. The sample has a higher percentage of tubewell owners than the average of the total farmers' population in the area. The bias introduced has to be recognized in the interpretation of the data and results presented in this paper.

Tubewell owners were specifically interviewed during rabi 1991/92 on their relation with their buyers, water prices and constraints on their water sales. Discharge measurements and analysis of the quality of the water supplied by the tubewells have complemented the tubewell data set.

The Irrigation Environment

THE FORDWAH/EASTERN Sadiqia area represents a conjunctive use irrigation environment, where canal water supplies are augmented by a range of private tubewells. The present study mainly focuses on tubewell operation and groundwater transactions, constituting the major component of water markets. However, since farmers have installed tubewells as a reaction to perceived deficiencies in canal water supplies (see Kuper and Strosser 1992), a closer look at the surface irrigation system is required to better understand the farmers' management of tubewells.

THE SURFACE IRRIGATION SYSTEM

The analysis of the surface irrigation system is focused on the distribution of canal water at the secondary and tertiary levels, as the water allocation and distribution at these levels have a direct bearing on farmers' tubewell operations. The impact of the performance of the main system on canal supplies at the distributary and watercourse levels has been reported by Essen and Feltz (1992) and Kuper and Kijne (1993).

Access of farmers in watercourses to canal water is site-specific, as it varies between distributaries and depends on the location along the distributary. In this paper, water delivery to the sample watercourses has been evaluated against the design criteria of the irrigation system.[1] The total volume of water delivered as a percentage of what was intended to be delivered is appraised in the Delivery Performance Ratio (DPR). A DPR of 100 means that the volume supplied equals the intended volume. The Coefficient of Variation (CV) is used as a proxy for the reliability of the flow. As the CV increases, the reliability decreases. The analysis was carried out separately for the kharif season and the rabi season, since the water supply to non-perennial canals (i.e., Azim) is discontinued in the rabi season. Results are presented in Table 1.

The sample watercourses in the Azim Distributary received significantly less water than those in the Fordwah and Fateh in kharif 1991. This was mainly caused by an operational preference for the Fordwah, with a DPR of 90 percent for the whole Fordwah Distributary versus only 60 percent for the Azim Distributary. At the same time, the reliability of water supplies to the Fordwah and Fateh watercourses was much greater than that to the Azim watercourses. This is evidenced by the fact that the Azim Distributary experienced 75 dry days at the tail (55% of the total number of kharif days), whereas the Fordwah had only 36 dry days (26%).

1 The design criteria—an equitable water distribution with fixed 'design' discharges for offtakes—are still considered valid by system managers. Crop water requirements, whether inter- or intra-seasonal, are not taken into account in the present system operation and it is assumed that farmers will manage available canal supplies optimally by adapting their cropping pattern. Cropping intensities, originally fixed at 70 to 80 percent, for non-perennial and perennial canals, respectively, have increased dramatically. Presently, Punjab Irrigation and Power Department (PID) data indicate intensities of 115 percent for Fordwah Division and 120 percent for Eastern Sadiqia. A comparison between these data and IIMI data for the sample watercourses suggests that actual intensities may well be even higher than the official PID data.

Table 1. Assessment of water delivery to sample watercourses—kharif 1991 and rabi 1991/1992.

Watercourse	Kharif 1991		Rabi 1991/1992	
	DPR (%)	CV (%)	DPR (%)	CV (%)
Azim 63-L	57	42	–	–
Azim 111-L	17	96	–	–
Fordwah 62-R	106	16	74	59
Fordwah 130-R	87	53	97	75
Fateh 184-R	162	31	138	44

Constraints in the water distribution at the secondary level impede the water supply to tail watercourses. Illegal irrigation, outlets with dimensions at variance with design values, and siltation (resulting in higher water levels in the first reach of distributaries) are taken to be responsible for the inequity in water distribution at the secondary level.

Fateh 184-R draws water in excess of the design discharge with a DPR of 162 percent. Farmers have succeeded in changing the dimensions of this outlet to obtain higher canal supplies, mainly to improve their cropping intensities and counter the poor groundwater quality in this command area that restricts tapping of the aquifer using tubewells. In kharif 1991, the dimensions of the outlet were changed back and forth a few times in a struggle between the PID and the farmers, thus increasing the variability of water delivery to this watercourse.

In rabi 1991/1992, only the watercourses in the Fordwah and Fateh (perennial) distributaries received water regularly. Azim 63-L received water only when the Azim was used as an escape in case of excessive discharges in the main system, and Azim 111-L did not receive any water during this rabi season. Fordwah 130-R received relatively more water in rabi 1991/1992 than Fordwah 62-R. A heavy desilting of the distributary, coupled with a large-scale remodeling of head-end outlets, ensured a higher supply to the tail, taking away water from head watercourses. Stage readings, taken by farmers at the tail of the Fordwah Distributary, show that supply to the tail was considerably better than it has been for the last 7 years. Observations from field staff indicate further that, in rabi 1991/1992, very few interventions by farmers (illegal irrigations) occurred because of a lower water scarcity, ensuring a more equitable distribution of canal water within the watercourse command area in rabi 1991/1992 than in kharif 1991.

The variability of canal supplies is generally greater in rabi. This is partly brought about by the uncertainty in supplies following the annual closure. In rabi 1991/1992, for instance, the annual closure was extended from the originally envisaged 3 weeks to a period of 7 weeks.

The existing farmer-established warabandi in the 5 sample watercourses was confirmed and made official by the Irrigation Department between 1960-1970. Ip has not been updated since, even though land has been divided among family members (typically after the demise of parents), and parts of land have been sold. Therefore, farmers frequently have 2 or even 3 different water turns in this 7-day period.

The warabandi system is perceived by the farmers to be a fair though rigid way of distributing water, with a high variation in the number of turns that cultivators actually secure. The main causes for deprivation of water turns (for which farmers are not compensated) are the large fluctuations in the water supply at the higher levels in the irrigation system. More turns were lost in the Azim watercourses than in the Fordwah ones, due to the operational preference for the latter distributary. The variation in the number of turns secured is even more pronounced within watercourse command areas. Farmers in Azim 63-L, for instance, reported losing their turn as often as 23 times during kharif 1991 (out of 26 turns), while other farmers lost their turns only 6 times.

The distance of the farm to the *mogha* (watercourse outlet) is an important factor influencing the canal water supply at the farm level. With a discharge at the mogha below a certain fraction of the design flow, conveyance losses in the watercourses prevent farmers in the middle and tail of the tertiary unit from irrigating. In the sample watercourses, the length of the main channel varies from 3 to 8 kilometers. In the case of Azim 63-L, for instance, the discharge was below 70 percent of the design discharge for almost 45 percent of the total number of days in kharif 1991.

Stealing of water at the tertiary level has not been reported as a major cause for losing water turns. Only occasional cases of water theft were reported by interviewed farmers, occurring mainly during the periods of high irrigation water demand. Differences, however, exist between watercourses, with Fordwah 130-R farmers estimating, on average, 7 cases of water theft per year whereas in Fateh 184-R, no such event has been reported by farmers.

CONJUNCTIVE USE OF GROUNDWATER AND SURFACE WATER

Farmers have reacted to these perceived deficiencies of the canal water supply by installing private tubewells and pumping groundwater, thus augmenting their irrigation water supplies. In the riparian tract along the Sutlej River, farmers traditionally have tapped groundwater for agricultural purposes, mainly by Persian Wheels. From 1960 onwards, these were replaced by mechanical pumps. The development rate of tubewells has increased dramatically over the last 10 years. Tubewell densities in the 5 sample watercourses monitored by IIMI range now from 28 tubewells per 1,000 ha of Culturable Command Area (CCA) in Fateh 184-R to 95 tubewells per 1,000 ha of CCA in Azim 63-L, depending on the quality of the groundwater, the access to canal water supplies, and the socioeconomic characteristics of the farmers.

Three different types of tubewells can be distinguished, Power-Take-Off (PTO), diesel and electric tubewells, constituting 45 percent, 38 percent and 17 percent, respectively, of the total number of tubewells in the sample watercourses. The choice of the source of power is influenced by the investment capacity of the farmers, their landholding size, and their expected utilization rate. Investment costs are relatively high for the installation of electric tubewells, for example, while their operation and maintenance costs are less than half of the expenses for diesel and PTO tubewells.

On average, tubewells in the sample watercourses were operated 620 hours for the 12-month period considered (June 1991 to May 1992), equivalent to a utilization rate of 10 percent only. Utilization rates vary tremendously, depending on the source of power and the availability of canal water. This is related to the watercourse in which the tubewell is located and the position of the tubewell along this watercourse (Kuper and Strosser 1992).

The temporal variability in the operation of tubewells is large, with different inter- and intra-seasonal crop water requirements and canal water supplies. Not surprisingly, the pumping rates of tubewells are higher in the kharif season than in the rabi season, and higher for the Azim Distributary than for the Fordwah Distributary with its more favorable water supply. Finally, tubewells located in the command areas of tail watercourses are usually utilized more than those located in the command areas of head watercourses. The contribution of groundwater to the total irrigation supply at the field level is considerable, ranging from 11 percent in Fateh 184-R to 93 percent in Azim 111-L as presented in Table 2.

Table 2. Irrigation application for sample watercourses in 1991/1992.

Watercourse	Surface water		Groundwater		Total
	mm	%	mm	%	mm
Azim 63-L	320	35	592	65	912
Azim 111-L	80	7	1,145	93	1,225
Fordwah 62-R	885	82	190	18	1,075
Fordwah 130-R	695	58	503	42	1,198
Fateh 184-R	815	89	101	11	916

Table 2 emphasizes the fact that the degree of access to canal water determines the share of groundwater in the total irrigation application with the Azim watercourses using relatively more groundwater than those of the Fordwah, and tail watercourses more than head watercourses. The relatively small share of groundwater in the irrigation application in Fateh 184-R is related to the low quality of the groundwater resources in this area.

Private tubewells have evidently augmented the quantity of irrigation water available for farmers. At the same time, they have increased the flexibility of farmers to manage their irrigation water supply at the field level, which is especially important at the vital stages of crop development.

These advantages are not restricted to the tubewell owners, but appear to be shared by other cultivators as well. All non-tubewell owners interviewed in the sample watercourses indicated that they had purchased tubewell water from other farmers, disclosing the existence of an active and extensive water market. Although this water trade mainly deals with groundwater pumped by private tubewells, canal water is also transacted. Farmers are combining canal water turns, exchanging them or even buying and selling these turns. The next section describes water markets in the 5 watercourse command areas, based on data collected in interviewing farmers.

General Characteristics of Water Markets

TYPE AND INTENSITY OF WATER TRANSACTIONS

DIFFERENT TYPES OF water transactions can be identified in this part of the Fordwah/Eastern Sadiqia Irrigation System, ranging from an informal exchange of water turns to a more market-oriented sale of tubewell water. Table 3 shows that it is mainly tubewell water that is transacted by farmers, with an average number of tubewell water sales and purchases of 9.4 and 7.2 per farmer, respectively.

Table 3. Average number of transactions per farmer in 1990/1991.

Transactions	Number of transactions per farmer
Partial canal turn exchange	4.4
Full canal turn exchange	0.4
Tubewell water for canal water	0.6
Canal water purchased	1.2
Canal water sold	0
Tubewell water purchased	7.2
Tubewell water sold	9.4

Farmers trade tubewell water more often than canal water, usually through selling and buying, while exchanges are the main type of activities involving canal water. The importance of transactions with canal water, however, is far from being negligible. On average, 15 percent of the water turns of the rigid warabandi system are transacted (various types of exchange and canal water sale) by the irrigators.

In the sample of 60 farmers, 58 participate in water markets and 43 of them are also involved in water sale and purchase stricto sensus.[2] The two farmers who do not participate in transactions are both Azim 111-L farmers (reported as less cooperative and with larger landholdings) and tubewell owners (with sufficient water supply). It is an interesting fact that only 1 farmer claimed that he was selling canal water, against 12 saying they had purchased canal water during the 2 seasons. The fear for fines for the selling of water (canal water sales are forbidden under the Canal and Drainage Act of 1873) could be a factor influencing the response of the farmers. However, the current low level of enforcement of the Act by the Provincial Irrigation Department does not support this argument very strongly.

2 Since tubewell owners are overrepresented in our sample, extrapolation of the results given in Table 2 would overestimate actual activities related to farmers for the Fordwah/Eastern Sadiqia area. At the same time, canal water trading activities may be underestimated where tubewell owners are less interested in canal water trading than non-tubewell owners.

Exchange of partial canal turns is a more common practice in the Fordwah watercourses than in the Azim and Fateh watercourses (for the average level of transaction per watercourse, see Appendix III). Tail watercourses (Fordwah 130-R and Azim 111-L) manifest a higher activity than the head watercourses, essentially due to a high level of tubewell water sales.

The Azim farmers turn out to be the most active in exchanging full canal water turns, especially those in Azim 111-L due to the higher number of tail farmers who do not receive cajal water during certain periods of the year. The same phenomenon applies for canal water purchases. Those farmers, often located at the tail of the watercourses, prefer to sell their water turns when they see (or predict) that the discharge in the distributary is too low for canal water to reach their farms. They trade the water with farmers located at the head of the watercourse who can use these small water flows in a more effective way.

Although farmers located at the tail of Fateh 184-R have a very poor canal water supply, they do not sell or exchange full canal water turns. Even small quantities of good quality canal water are of prime importance to them to leach a fraction of the salts accumulated in the soil due to the use of poor quality groundwater.

Several factors influence the intensity of groundwater markets. Farmers located in tail watercourses report a higher involvement in tubewell water sales and purchases, due to a lower canal water supply and a higher percentage of electric tubewells (with lower water prices, see next section) in these watercourses. Two electric tubewells of Fordwah 130-R were managed as commercial enterprises, being operated continuously and selling water to more than 15 farmers each. In contrast, farmers of Azim 63-L participate far less in groundwater markets, using most of the tubewell water pumped on their larger landholdings.

A further analysis of the data shows that, on average, water markets are more active during the kharif season for all types of transactions but tubewell water sales. However, differences exist between watercourses: transactions in tail watercourses are more important during the rabi season than in head watercourses. As could be expected, canal-water-related activities are less intensive in the Azim (non-perennial) than in the Fordwah (perennial) during the rabi season. But the opposite tendency is found for the kharif season. When all transactions are taken into account for the entire year (exchange, sale and purchase of canal water or tubewell water), no difference is found between the Azim watercourses (non-perennial) and the Fordwah watercourses (perennial).

Fateh 184-R has a much lower water market intensity than the 4 other sample watercourses for each of the kharif and the rabi seasons; less people participate in water transactions and participants record a lower number of activities. The relatively good canal water supply (in terms of quantity and reliability, as highlighted in the presentation of the irrigation environment) and poor groundwater quality limiting the number of tubewell water sales and purchases are probably the main causes for this situation.

It is important to note that while describing water markets, only the number of transactions and not the quantities of water sold, purchased or exchanged, have been compared so far. The degree of correlation between the intensity of the transactions and the quantity of water transacted remains to be assessed. Moreover, a larger number of watercourses should be analyzed to complement these initial results.

CHARACTERISTICS OF THE PARTICIPANTS

Tubewell owners are the most active sellers, but the least active buyers among the population of farmers. They control part of the irrigation water resources themselves, and gain directly from their tubewells a higher, more reliable and flexible irrigation water supply. Some of them, however, have purchased water as well, to compensate for the failure of their own tubewells, to irrigate isolated fields far from their well or because water purchased (generally from an adjacent electric tubewell) is less expensive than operating their own tubewells.

The position of the farm within the watercourse command area has an impact on the level of activity of water markets. Farms in the middle of the watercourse command areas show a larger activity than farms at the head and tail of the watercourses. However, it is mainly due to a larger presence of tubewell water sellers in this reach; they are in a good position to provide water to the largest part of the downstream water-short farmers. When looking at the activity of "buying water," the difference between the three watercourse reaches is not significant (7, 9 and 9 times water has been purchased on average for the respective year by head, middle and tail farmers, respectively).

The average number of transaction for different farm sizes given in Table 4 show that small farmers and large farmers participate less in water markets than middle-size ones. The significantly higher involvement of farmers with middle-size farms (between 4 and 12 ha) is related to two factors: most of the tubewell owners, the most active participants in water transactions, have farms larger than 10 acres (4.05 ha); however, above a certain farm size, most of the water pumped is allocated primarily to their own fields reducing the quantity of water available for sale.

Table 4. Water trading activities and farm size.

Farm size	Average number of water trading (one year)
Below 4 ha	17
From 4 to 12 ha	32
Above 12 ha	17

A specific focus on the purchasing activity of only non-tubewell owners is of interest to assess the characteristics of farmers who would be water-short without water markets. Data show that small farmers do participate significantly more than large farmers in water purchasing. The "non-active" group (50% of the non-tubewell owners) had an average number of transactions of 4 and an average farm size of 8 ha versus 28 transactions per year for the active participants cultivating an average farm of only 3 ha.

The difference in farm size between tubewell owners (7 ha on average) and non-tubewell owners (2 ha on average) is the main reason that small farmers rely more on water purchases than large farmers. Moreover, with a large landholding, farmers can find within their own water allocation a certain flexibility (the same flexibility desired by farmers who manage their turns jointly).

SOME CONSIDERATIONS ON WATER PRICES

Prices of water vary considerably from one trading activity to another: the lowest price found in the area is 12 rupees per hour (electric tubewell) against 70 rupees per hour for the highest one (diesel tubewell and canal water). On average, there is no significant difference between the price of canal water and the price of tubewell water, even though farmers give more value to canal water than tubewell water because of the better quality of canal water and its silt load, which has a positive impact on soil fertility.

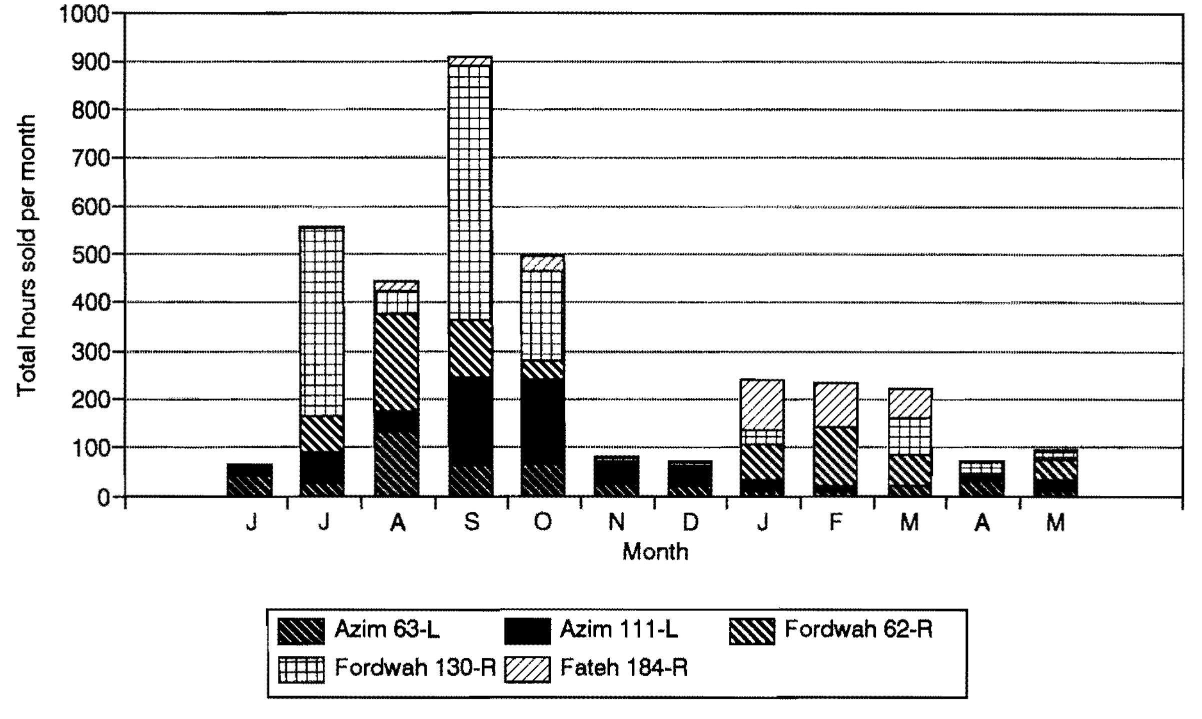
The seemingly comparative advantage of canal water, theoretically translated into a higher value or price, could be offset by the fact that the supply of canal water is less flexible and reliable than the supply of tubewell water. The small sample of canal water prices, with few farmers purchasing and selling (or reporting to sell) canal water, could in itself limit this comparison.

Canal water is sold at a much higher price than what is paid to the Irrigation Department through the formal water charges system. Sample farmers reported a market price of canal water approximately 10 to 15 times the average official rate. The low rate based on the crop and the area irrigated, and not on the quantity of water used, could also explain why canal water prices are not higher than tubewell water prices.

TUBEWELL WATER SALES IN THE SAMPLE WATERCOURSES

TUBEWELL-RELATED DATA gathered by regular monitoring of private tubewell operation over a year were found to be a suitable (and unique) basis for a good understanding of tubewell water sales. Tubewell water sold by the 49 tubewells located in the 5 watercourse command areas accounts for about 3,600 hours for the 12-month period considered (or 12% of the total private tubewell operation), ranging from 1,200 hours sold in Fordwah 130 to only 200 hours in Fateh 184. On average, each private tubewell owner sold 75 hours to primarily neighboring farmers. Large differences exist between watercourses and between periods of the year as shown in Figure 1.

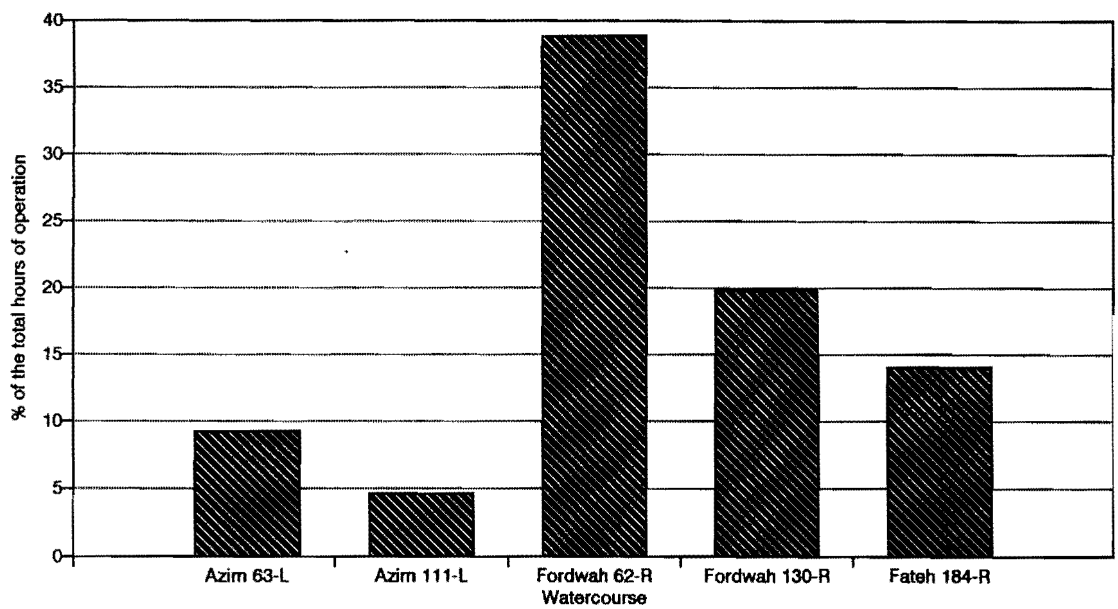
Figure 1. Monthly tubewell water sales in the 5 sample watercourses.



Tubewell water sales are substantially higher during the kharif season, when there is a larger difference between the crop water requirements and the canal water supply. The recorded peak in water sales is later in Azim 111-L than in other watercourses, related to the importance of rice in its command area. In the rabi season, the bulk of the tubewell water sales stems from the Fordwah watercourses and Fateh 184-R. The comparatively better water supply of these watercourses during the rabi season would explain these different strategies. As no canal water is supplied to Azim watercourses during rabi, tubewell owners in these command areas have less potential to sell water to purchasers because they have to cater to their own requirements first. The high percentage of fallow land in Azim 63-L seems to point in that direction.

The tubewell water sales as a percentage of the total operated hours gives a different picture (see Figure 2). The share of water sales in the total operation of the private tubewells is the highest for Fordwah 62-R (nearly 40% of the water pumped by private tubewells is sold to other farmers) and the lowest for Azim 111-L (less than 5%). With the percentage of hours sold used as a proxy for the involvement of tubewell owners in water markets, it appears that tubewell owners in head watercourses participate more than those in tail watercourses and tubewell owners in the Fordwah Distributary command area participate more than those in the Azim Distributary command area.

Figure 2. Tubewell water traded as a percentage of the total hours of tubewell operation.

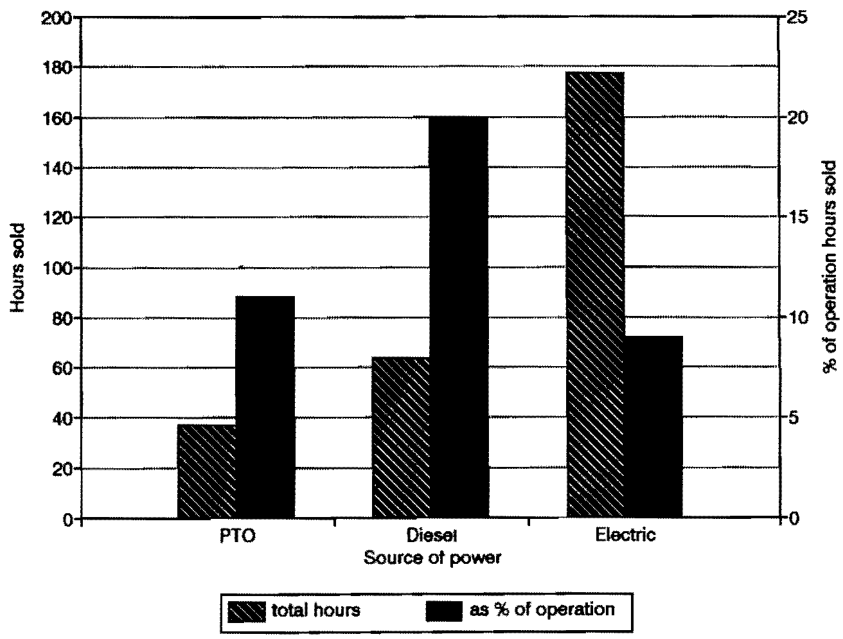


Another aspect explaining the difference between the farmers of the Fordwah Distributary and the Azim Distributary could be the difference in origin of the farmers from the two areas, as explained in the Research Locale section of this paper (see also Kuper and Strosser 1992). "Locals" of the Azim Distributary are less cooperative than "settlers" from the Fordwah Distributary and participate relatively less in water transactions. A similar difference is found in the management of the surface water resources, joint management of water turns being a common practice in the Fordwah area while nonexistent in the Azim area. However, the present data set does not allow an analysis of this issue in more detail. The impact of the social organization of farmers on the management of the irrigation water supplies and on the water markets should be further investigated.

STRATEGY OF THE WATER SELLERS

Out of a total of 49 tubewell owners in the 5 watercourses 41 sell their tubewell water. For most of them, however, water marketing is not a major activity. Only one owner has sold more than 300 hours during the one-year period analyzed. Similarly, 60 percent of the tubewell owners have sold less than 30 percent of their pumped water and 98 percent less than 60 percent of their pumped water. The source of power of a given tubewell explains a large part of the differences recorded in the intensity of water sales among tubewell owners (see Figure 3).

Figure 3. Tubewell water sales and sources of power.



As presented in Figure 3, electric tubewell owners are the most active sellers (180 hours per tubewell per year), selling on average 3 times more hours than diesel tubewell owners (60 hours per tubewell per year) and nearly 5 times more hours than PTO tubewell owners (less than 40 hours per tubewell per year). This is due to the fact that the unit cost of energy and the O&M costs of operating tubewells are lower for electric than for diesel wells (Kuper and Strosser 1992). Accordingly, water prices are lower for electric wells. The comparatively low price for electric tubewell water stimulates the demand from the neighboring potential purchasers.

The comparison between the percentage of operation hours sold per tubewell provides a different view on the differences between the three types of tubewells. The percentage of the total hours of operation sold to other farmers is the smallest for electric tubewells, due to their much higher utilization rates than diesel and PTO tubewells. On average, diesel tubewell owners sell the largest share (20%) of their pumped water.

There are several reasons why a number of tubewell owners do not participate in water trading activities (8 tubewell owners or 16% of the total number of private tubewells). In a few cases, there is no water readily available for sale (in the case of a large farm or of a large number of shareholders). The absence of purchasers is another reason (because the canal supply is appropriate, most of the neighbors own their own tubewell, or potential purchasers prefer to buy water from a less-expensive electric tubewell). One tubewell owner reported that he was not selling water because he did not have enough time to manage this activity properly.

Farmers usually do not discriminate among their potential buyers. Even if they sell more often to their neighbors and to the surroundings members of their family, it is mainly because they are the closest. However, distances between tubewells and the buyers can be quite high. The maximum distance to a buyer was recorded for each tubewell and averaged per watercourse. The average for all the tubewells is equal to 450 meters, with a much higher maximum distance (715 meters on average) for tubewells within the command area of Fateh 184-R. The very low tubewell density related to the poor groundwater quality in this watercourse is probably an important factor explaining this situation.

Sometimes, however, disputes between farmers lead to the refusal to sell water. In the sample area, two cases were reported where tubewell owners have refused to sell tubewell water to their neighbors who eventually had to invest in a new tubewell to ensure their irrigation water supply.[3]

Most of the farmers report that when situations with water shortage arise, they first fulfill their own irrigation needs and then sell water to potential purchasers. Tubewell owners are, first of all, farmers and then water sellers. Most of the farmers say, however, that the situation in which the choice has to be made between their needs and the demand of other farmers rarely occurs, due to the low utilization rate of most of the private tubewells (Kuper and Strosser 1992) and a common policy among tubewell owners (especially PTO and diesel tubewell owners), of limiting the number of buyers in order to be in a position to offer a service that remains reliable even when water shortages occur.

The average number of buyers is 4.6 per tubewell, 2 purchasers being the most common figure reported by tubewell water sellers. The highest number of purchasers for one tubewell is found for an electric tubewell of Fordwah 130-R command area. With a total of 25 buyers, this tubewell is operated most of the time and functions as a commercial enterprise. As reported in the previous section, differences exist between the Fateh and the Fordwah distributary areas (perennial canals) and the Azim Distributary area. The average number of buyers per tubewell selling water is lower in the latter (3 buyers per tubewell) than in the former (on average 5 buyers per tubewell).

The average numbers of buyers for electric, diesel and PTO tubewells are 8, 5 and 3, respectively, with a very large variability for electric and diesel tubewells. Electric tubewell owners not only sell the largest quantity of water as described above, but also sell it to the largest number of purchasers.

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3 One of the disputes was eventually settled. The first tubewell owner agreed to sell his less-expensive water (electric tubewell) to the second one, who simply abandoned his newly purchased PTO tubewell !

CONTRACTS AND WATER PRICES: A FURTHER ANALYSIS

Water transactions between the different participants are always informal and based on some implicit arrangements. It is quite surprising to see that nearly all the water purchases and sales taking place in the sample area involve cash. Even when a tubewell owner sells water to his tenant, a price per hour is fixed and paid in cash, generally at the end of the cropping season. In two cases only, interviews found that payment was made by exchanging water for labor or by exchanging water for the plowing of fields.[4]

Farmers buying water from electric tubewells are often asked to pay at the time of use or at the end of the month when the electricity bill is sent by the Water and Power Development Authority (WAPDA). For PTO or diesel tubewells, both options (to pay at the time of the transaction or at the end of the season) are equally used by farmers.

Changes in the water scarcity over a season, or over a year, are not translated into changes in water prices as would have been expected; for a specific season, the price per hour of water sold remains constant for a given tubewell. Between years, prices are modified to follow changes in the price of energy (electricity rate or price of diesel).

Most of the time, the price of water is the same for all the buyers. The only recorded exception is when a tenant-landlord relation is superimposed on the relationship between the seller and the purchaser; the tenant will pay a share of the total operational hours (according to the share fixed in the contract, i.e., from 1/6 to 1/2 in 5 cases) but sometimes for a lower price than other purchasers (60 or 65 rupees per hour instead of 70 rupees). It is interesting to notice that a different price for tenants is only found in the Fateh 184-R command area. Relations involving tenants in the 4 other watercourses do not show any difference between the price paid by the tenant and the price paid by other farmers.

An analysis of the price of tubewell water was undertaken to detect possible factors that impact on the price of water, such as investment costs, operation and maintenance (O&M) costs, tubewell discharge, tubewell groundwater quality, competition with other sources of water (canal water or other tubewells), demand, etc.

The responses of tubewell owners provide the first insight into the formation of water prices. Farmers reported that they take investment costs into account very rarely. A striking example is found for PTO tubewells, where the buyer comes with his own tractor, pays his petrol and does not give any financial compensation to the owner of the bore-point. In some cases, the tubewell owner provides the tractor as well, the buyer supplying the petrol or paying the fuel costs to the tubewell (and tractor) owner. O&M costs of the tubewell are the main factors (and most of the time the single factor) influencing the price of the tubewell water. Only two tubewell owners, both from Azim 63 command area (out of a total of 40 tubewell water sellers) were found to include investment costs in the water sale price, asking for 5 and 10 rupees extra per hour of water sold.

A comparison between the average price per hour for PTO, diesel and electric tubewell water shows that there is an important and significant difference between the different sources

4 A correlation between the type of contract and the sensitivity of crops to water stress could explain why share-cropping is not a more common practice in the area characterized by a cotton-wheat rotation. Sharecropping arrangements have been reported in the literature for crops with high water requirements like rice, fodder crops, tomato and onion (Meinzen-Dick and Sullins 1993). Field observations in the rice-wheat agro-ecological zone confirm this idea. Thus, the higher risk related to the cultivation of these high delta crops would be shared by the landlord and the tenant.

of power. On average, an hour costs 55 rupees, 32 rupees and 17 rupees when purchased from a PTO, diesel and electric tubewell, respectively. Because of their lower operation and maintenance costs (Kuper and Strosser 1992), electric tubewell owners are in a position to sell their water at a much lower price than diesel and PTO tubewell owners. That is certainly the main reason explaining the large difference between the average number of hours sold by electric, diesel and PTO tubewells highlighted in the previous section.

A regression analysis (using linear and logarithmic functions) was undertaken with the different variables listed above or proxies of these variables. The source of power, for example, was used as a proxy for the costs of operation of the tubewell; the position along a specific watercourse was used as a proxy of the quantity of canal water supply to a specific location of the watercourse command area. A satisfactory result was obtained with 4 independent variables related to the price variable in a linear form.

The equation estimated is[5]

$$P = 16.3 + \underset{(4.1)}{8.9}*Cred - \underset{(5.0)}{9.1}*Pow + \underset{(5.6)}{11.4}*Q + \underset{(5.6)}{37.5}*WC$$

(standard errors of the estimated coefficients within brackets
R^2 : 0.72 ; No. of Observations : 29 ; Degrees of freedom : 24)

The coefficient before the dummy WC highlights the significant difference between Fateh 184-R and the 4 other watercourses. The low tubewell density[6] limiting the competition between potential sellers could be the main reason explaining why purchasers in Fateh 184-R command area face a much higher tubewell water price (37.5 rupees more per hour) than in the other watercourse commands.

The positive coefficient of the discharge variable and the negative coefficient of the source of power were expected. With lower O&M costs, electric tubewell owners are in a position to sell their water at a comparatively lower price (9 rupees less per hour) than diesel and PTO tubewell owners. Hourly water prices are positively correlated with the discharge (thus the quantity of water supplied) of the tubewells. The marginal impact on the price of the discharge, given by the estimated coefficient of this variable, is however surprisingly small (a 0.7-cusec tubewell hour would only be 8 rupees less expensive than a 1.4-cusec tubewell hour).

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5 P : price of water sold in rupees per hour
Cred : dummy variable
Cred = 1 when the price is paid at the end of the season
Cred = 0 otherwise (price paid at the time of the sale or just before or after)
Pow : dummy variable
Pow = 1 when electric tubewell
Pow = 0 otherwise (diesel and PTO tubewells)
Q : discharge of the tubewell in cusecs
WC : dummy variable
WC = 1 when tubewell located within Fateh 184-R command area
WC = 0 otherwise (tubewell located in Azim 63-L, Azim 111-L, Fordwah 62-R or Fordwah 130-R)

The dummy WC is used to separate Fateh 184, with a very low tubewell density and a very low groundwater quality, from the 4 other watercourses that are more similar for these two characteristics.

6 The relatively good canal water supply and the poor groundwater quality are seen as the main factors explaining the low tubewell density in this watercourse.

The positive coefficient of the dummy Cred indicates that tubewell owners ask for a higher water price per hour (plus 9 rupees per hour) when water is paid at the end of the season or at the end of the year. To postpone the time of payment is the equivalent of a short-term loan which has to be paid by the purchasers. In this case, it would be expected that short-term credit and water markets would be interrelated. The situation is even more complex when tenant-landlord relations are included and superimposed on the seller-purchaser relations, thus involving labor and land markets as well.

A First Assessment of the Impact of Water Markets[7]

WATER MARKETS IN their current form have been spontaneously developed by farmers within the conjunctive use environment of irrigated agriculture in the Punjab Province. Although the existence of water markets (especially related to groundwater use) is well recognized (but not always officially acknowledged by irrigation officials), comprehensive information on the impact of water markets on agricultural production is not well known.

As a specific way of allocating (or reallocating) irrigation water between irrigators of a given watercourse, it is important to evaluate the impact of water markets not only on the agricultural production, but also primarily and more directly on the quality of irrigation services available at the farm level. Although the impact of water markets on environmental sustainability (via soil salinization or groundwater resources mining) is important, this issue will not be addressed in the present study.

IRRIGATION SERVICES

In this study, irrigation services of good quality are defined as reliable irrigation water supplies close to the demand of the farmers in terms of quantity and timeliness. This implies also a certain flexibility of the irrigation system for responding quickly to changes in the water-related environment (rains for example). Another dimension considered is the equity in the access to water (both canal water and tubewell water) resources.

The objectives of the different type of transactions are not similar. Exchange of canal water turns aims at improving the flexibility of the otherwise rigid warabandi system, while the sale and purchase of canal water and tubewell water have a direct impact on the total quantity of irrigation water available to farmers. Tubewell water sales play an important role by increasing the total quantity of water available to non-tubewell owners, especially in Fordwah 130-R and Azim 111-L watercourses. The existence of electric tubewells in these watercourses, with a larger number of hours sold to a larger number of purchasers, explains this partially.

The sale of canal water is mainly done by tail-end watercourse farmers, selling their turns to farmers located at the head of the watercourse command area. One could argue that canal water sales increase the already existing inequity in canal water supply along a watercourse. But if the seller has a good access to groundwater (of an appropriate quality), he has an interest to sell his water turns (he retains however his water rights).

Although equity is often considered solely in terms of canal water supply, it is important to include a groundwater component in this definition. In fact, in a conjunctive use environment characteristic of most of the irrigated areas in the Punjab of Pakistan, the inequity in the access to irrigation water would be much more related with the access to groundwater and to tubewell

7 The main purpose of this part of the paper is to list some of the issues related to the impact of water markets on the quality of irrigation services and on the agricultural production. Whenever available, data have been analyzed to support statements.

ownership. Water markets are a good means for improving the equity in access to groundwater resources, especially for small farmers who cannot afford to invest in a private tubewell (for similar conclusions in other agro-ecological areas, see also Khan 1990; Meinzen-Dick and Sullins 1993).

Data collected in the five sample watercourses show that tubewell owners usually remain the first users of their tubewell water. This is especially the case in the Azim watercourses with a poor canal water supply, and for electric tubewells that sell the largest number of hours but the lowest percentage of pumped hours. Although the equity in access to groundwater is improved through the sale of private tubewell water, tubewell owners retain the largest share of the groundwater resources for their own farm needs. To improve the equity in access to groundwater, tubewell shareholding would be a better alternative than water markets in their present form. However, the problems in managing such tubewells (some have been abandoned in the area because of management problems by the shareholders) should not be underestimated.

Via tubewell water purchases, farmers improve the reliability and the flexibility of their irrigation water supply. In some situations, however, tubewell water sales always take place during the canal water turns of the purchasers. Thus, the rigidity of the warabandi system with fixed turns is transferred to tubewell water transactions as well. The poor quality of the groundwater pumped is the main factor forcing farmer-purchasers to mix tubewell water with canal water (such is the case in Fateh 184-R command area with an average groundwater EC of 3.1 dS/m), to minimize the process of secondary salinization in their fields. In this case, the availability of irrigation water is influenced by tubewell water sales, but not the flexibility or reliability of the irrigation water supply.

Generally speaking, tubewell water markets improve the reliability of the irrigation water supply. Differences exist, however, from one watercourse to another and from one tubewell to another. A general policy among tubewell owners is to attempt keeping the number of water purchasers low to avoid any problem in case of deficits created by water shortages or operational problems (mechanical or power-supply problems). Thus, they can offer a reliable and flexible service to their customers. However, with a high utilization rate, a larger number of water sales in terms of quantity of water sold and number of purchasers, and difficulties of power supply (load shedding) during certain periods of the year, the reliability of electric tubewell water sales is expected to be lower than for diesel and PTO tubewells.[8] Within the current environment, a certain trade-off exists between the level of tubewell water sales (quantity of water sold and number of purchasers) and the reliability of the service offered by tubewell water sellers.

The next step in the analysis would be to define adequate indicators for the quality of irrigation services and quantitatively evaluate the impact of water markets on irrigation services (comparatively with the existing warabandi system or with other forms of water allocation). Findings should be cross-checked with the way farmers themselves perceive their irrigation water supply.

8 Based on how tubewell water purchasers perceive the reliability of water sales, Meinzen-Dick and Sullins (1993) show that electric tubewell water sales are significantly less reliable than diesel and PTO tubewell water sales. Within the current environment, a certain trade-off exists between the level of tubewell water sales.

AGRICULTURAL PRODUCTION

Several studies have addressed the issues of water market impacts on agricultural productivity. Freeman et al. (1978) found a significant impact of water purchases on wheat, cotton and rice yields. A study by the Water and Power Development Authority (WAPDA) (1980) reached a similar conclusion for sugarcane, rice, wheat and vegetables. Finally, Meinzen-Dick and Sullins (1993) highlighted the impact of irrigation applications from purchased tubewell water on wheat yields. The same study shows that the impact on yields of irrigations from an owner's tubewell was higher than the impact of irrigations from purchased tubewell water.

Differences in farming systems and farming practices (cropping pattern, agricultural inputs and outputs) are expected between participants and non-participants in water transactions. The impact of water transactions on agricultural production is more significant for water purchases (with a net increase in the water supply) than for canal turn exchangers, with the improvement in water supply flexibility as their main goal. More important for the farmer, in this case, is the ease with which he manages his water flows and not the potential impact on the crop yields.

The size of the sample and the variability in the type and intensity of water transactions from one farmer to another have limited the scope of the analysis of IIMI agricultural production data. The comparison of the impact on the agricultural production resulting from the different water transactions did not lead to significant conclusions.

This analysis does not control input or management (nonirrigation) variables, but the choice of levels of other inputs (fertilizer, labor, etc.) is affected by farmers' expectations about irrigation. A full-scale analysis would need to control inputs, but a two-stage analysis might be required, with the levels of inputs being affected by the type of irrigation and the output being jointly affected by the levels of inputs and irrigation.

Wheat and cotton yield data for the 60 farmers in this study are presented in Table 5 where the differences between the categories presented are however difficult to explain. Moreover, different trends exist for cotton and wheat.

Table 5. Wheat and cotton yields—kharif 1990 and rabi 1990/1991 (in kg/acre).

Category of farmer	Average wheat yield	Average cotton yield
Tubewell (TW) owner	895	695
Tubewell shareholder	835	587
Purchaser	820	674
TW owner/purchaser	1,170	664
TW shareholder/purchaser	1,030	601

Tubewell owners who are able to purchase water from other neighboring tubewells seem to have the higher agricultural productivity, certainly due to their nearly perfect control of the water resources. On the contrary, tubewell shareholders have nearly the lowest productivity, which could imply that the competition between the different needs of the shareholders has a negative impact on their agricultural productivity. General conclusions are more difficult to reach for other categories.

More significant results have been obtained when relating the cropping intensity and cropping pattern to the access to tubewell water. Farm characteristics have been calculated for three groups of farmers, tubewell owners, tubewell shareholders and tubewell water purchasers and are presented in Table 6.

Table 6. Tubewell owners, tubewell shareholders and tubewell water purchasers.

Status	**Tubewell owner**	**Tubewell shareholder**	**Purchaser (Non-tubewell owner)**
Area operated in the WC	19 ha	8 ha	5 ha
Cropping intensity	171%	145%	137%
Area under cotton	69%	45%	51%
Area under wheat	68%	58%	52%

The first aspect highlighted in Table 6 is that the landholdings of tubewell owners are larger than those of tubewell shareholders and non-tubewell owners. The difference in landholding size is not only characteristics of the sample area, but seems to be valid for most of the irrigated areas of Pakistan (see for example WAPDA 1980; Johnson 1989; GOP 1991; Meinzen-Dick and Sullins 1993[9]). Second, Table 6 shows that the cropping intensity as well as the area under wheat and cotton, the two major crops in the area, are higher for the tubewell-owner category. The three categories complement their canal water supply (if any) with tubewell water. However, the impact of this extra irrigation water supply on the cropping intensity and cropping pattern is higher for tubewell owners, who have the better water control resulting from using the groundwater resources, than for tubewell shareholders and tubewell water purchasers. Statistical analysis shows that the differences between the different variables presented in Table 6 are all significant at the 5 percent level.

The comparison between the tubewell shareholders and the purchasers is rather interesting; their similar cropping pattern and cropping intensities would suggest that purchasers, with their access to water markets, and tubewell shareholders face irrigation services of similar quality. Analysis of a larger set of data would, however, be needed to further compare tubewell shareholding versus water markets as two different ways to allocate the groundwater resources.

A more in-depth analysis of water market impacts on agricultural productivity is a next step to be conducted in order to correlate the quantities of irrigation water applied from each source of irrigation (instead of the number of irrigations from each source and the number of transactions of each type) to cropping pattern, agricultural production and agricultural productivity.

9 Meinzen-Dick and Sullins (1993) report that landownership status has a significant impact on tubewell ownership as well, tenants being at a disadvantage because they do not have rights to land.

Conclusions and Recommendations

MAIN FINDINGS

THE PERCEIVED DEFICIENCIES of the surface water supply in the Fordwah/Eastern Sadiqia Irrigation System have modified the irrigation environment in the area. First, farmers have invested on a large scale in private tubewells to tap groundwater resources. In the sample watercourses, groundwater represents currently between 10 percent to more than 90 percent of the total water available for irrigation. Second, groundwater pumped by private tubewells, and also surface water supplied at the head of the watercourse outlet, are transacted by most of the farmers in the area.

The present study has shown that water markets have improved the quality of the irrigation services for farmers in the sample watercourses, not only in terms of adequacy and flexibility, but also in terms of access to irrigation (surface water and groundwater). Water markets have some potential to assist in solving problems resulting from the current irrigation water supplies and to increase the agricultural productivity of irrigation water in a conjunctive use environment.

Although water turn transactions are forbidden by the Canal and Drainage Act of 1873, 15 percent of the water turns are subject to transactions, mainly to increase the flexibility of the water supply.[10] Tubewell water transactions, however, represent the bulk of water market activities. With lower operation and maintenance costs and a lower price per hour sold, electric tubewell owners sell a larger number of hours to a larger number of farmers than diesel and PTO tubewell owners. The percentage of hours of operation sold is, however, the highest for diesel tubewells, because of their reliability because of interrupted electric supplies due to load shedding.

The canal water supply has an impact on the intensity of tubewell water sales. When canal water is a relatively scarce resource (due to a low supply compared with the crop water requirements), tubewell owners sell a lower percentage of the pumped groundwater. Groundwater of poor quality (as in Fateh 184-R watercourse) is another factor limiting the development of tubewell water sales, directly or indirectly, via its impact on tubewell development.

Groundwater sales mainly benefit small farmers and tenants. Without the financial capacity to invest in the installation of a private tubewell, the current arrangements give them the access to groundwater resources and improve the equity in irrigation water supply. With prices usually based solely on operation and maintenance costs in the sample area, tubewell owners support the investment costs alone and the risks, but still retain the largest share of the groundwater resources for their own needs.

10 Merrey (1990) relates the development of water turn transactions also to past subdivision of landholdings that have not been accommodated by warabandi changes.

The studied water markets represent, in fact, a large number of informal micro-markets scattered in the sample areas, involving a relatively small number of participants. The relations between the participants is generally complex and not only limited to water transactions. Short-term credit and water are often related, and in a few cases, a landlord-tenant relationship is superimposed on the seller-purchaser. Thus, water, land, labor and credit markets are closely interrelated. This situation is met more often in the rice-wheat agro-ecological zone where sharecropping arrangements are common. The high risk related to the cultivation of high-delta crops (rice or vegetables) in an unreliable environment is, in this case, shared between the landlord and his tenant.

POLICY RECOMMENDATIONS

With the recent stagnation in the performance of the irrigated sector, especially in food grain production (Bandaragoda 1993), the efficiency of irrigation water use has became a major concern for policymakers (and funding agencies) in Pakistan. The development of water markets is increasingly seen (by some donors and government officials) as an appropriate answer to improve the allocation of water resources and stimulate the growth of the irrigated agriculture sector.

A leading role in this process is played by the World Bank, which has presented its views on the potential for water markets in addressing current problems and constraints in the irrigation and drainage sector in a recent report (World Bank 1993). The report identifies water markets and privatization of the surface irrigation system as **the** most appropriate option that would help improve the low productivity and efficiency of the irrigation system, and would eventually reduce the currently increasing gap between demand and supply of food and fiber products.

Numerous questions, however, have to be answered before the institutionalization and development of any form of water market in Pakistan. There is the need first to assess empirically whether it would be beneficial (in terms of irrigation water allocation and productivity) to develop water markets. The present study can already provide some insight regarding important issues to be addressed.

Merrey (1990) has highlighted the need for more flexible and equitable water allocation alternatives to distribute canal water below the outlet. Canal water transactions fulfill one of the requirements by improving the flexibility of the warabandi for the 5 sample watercourses and could represent an alternative to be encouraged. It is important to highlight that farmers exchanging or selling canal water turns retain their water rights implicitly defined by the (official or agreed-upon) warabandi. A *pakka* (or fixed) warabandi combined with canal water transactions is seen as an appropriate way of ensuring fixed (canal) water rights for farmers, providing them at the same time with a flexibility in water supply for an optimum and efficient irrigation water management.

Three important aspects still have to be considered before any serious effort is undertaken to officially promote canal water transactions. The first one is a review and update of the 121-year old Canal and Drainage Act, to integrate features of the current conjunctive use environment with existing canal water transactions. The second aspect is to assess carefully the equity dimension related to the process. The third one would be the possible involvement of effective farmers' organizations into this process. To allocate canal water to Water Users'

Associations that would redistribute water among individuals is an option already envisaged by government and funding agencies.[11] A rigorous field testing would however be needed before any implementation on a large scale.

The main benefits resulting from further development of groundwater transactions are an enhanced utilization of the tubewell capacity, an increase in the access to irrigation water supply (especially for small farmers and tenants) and lower water tables. A promotion of the installation of private tubewells for medium-size or small farmers and/or an extension of electric-line networks and improved reliability of the electricity supply, (Meinzen-Dick and Sullins 1993) have been proposed as means for improving the development of groundwater markets.

The decision to promote or to control groundwater markets is relatively environment-specific and will depend on local conditions like water-table depth, groundwater quality, canal water supply, etc. Irrespective of location, a first step would be to assess the tubewell capacity for further development of groundwater transactions. The overinvestment in private tubewells in large areas of the Punjab is well known. However, this apparent overinvestment is a response to the unreliability of the canal water supply. It plays an insurance role to mitigate the erratic variations in the canal water supply. To provide a more reliable canal water supply would reduce the stabilization role of the private tubewells and would make available an extra share of the tubewell capacity for potential water sales. Another incentive to promote tubewell water sales (Meinzen-Dick and Sullins 1993) would be the improvement of the water distribution network.[12]

It would be appropriate in areas, where water tables are relatively high and stable and groundwater is of adequate quality, to facilitate the installation of electric tubewells (by targeting medium-size or small farmers). This will make available the higher number of hours to the higher number of purchasers compared to PTO and diesel tubewells. However, in many cases, water tables are already declining (Government of Pakistan 1991). The installation of electric tubewells is probably not the appropriate answer for this situation, and equity in access to groundwater resources has to be considered seriously. Diesel tubewells, with the highest percentage of hours of operation sold, would represent the best alternative to tackle problems related to equity.

With the depletion of the groundwater resources already being reported in several areas of Pakistan (Government of Pakistan 1991), problems of groundwater rights will become more acute. An efficient management (monitoring and control) of the groundwater extraction process, is needed taking into account water transactions. Which mechanisms are to be used, who will enforce them, who will monitor the conjunctive use system, etc., are issues to be addressed. To date, the monitoring of private tubewell operations is not in the mandate of any line agency or research body, while private tubewells supply more than 40 percent of the total irrigation water in the Punjab.

11 The Command Water Management component of the recent project proposal for the Fordwah/Eastern Sadiqia (South) Irrigation and Drainage Project (World Bank-funded) includes the exploration of substitutes for the warabandi system involving farmers' groups or federations of Water Users' Associations (World Bank 1992).

12 Watercourse lining reduces water losses and increases the number of potential purchasers for a given tubewell.

THE NEED FOR FURTHER RESEARCH

Some of the results from this study are expected to be generic for much of the Punjab. For example, the differences in operation and participation in water transactions between PTO, diesel and electric tubewells, related to differences in costs of operation and maintenance, are thought to be similar in other areas of the Province. However, other results, largely related to characteristics of the conjunctive use environment (groundwater quality, quality of the canal water supply, water-table depth), are expected to be more site-specific.

The need for further research has recently been advocated by Meinzen-Dick and Sullins (1993). Most of the research to date has been in locales with relatively favorable conditions, with groundwater of relatively good quality and an appropriate recharge to the aquifer. Thus, more research is needed in environments with groundwater of very poor quality, or aquifer depletion, in various agro-ecological zones.

To propose a specific research agenda on water markets is a first priority. To date, policymakers and funding agencies (see World Bank 1993 for example) see the privatization of the water sector and the institutionalization of water markets as an appropriate way to increase the efficiency of the water allocation system and to increase the agricultural productivity of the country. However, most of the issues related to water markets have not yet been addressed comprehensively. For example, if water markets are to be promoted, what would be the related transactions costs (costs of obtaining the information, cost of contracting, and cost of enforcement) faced by participants? Are sharecropping arrangements in this regard appropriate and under which conditions? What would be the impact of water markets on environmental sustainability?

Systematic research focusing on the functioning of water markets, their impact on the quality of irrigation services, and on production and environmental sustainability has to be conducted in different environments. Groundwater quality, evolution of the water-table depth, and supply of canal water would be the main variables for selecting research sites in various agro-ecological zones.

As a consequence of the increasing interest in market mechanisms for the allocation of irrigation water, and based on the present study results, the International Irrigation Management Institute (IIMI) has recently started a comprehensive research program focused on water markets in the Fordwah/Eastern Sadiqia Irrigation System. The research, conducted in collaboration with a French research institute, the Centre National du Machinisme Agricole, du Génie Rural, des Eaux et des Forêts (CEMAGREF), combines technical and economic aspects of irrigation water supply and demand. The main objective of the research is to evaluate the feasibility of water market development in Pakistan (appropriate level[s] of the irrigation system, institutional arrangements, required technical and management changes), and estimate the related impact on agricultural production and sustainability.

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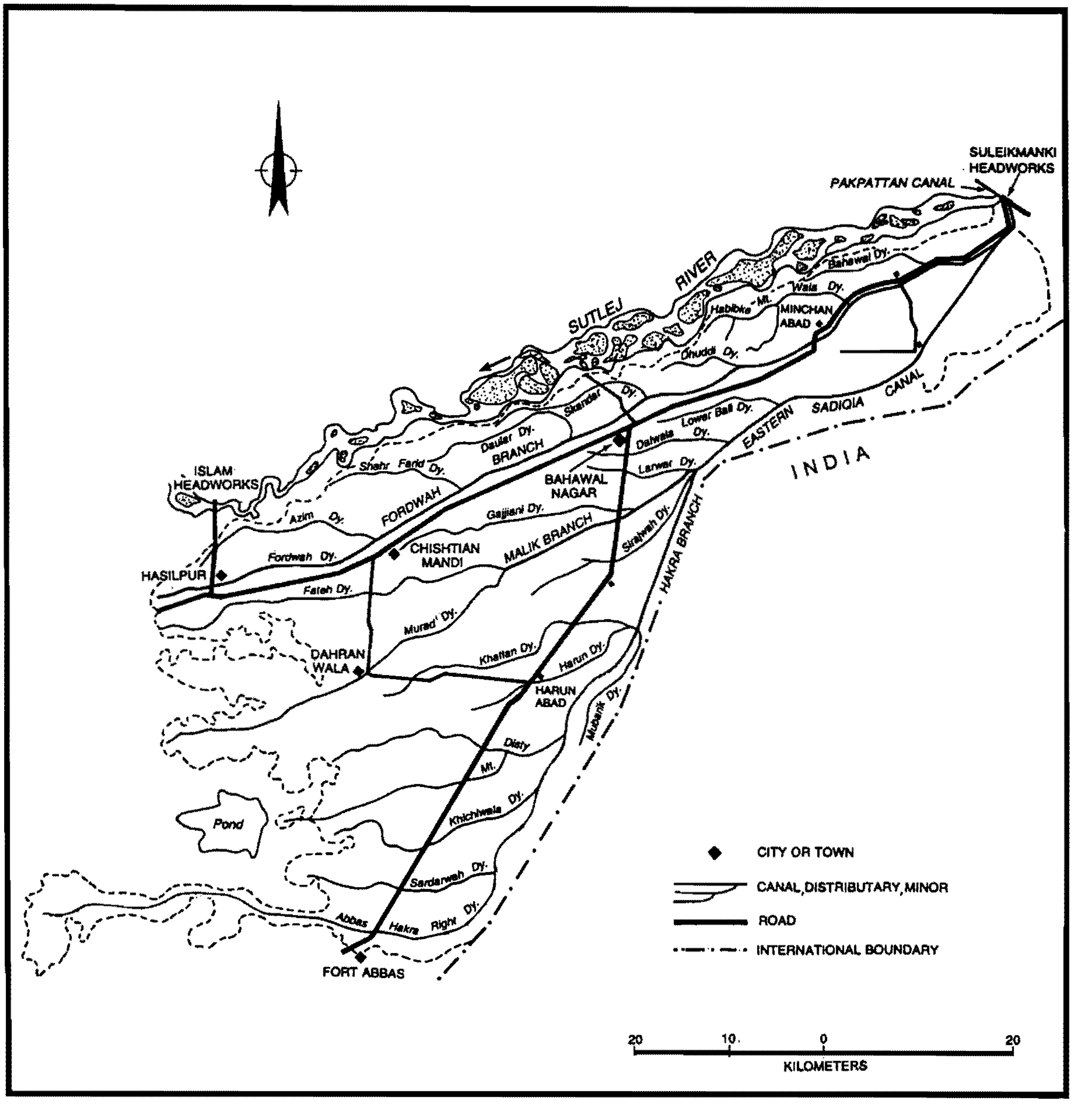
Appendix I

Fordwah/Eastern Sadiqia location map.



Appendix II

Characteristics of the sample distributaries.

Name of distributary	Offtaking from	Status	Length (km)	CCA (ha)	Number of outlets	Design discharge (m^3/s)
Fordwah	Fordwah Branch	Perennial	42.1	14,844	87	4.5
Azim	Fordwah Branch	Non-perennial	36.0	12,327	75	6.9
Fateh	Malik Branch	Perennial	68.3	39,242	159	12.2

Characteristics of the sample watercourses.

Watercourse	GCA (ha)	CCA (ha)	No. of landowners	Design discharge (l/s)	Water quality of TW* (dS/m)	TW's density (/1000 ha)
Azim 63-L	123	113	14	59.2	0.8	95
Azim 111-L	121	101	19	45.9	1.1	80
Fordwah 62-R	131	117	45	33.4	1.1	82
Fordwah 130-R	265	174	42	64.6	1.3	92
Fateh 184-R	344	213	39	69.6	3.1	28

* TW = private tubewell.

Appendix III

Type and intensity of water transactions
(average per farmer per year).

Transactions	Fordwah 62-R	Fordwah 130-R	Azim 63-L	Azim 111-L	Fateh 184-R	Average
Partial canal turn exchanged	6.9	7.6	3.4	2.3	1.4	4.4
Full canal turn exchanged	0	0.2	0.6	1.5	0	0.4
Tubewell for canal or vice versa	0	0.2	0.5	2.4	0	0.6
Canal water purchased	0	1.6	0.3	4.3	0	1.2
Tubewell water purchased	10.7	13.9	1.7	6.8	3.2	7.2
Canal water sold	0	0	0	0	0	0
Tubewell water sold	3.3	40	0	6.6	2.8	9.4