FARMERS ACTIONS AND IMPROVEMENTS IN IRRIGATION PERFORMANCE BELOW THE *MOGHA*

How farmers manage water scarcity and abundance in a large scale irrigation system in South-Eastern Punjab, Pakistan

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Propositions

1. Nay were ye to know with certainty of mind (ye be ware).

   Al-Quran

2. For farmers, control over irrigation water is like control over their own lives - as water is life.

   This thesis

3. It is better to clean your own watercourse than to borrow an irrigation water turn.

   This thesis: A farmer from watercourse FD 84-L

4. Nowadays, no one accepts authority from others, everyone wants to be an elder of the village. We lack unity therefore we can not organise collective action anymore.

   This thesis: A farmer from watercourse FD 84-L

5. Although some of the actions by farmers can be called reactive management, in general farmers do plan their irrigation management activities and they have learned through experience to manage their irrigation system. Their management can not be classified as 'contingent management' and is rather performance oriented.

   This Thesis

6. The assumption that watercourses are managed collectively because of the fact that farmers are grouped together is an over-simplification of the realities in which water management takes place in a watercourse command area.

   This Thesis

7. I am a queen and you are a queen as well, which of us shall carry the water?

   A Pukhtoon Proverb

8. The radical of one century is the conservative of the next. The radical invents the views. When he has worn them out, the conservative adopts them.

   Mark Twain

9. Time present and time past are both perhaps present in time future, and time future continues in time past.

   T. S. Elliot

10. Washing one's hands of the conflict between the powerful and the powerless means to side with the powerful, not to be neutral.

    Paulo Freire

ABSTRACT

The irrigation systems of Punjab, Pakistan are not functioning effectively in relation to design criteria or farmers' needs. This under-performance is attributed to among others, scarcity of irrigation water, changes in cropping intensity and mis-allocation of available resources. Presently irrigation system management in Pakistan is undergoing institutional reforms- to introduce Participatory Irrigation Management with involvement of new Farmers Organisations in water management- that is expected to result in improved water distribution performance and financial sustainability of the system. This study was conducted to investigate the impact, value and capability of farmers' local water management actions in a large-scale canal irrigation system, to contribute in the wider debates about Participatory Irrigation Management and sustainability of groundwater use in such schemes in Pakistan.

An interdisciplinary, socio-technical approach was used as the main methodological approach for this study. A comparative study method was used to analyse farmers' actions for water management. The research was undertaken in the Fordwah Irrigation System, which serves a command area of 232,000 hectares. Six watercourses along the two distributaries (at the tail of the system) were selected for in-depth study. Fieldwork was conducted between November 1996 to April 1998. Water delivery performance was measured at the outlets of these watercourses. Collective and individual water management actions were studied to understand their dynamics and their impact on improving water delivery to the farm.

The study suggests that there is neither a standard set of water management activities nor they are strictly planned, in the study area. Farmers' actions are mostly subject to their desires to match water demand with supply, however one can still see some of the water management activities that are inevitable to operate the system. The actions taken and the way and time these activities are organised and performed is difficult to predict in advance. Collective action is undertaken more at the watercourse or higher level in the irrigation system, whereas individual actions are mainly undertaken at the farm level.

The four main findings of the study are: 1) that farmers are knowledgeable and capable actors who take actions that improve water supply and compensate for dysfunctional delivery; 2) farmers actions are not only technically and economically sound but also have motives other than just economic benefit; 3) farmers' management cannot be classified as 'contingent management' and is rather performance-oriented; and 4) current performance indicators, which are not able to show realities of social relations shaping water availability, could be improved by including criteria to assess performance of irrigation system from the perspectives of different actors. By incorporating the way farmers intervene with the system and thus appropriate the water delivery, such new performance studies could portray local water dynamics of a system and support recommendations based on reality to improve the functioning of the irrigation system.

The patterns of conjunctive water use at the farm level suggest that in future groundwater must continue to provide significant amount of water for crop production. Farmers already organise management actions in the irrigation system: new Farmers' Organisation may improve the accountability of these to other farmers.

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ABREVIATIONS AND GLOSSARY

ABREVIATIONS

ACA	Actual Cropped Area
APM	Adjustable Proportional Module
AWB	Area Water Board
CCA	Culturable Command Area
DPR	Delivery Performance Ratio
FO	Farmers' Organisation
GCA	Gross Command Area
ID	Irrigation Department
IMT	Irrigation Management Turnover
IWMI	Irrigation Water Management Institute
MNA	Member of National Assembly
MPA	Member of Provincial Assembly
MREP	Mona Reclamation Experimental Project
OF	Open Flume
OFRB	Open Flume with Roof Block
OFWM	On Farm Water Management
PIDA	Provincial Irrigation and Drainage Authority
PIM	Participatory Irrigation Management
PM	Prime Minister
RD	Reduced Distance
RIS	Relative Irrigation Supply
RWS	Relative Water Supply
SDO	Sub-Divisional Officer
XEN	Executive Engineer
WAPDA	Water and Power Development Authority

GLOSSARY

Abiana	Water tax
Bharai	Time required filling the watercourse
Biradari	Kinship group based on the patrilineal descent and marriage
Budh	Old river bed
Chak	Tertiary irrigation command
Chowkidar	Watchman
Culturable Command Area	Command area of a tertiary unit for which water is allocated
Dera	Farmhouse
Gilla shikwa	Complaining
Imam	Someone who leads the prayers
Izzat	Honour, Respect
Kanah	Stick of any size, used to distribute work during watercourse desilting
Karam	5.5 feet
Katcha	Unofficial, informal
Killa	An acre
Khal	Watercourse, channel
Kharif	Summer cropping season – mid April to mid October
Mauza	A revenue village
Mogha	Tertiary outlet
Murrabah	Square
Nakka	Farm inlet, Farm-gate

Nikal	Time required draining the watercourse
Numberdar/ Lumbardar	Headman of a village, who collects *abiana*
Pacca	Strong, Official, Formal
Panchayat	Traditional system of conflict management in which elders and respectable take decisions
Pattidar	Shareholders
Patwari	Revenue official who records crops and makes *warabandi*
Rabi	Winter cropping season – mid October to mid April
Riasat	State
Rouni	Pre-sowing irrigation
Sarkari	Something that belongs to or owned by the Government
Shareholder	Farmers sharing canal water from the same *mogha*
Warabandi	Method of water allocation and distribution. Time is allocated according to landholding size
Zid	Being stubborn, being destined

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Robina Wahaj
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1 INTRODUCTION

1.1 PROBLEM STATEMENT

The large irrigation systems in Pakistan were constructed to protect the region from the threat of famine and to open up new areas for settlement to generate income to the then colonial British Government by the sale of crown waste lands (Michel, 1967; Bandaragoda and Badruddin, 1992; Gilmartin 1994). With the objective of maximizing the production per unit of surface water available, the water was spread thinly over as large an area as possible to achieve maximum social benefits from the distribution of available surface water resources. This concept of irrigation is referred to as Protective Irrigation[1]. The irrigation systems constructed, based on the protective irrigation concept, are characterized as supply based systems - which do not respond to changes in demand - with low design cropping intensities and high water 'duties'[2] (Jurriens *et al.*, 1996). Canal water provided was sufficient to irrigate only one third of the command area[3]. Infrastructure was needed that could distribute water proportionally and equitably. Because of the high silt content in the river waters, infrastructure was also required to distribute silt proportionally to the secondary channels and tertiary outlets in order to avoid siltation (or sedimentation) in the main and secondary canals and therefore reduce the maintenance requirements. To limit human interference in the operation of the system, regulation points were minimised and the watercourses were provided with ungated tertiary outlets. In the recent past, research on the performance of these irrigation systems at primary and secondary sub-system levels by the International Water Management Institute (IWMI) (Vander Velde, 1991; Kuper and Kijne, 1992; Bhutta and Vander Velde, 1992; Habib and Kuper, 1996; and Kuper 1998) showed that the distribution of canal water is neither proportional nor equitable anymore.

The poor functioning of the irrigation system in Pakistan has been a source of concern since the 1960's, and since then it has been the subject of considerable external assistance and internal policy reforms. This under performance is mainly attributed to the scarcity of surface water. The previously planned scarcity now manifests itself in inadequacy, unreliability and inequity in the distribution of surface water for farmers at watercourse level. The surface water scarcity is not only a reflection of changes in the cropping patterns and cropping intensities, but also shortcomings in agency management. Deteriorating infrastructure due to poor maintenance of the canals is resulting in unreliable and inequitable canal water distribution. Poor cost-recovery is considered one of the main reasons for lack of funds available for the operation and maintenance of the infrastructure (Strosser, 1997). These discrepancies in the distribution of surface water also lead to other problems like water-logging and salinity, and over exploitation of groundwater[4] at farm level (Badruddin, 1993 and World Bank, 1994). To address these problems in the management of irrigation systems, the World Bank (1994) proposed a number of institutional changes for irrigation management turnover.

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[1] Jurriens *et al.*, (1996) has described the concept of protective irrigation in depth.

[2] Water duty is the area to be irrigated by a unit discharge. It is expressed as number of acres/ft^3/s.

[3] In fact canal water was provided to protect the crop from failure, which is reflected from the fact that a farmer is supposed to pay full water tax, provided his crop reaches maturity, even if he receives only one irrigation turn during the whole season (Kuper, 1997).

[4] Groundwater is currently contributing about 30 to 40 % of the total irrigation water at the farm-level (this study; Vander Velde and Johnson, 1992; Nespak/SGI, 1991).

The policy of Irrigation Management Turnover (IMT) to the farmers was considered as an option to resolve some of these management problems of irrigation system in Pakistan. However, after several rounds of discussions between the different stakeholders in Pakistan and the World Bank an agreement was reached to decentralise, instead of privatise, the irrigation system management and to promote farmers' participation (Strosser, 1997). The Government of Pakistan announced a policy decision in September 1995 to introduce Participatory Irrigation Management (PIM) in the primary irrigation system level, and to transform Provincial Irrigation Department(s) (ID) into Provincial Irrigation and Drainage Authority (ies) (PIDA). As a result the Provincial Assembly of Punjab Province has also approved a bill in 1997 to form the PIDA and the Area Water Boards (AWBs)[5]. The Government of Punjab is now preparing to test these AWBs as pilot projects in the province. New local level water management organisation has already been initiated at watercourse and distributary on pilot basis.

One of the anticipated impacts of PIM is the better functioning of irrigation systems, in both water supply and administration. Its objectives are not only to improve the performance of the irrigation system through better operation and maintenance, but also to enhance accountability of the managers of the system to the water users. However, the success of PIM in other countries is taken as a guarantee of successful transfer of the irrigation system in Pakistan too. Nevertheless, the impact of the PIM is not yet fully evaluated even in those countries where it was presented as a success story. Therefore, before the implementation of this Act, it is very important to know the existing level of management as achieved by the water users of the irrigation system in relation to the water supply conditions. Not only that, the implementation of this Act should also be based on an understanding of what farmers can do, and on the interactions between farmers and Irrigation Department in shaping water delivery. Very little is known about how various water management actions on a daily basis by farmers are shaped by the poor functioning of the irrigation system at primary and secondary sub-system levels. In reality, no one has studied systematically how farmers' water management activities can amend water distribution to improve outcomes of the irrigation system at watercourse and farm level. The objectives of this study are thus to improve understanding of the impact, value and capability of farmers' local water management actions in large-scale canal systems, to contribute in the wider debates about PIM and sustainability of groundwater use in such schemes in Pakistan.

The study of water delivery problems and their resolution has given rise to a field of study on design-management dimensions, which has also diverged in themes of study. A practical interest in problem diagnosis has triggered a range of water management assessment methodologies, one of which is Performance Assessment Methodologies. Vincent (2001) notes how these have been developed by IWMI in particular since 1985, both to show types of delivery problems, and to be used for comparative studies that can evaluate effects of investment or reform programs. Since 1994 they have also been developed beyond water supply analysis to attempt to evaluate the whole 'design-management environment' of an irrigated farming area (Murray-Rust and Snellen, 1993). However, Vincent also notes that

[5] PIDA will act at the provincial level, whereas AWB will be formed at each canal command to distribute canal water among the distributaries. Each major canal command within a province will have an Area Water Board (AWB). These AWBs will have representatives of water users and the Government. The Farmers' Organizations (FOs) will be formed on each distributary (i.e., at secondary sub-system level). The FO consists of representatives of the water users from all the watercourses in that distributary. Water Users Associations (WUAs) will be the lowest unit of organization in which all the water users of a watercourse command area will be represented.

these studies are often not 'user focused' in terms of understanding what people can or cannot do locally with the technology for delivery of water, or organising collective action for management needs like the maintenance or fee payment. Thus since the 1970's there has been another field of study of design-management interaction, to debate what can work and how for the delivery of water.

In the past, performance assessment has been done mainly on the performance of irrigation systems at the primary and secondary sub-system levels (Bishop and Long, 1984; Clemmens and Dedrick, 1984; Sharma *et al.*, 1991; and Bird and Gillot, 1992). However, while these studies are very helpful in making the performance of the irrigation system visible, they only show the performance of one (or sometimes two) elements of the irrigation system and do not consider the links between the different elements of the irrigation system in detail. Besides, these studies deal with the performance of water delivery system at main or secondary level and do not take into account of what happens inside the watercourse. Moreover these studies also did not capture the part played by farmers intervention in achieving these performance levels. Perry (1995) has already stated that the performance evaluation of an irrigation system at primary and secondary sub-system levels in isolation from the performance evaluation of an irrigation system at watercourse and farm level would not provide full understanding of the system. However, little work has been done on the performance of the surface water supply system at watercourse level.

The alternative line of study of design-system management relations has a focus on users and their interaction with their technology to ensure water supply. Rather than supply technical arrangements for ideal conditions and prescriptions for better main system management, they look to learn from interactions between technology and people, people and people, and central and local domains of management to see what might be workable options in developing or transforming irrigation. Recently studies have begun which use flow criteria, which are also called performance criteria, as a means to show the wider water conditions and what local actions make water delivery 'actualised' (Lankford and Gowing, 1996; Vos, 2001). Such studies use flow criteria now called 'performance indicators', but as a means to show the wider water conditions in which actions take place for better water supply, and also the effects of these interactions. These studies (Mollinga, 1998; Pradhan, 1996; Van der Zaag, 1992. Horst, 1998) of farmer-system interactions have debated which kind of technologies work better in different agrarian and water supply contexts, and are still quite rare for large irrigation systems.

Mollinga's study (1998) of the Tungabadra provides an insight of the social relations emerging in a water-scarce system with gated pipe outlets. There is limited work to date studying social relations and water management activities in large-scale systems with fixed division structures and with extensive groundwater development. How do farmers in such conditions make estimates, choices and preferences over actions to improve their water supply? Groundwater is often treated as just a black box response to dysfunctional canal supply whereas a farmer focus can help understand better the strategies that shape conjunctive use and its sustainable use. The present study was conducted to study the impact of farmers' water management actions in a conjunctive water use environment of Fordwah Irrigation System.

1.2 STUDY SITE

Research was undertaken in the two distributaries of the Fordwah Irrigation System, Punjab, where the International Water Management Institute (IWMI) had a wider research program in which the researcher could undertake further work in sample watercourses. This gave the researcher access to additional data for analysis. The following paragraphs present information about the research site i.e. Fordwah Irrigation System and the selection of distributaries for carrying out in-depth research.

Fordwah Irrigation System

The Fordwah system irrigates about 232,000 hectares (ha) of Culturable Command Area[6] (CCA) out of a Gross Command Area (GCA) of 301,000 ha and is classified under the cotton-wheat agro-ecological zone with cotton and forage as main *kharif* (summer) crop and wheat and forage as main *rabi* (winter) crops. The annual precipitation of 200 mm[7], which mostly falls in the monsoon season (July to September) is much less than the evaporation of 2400 mm (Kuper, 1997) hence irrigation is essential for the cultivation in this area.

The Fordwah canal off takes from Suleimanke headwork[8] that was constructed from 1921 – 1926 (and opened in April 1926) under the Sutlej Valley Project (Sutlej Valley Project, 1933). This project was initiated to make use of the surplus water of the Beas River, a tributary of the River Sutlej (Sutlej Valley Project, 1920). Initially the source of irrigation water was the River Sutlej (and Beas), but India was awarded the rights to water from Sutlej (and Beas) as a result of Indus Basin Treaty between Pakistan and India in 1960. Afterwards link canals were constructed to convey water from the Balloki headwork to the Suleimanke headwork (the layout of the irrigation network in Pakistan is shown in Appendix I). This irrigation system has two different sources of water, in the flood season (mainly *kharif*) it gets water from river Chenab and rest of the year it gets water from Mangla dam[9] that is built on river Jhehlum. A schematic diagram of the Fordwah irrigation system is presented in the Figure 1.1.

The main canal is relatively short (about 13 kms.) and bifurcates into two branches, McLeodganj branch and Fordwah branch, at RD[10] 44. Fordwah Branch is a non-perennial canal that receives water, from Suleimanke headwork, only in *kharif* season (April 16 to October 15). However, 6 distributaries along this canal are perennial among which 5 lie in the Chishtian Sub-Division. The reasons for keeping other distributaries non-perennial were limited availability of surface water, historical water rights[11] and negotiations between the then Bahawalpur State (of which the study area is a part of) and the colonial Government of British India (which initiated the project) (Sutlej Valley Project, 1933). A feeder canal, called

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[6] Culturable Command Area is the irrigable area for which water is allocated.

[7] This value is quoted in Kuper 1997. He averaged the 30 years of rainfall data of the Bahawalnagar and Bahawalpur meteorological stations. However rainfall data collected for this study showed a high rainfall during the study period. Farmers also confirmed more than average rainfall during that year of 1997.

[8] Three canals off-take from Suleimanke headwork: Eastern Sadiqia and Fordwah canals from the Left Bank and Pakpattan canal from the Right Bank of the headwork.

[9] The route of water in the flood season is the Qadirabad-Balloki link canal and Balloki-Suleimanke link canal. In the dry season when water comes from the Mangla dam it is conveyed through Rasool-Qadirabad link canals, Qadarabad-Balloki link canals and then Balloki-Suleimanke link canals.

[10] RD is Reduced Distance from the head of the Canal. 1 RD = 1000 ft. = 304.8 m.

[11] There were already some inundation irrigation canals, which were used for the irrigation especially during the flood season. Farmers who were using these canals were assumed to have right on the water from the Sutlej River and therefore provided with the perennial canal water supply.

Sadiqia-Ford Feeder, caries water for these perennial distributaries from the Eastern Sadiqia canal, which also off takes at the Suleimanke headwork, to the Fordwah branch canal. All the perennial distributaries except one lie in one sub-division of the Fordwah Irrigation system, which is Chishtian sub-division. The feeder canal comes under the rotation of Eastern Sadiqia irrigation system; therefore its management also influences the Fordwah irrigation system. In addition to carrying water for the perennial distributaries of Fordwah canal in winter, the feeder canal also supplies water to two distributaries of which one is perennial and the other is non-perennial.

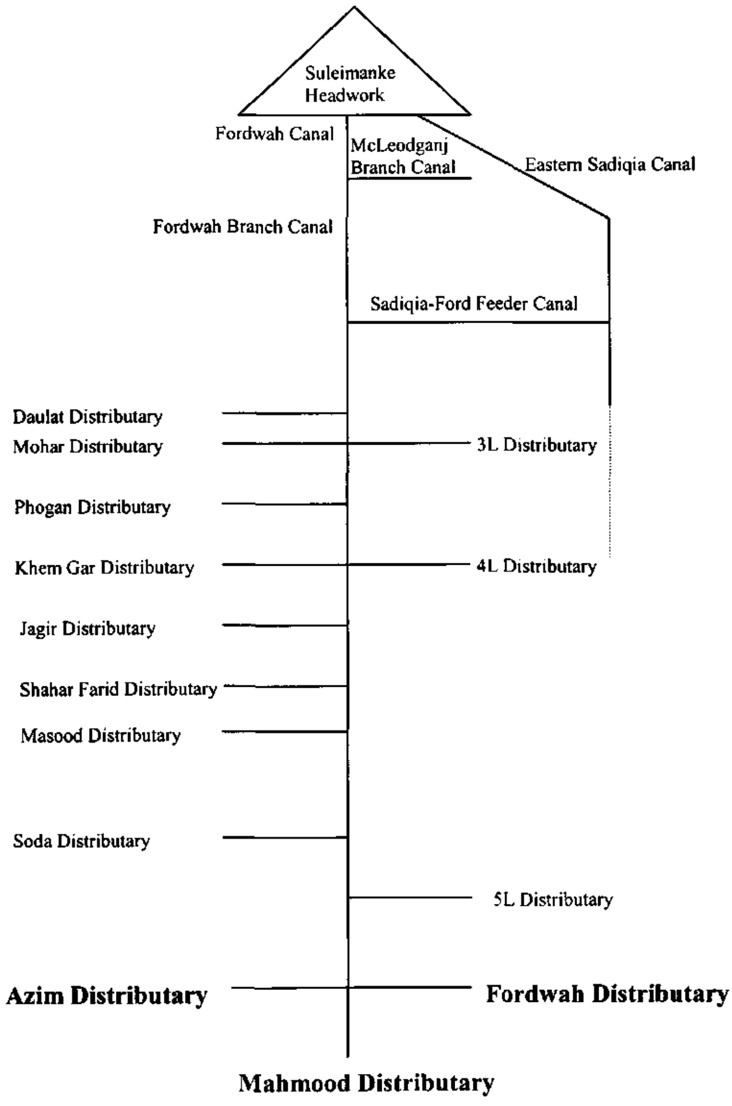

Figure 1.1: Location of the two selected distributaries, Mahmood distributary and Fordwah distributary (in the Chishtian Sub-division) along the Fordwah Branch Canal

Recent studies (Hart, 1996; Habib and Kuper, 1996; Habib and Kuper, 1998; Kuper, 1997; Visser *et al.*, 1998) on canal operations of Fordwah Canal Irrigation system have shown that the system is neither equitable nor proportional. These studies have also demonstrated a large fluctuation in the daily discharges of the distributaries along the canal, which are amplified as water moves downstream. This results in considerable discharge fluctuation at the tertiary outlet and therefore at the farm-gate. These fluctuations at the farm-gate cause serious problems for farmers[12], as they effect the number of bunded units that could be irrigated in one canal water turn (Sarwar *et al.*, 1997).

The Punjab Irrigation Department (PID) is currently responsible for the management of the main system that is from the headwork to the tertiary or watercourse outlet. The watercourse outlet is locally called *mogha*. Below the *mogha* a group of farmers are supposed to distribute the canal water and maintain the watercourse, however the guidelines for water distribution are provided in form of fixed roster (*warabandi*) schedule (section 2.5.2 explains different kind of *warabandi* schedules).

1.3 RESEARCH METHOD

The core concern of this thesis is to see how farmers take actions to improve their water supply, to acquire canal or groundwater, in the given conditions of water availability in a system that is known to face serious water inadequacies. The study was also concerned to undertake an interdisciplinary approach that could provide a focus on users actions and inter-relations, rather than an approach where system-level characteristics were the main object of study and comparison.

The method used in this study was a comparative study of irrigators' actions in six selected watercourses from two selected distributaries. Water availability, from canal water and groundwater was taken as a key factor in the selection of distributaries and watercourses. However, some other practical considerations also influenced the choice of the distributaries. These were: 1) IWMI-Pakistan already had a good basic data base of the area and the distributaries; and 2) It was convenient to work in these two distributaries in terms of mobility. Since IWMI-Pakistan had a field office in Hasilpur, a town very close to these distributaries, it was relatively easy for the field staff to commute this distance. Some of the research staff still had to cover a distance of 42 kilometers daily. The two selected distributaries, Fordwah distributary and Mahmood distributary, are perennial distributaries at the tail end of Fordwah branch canal[13].

Two variables were considered in selecting sample watercourses. The first was average water canal water availability in *kharif* 1994 to all the watercourses along the chosen distributaries. This volume of water was estimated by a hydraulic model, Simulation of Irrigation Canals (SIC)[14]. The second variable that influenced the selection of sample watercourses was

[12] Keller (1986) Freeman (1990) and Lowdermilk (1990) have written about the variability of water supply and its effect on the organisation of water distribution elsewhere.

[13] There are three distributaries at the tail of the Fordwah branch canal: Azim distributary, Fordwah distributary and Mahmood distributary (see figure 1.1). Azim is a non-perennial distributary that off-takes from the left bank of the canal, whereas both Fordwah and Mahmood are perennial distributaries and off-take from right and middle of the Fordwah branch canal respectively.

[14] Simulation of Hydraulic Canals (SIC) is a hydraulic simulation model developed by the Irrigation Division of Research Center for Agricultural and Environmental Engineering (CEMAGREF) Montpellier, France. This model is based on one-dimensional hydraulic analysis for transitional and steady state flow.

documented tubewell density per 100 ha in the watercourses of the two distributaries. Using these two variables, four clusters of watercourses were identified along the Fordwah distributary and two along Mahmood distributary. Along the Fordwah distributary, the first cluster comprised of the watercourses with above average canal water supply and above average tubewell density. The second cluster has watercourses with above average canal water supply and below average density of tubewells. Watercourses with below average canal water supply and above average tubewell density are in third cluster. The fourth cluster comprises of watercourses with below average canal water supply and below average tubewell density. Along the Mahmood distributary watercourses with above average tubewell density were kept in one group and watercourses with below average tubewell density were kept in another group. One watercourse from each cluster was chosen along the two distributaries. Random selection methods were used partly at the choice of the researcher to gain appreciation of the diversity of conditions in the system, but also at the choice of the researcher and the of the host institute so that certain statistical tests could be performed in analysing data, both for this study and in the wider programme. Alongside this study, some special analysis has been made of events in other distributaries and watercourses, which were relevant to the scope of this study. While the watercourses were first selected randomly, the selection was developed so that the watercourses were spread along the distributary, to take into account water supply to the upper and lower halves of the distributary. After the selection of the watercourses it was found that one of the watercourse along the Fordwah distributary was very small with only two cultivators (3 owners). However, after a reflection it was kept to compare its difference of water management activities undertaken with a watercourse with a higher number of cultivators. Further it was assumed that it would be easier to get in-depth information about the water management activities in case of a watercourse with fewer cultivators.

The watercourses selected for in-depth study were 1030-R and 11860-TC along the Mahmood distributary and 38830-L, 67670-L, 84140-L, and 96692-R along the Fordwah distributary[15]. They belong to group 1 and 2 of Mahmood distributary and clusters 2, 1, 3 and 4 of Fordwah distributary respectively. Location of the selected watercourses along the distributaries is presented in the Figure 1.2. These watercourses are referred to as MD 1-R, MD 11-TC, FD 38-L, FD 67-L, FD 84-L and FD 96-R in the rest of the thesis. More details of these watercourses, the irrigators using them and their water supply are given in chapter 3.

Then followed a period of initial monitoring and studies of actions which helped to define measurement points of focus in this study, as outlined in chapter 2. Fieldwork was undertaken from November 1996 to April 1998. Data was collected for three crop seasons: *rabi* 1996-97, *kharif* 1997, and *rabi* 1997-98[16]. Facilities to successfully undertake the fieldwork were provided by the International Water Management Institute (IWMI). This study had the privilege to get short-term assistance from a Dutch student/researcher, and a national student from the Water Management Department of the NWFP Agricultural University, Peshawar. Long-term assistance was provided by three IWMI field-assistants. The students joined the team for six months each. The Dutch student/researcher supported the research by getting information regarding some social aspects of the water management activities especially related with tenancy conditions. The national student assisted in collecting some physical data e.g. conveyance losses. Major data collection was provided by the IWMI field assistants,

[15] The number of the watercourses refer to their location along a distributary (that are expressed in RD) and the side (Right - R or Left - L) from which they off-take.

[16] *rabi* is the winter crop and *kharif* is summer crop.

who collected daily data regarding water distribution and other activities throughout the period of data collection.

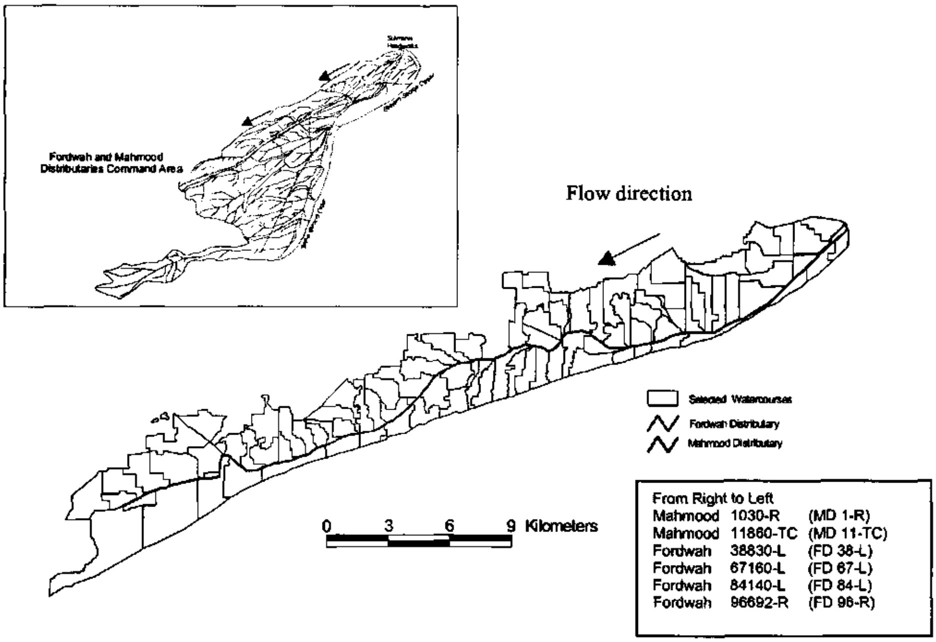

Figure 1.2: Location of sample watercourses along the two selected distributaries, Fordwah and Mahmood, of the Fordwah Irrigation System

Two major events happened during the course of data collection, one was the unexpected canal water scarcity because of some infrastructural problems and the other was visit of the Prime Minister to the study area. At the end of May 1997, a weir of one of the two link canals[17] was washed away, therefore the total inflow to the Suleimanke headwork was decreased to about half. This incidence caused unusual water scarcity during June 1997[18]. The Mahmood distributary still received some water during this period, however Fordwah distributary did not receive any water in that month and farmers had to rely mostly on the pumped groundwater for irrigation. The effect of this water scarcity on the gap between demand and supply and on the farmers' actions for water management is described in chapters 3, 4 and 5.

[17] There are two (link) canals, Balloki-Suleimanke link canal 1 (BS 1) and Balloki-Suleimanke link canal 2 (BS 2), which carry water from Balloki headwork to Suleimanke headwork.

[18] The distributaries along the Eastern Sadiqia canal were given priority for water supply since those channels also carry water for drinking and other domestic use: in that area canal water is used for drinking as well. The groundwater quality along in the Eastern Sadiqia irrigation system is so bad that it can not be used for drinking.

Another unusual incidence that happened during the fieldwork was the visit of the Prime Minister to the study area. It is very common in the area, especially in the Azim distributary that the big landowners cut the distributary and steal water. Hence farmers at the tail of the distributary hardly receive any canal water[19]. In the past farmers from the tail of the distributary had been complaining about the situation to the Irrigation Department staff and to the politicians of the area but the situation did not improve. In July 1997, farmers with the help of a Member of the Provincial Assembly (MPA) and a Member of the National Assembly (MNA) filed a complaint to the Secretary for Irrigation Punjab and they invited the Prime Minister (PM) to visit the site. When the PM visited the site, he witnessed a cut in the distributary by a big landowner. The PM ordered to suspend the whole Irrigation Department staff of the area[20] and to improve the water distribution in the area. This had an implication on the water supply of the selected distributaries as well; the water supply to the Fordwah distributary improved, which made farmers, at the tail section of the distributary, very happy. However the farmers of the Mahmood distributary became extremely unhappy because water supply to their distributary was reduced and brought back to its design discharge. The responses of the farmers, from the selected watercourses of the Mahmood distributary, to this reduction in canal water supply are discussed in the chapter 3.

1.4 THESIS OUTLINE

An interdisciplinary, socio-technical approach was used as the main methodological approach for this study of farmers' actions for water management and their influence on the water availability at the farm-gate in a supply-based large-scale irrigation system. The socio-technical approach enables to study both of the artefacts and water supply, and the social relations in detail. Mollinga (1998) states that a comprehensive understanding of irrigation requires addressing of both (social and technical) dimensions simultaneously, and not consecutively and separately, as is usually done.

However, this research focus more on assessment of the delivery of water, and the functional actions of people in different locations, and much less in documentation of the power relations of people or events and societal factors that bring collective action into being. Still, several attempts are made to discuss this for particular events studied in this thesis. Furthermore, where ever possible additional information was also gathered on such locations by working with other colleagues in IWMI during the course of this study (Terpstra, 1998; De Klein and Wahaj, 1998). The following paragraphs give the layout of the book.

Chapter 1 has introduced the subject of the research, and the research site. It has also presented the methodology, the scope, and the layout of the thesis. In Chapter 2 a conceptual framework is presented and the main research question is formulated. This chapter also summarises the information gathered in the field during the 18 months of fieldwork.

Chapter 3 summarises the general water supply situation and the agrarian conditions of the study area. The water delivery environments in the selected watercourses and distributaries are described and some conventional irrigation system performance indicators, like Delivery Performance Ratio, and Relative Water Supply are presented. These indicators are used to show on the one hand the water supply situation and the gap between the demand and supply

[19] Tail farmers receive canal water usually when it is not needed, either after heavy rainfall or during the period of harvesting of a crop - when it is surplus form the upstream.
[20] Only one officer, Executive Engineer, was not suspended because he was just being transferred to the area.

over time of the watercourses and the distributaries. On the other hand, these indicators are used to show the difference in the water availability of the selected distributaries and the watercourses. This chapter also introduces different social and agrarian characteristics of the studied watercourses, and thus explains the context in which irrigation is taking place. The conditions in the villages and the watercourses presented in this chapter helps in explaining some of the factors influencing collective and individual actions in the following chapters.

Chapters 4 and 5 discuss the collective and individual actions taken by the farmers to improve irrigation water availability at the farm-gate. Collective action is referred to when most of the farmers from a watercourse command area are involved in an activity. This happens mainly at the watercourse level and above. Individual action, on the other hand, is taken more at the farm level. The timing of the actions taken and the benefits to different farmers and groups of farmers are also discussed. Hence the outcome of the operational management of the irrigation water in watercourse command areas is described. These chapters explain why some activities occur more in some watercourses than others and also show the improvements that farmers are able to make in their water deliveries. Farmers are found to be effective decision-makers. Chapter 4 deals with the collective action of the farmers and explains the way these activities are organised – the main activities studied were water acquisition and watercourse maintenance. It also describes the rules, roles, and responsibilities of different farmers within a watercourse command area who are undertaking collective action for these activities. The processes involved in organising these activities are also discussed. Finally the factors influencing (both in positive and negative ways) collective action in the sample watercourses were identified. The efforts made by individual water users to manage irrigation water within the watercourse command area are explained in Chapter 5. Different water management strategies of the farmers to try and get more control over irrigation water at the farm-gate, and the way these activities are performed by the farmers, are explained. The financial rewards of these physical and institutional interventions by the farmers are discussed at the end of the chapter, which show the motivation of farmers for undertaking these actions for water management.

In chapter 6 the outcome of most commonly practised individual and collective actions for water management are presented in terms of water availability at the farm-gate. The responses of farmers at the time of canal water scarcity and canal water abundance are quantified in this chapter. The indicators used to show the impact of most of the activities are the Relative Water Supply (RWS) and Relative Irrigation Supply (RIS). At the end of the chapter some farmers are selected for in-depth study: their demand and supply situation over time is presented and the actions they undertake are explained to present the management of individual farmers to match demand with supply.

Chapter 7 gives the summary and conclusions of the thesis. It presents the key findings of the study, reflects on the usefulness of the approaches used in the study and the limitations of some of the study tools. The strengths and weaknesses of the research as a whole are discussed and recommendations for policy implementation and follow up research are suggested.

2 WATER MANAGEMENT, IRRIGATION PERFORMANCE AND FARMER'S ACTIONS: A CONCEPTUAL REVIEW

2.1 INTRODUCTION

The irrigation systems of Punjab are not functioning effectively in relation to design criteria or farmers' needs. This under-performance is attributed to among others, scarcity of irrigation water, changes in cropping intensity and mis-allocation of available resources. Much of the contemporary debate about water management is concerned with interventions designed to improve water management to resolve this 'underperformance'. However, there are choices in both what to study and how to study a system to understand possible changes to it. This review looks first at approaches to the study of irrigation water management and its 'performance'. It then looks at frameworks to study water management and farmers actions to improve their water supply. The chapter then presents the principles of the 'design-management environment' in irrigation systems in Pakistan, and its problems in reality. From this review it then sets out the key research questions and the framework for the research and data collection, to show how farmers actions improve water delivery at watercourse level.

Vincent (2001) notes how there has been a divergence of studies to understand water management to assist interventions. One line of work has emerged on 'methodologies for irrigation management' (Lenton, 1986), in which performance monitoring has become a specific focus of work. Most of this research has focused on the specific design of performance indicators to assess system performance[1], first for diagnostic analysis of problems causing poor water delivery (see Bos *et al.*, 1994; and Molden and Gates, 1990), but also to compare different types of irrigation systems (Abernethy, 1991; Perry, 1996; Kloezen and Garces-Restrepo, 1998; Molden *et al.*, 1998) and in some cases to design a framework for business management of an irrigation enterprise (Murrey–Rust and Snellen, 1993; Snellen, 1998)[2]. The main criteria used for performance evaluation are Adequacy, Reliability and Equity of the irrigation water delivery. Table 2.1 summarises commonly used water delivery performance parameters, their definition and indicators.

[1] The most widely used definition for performance of an irrigation system is the one given by Abernethy (1989), "The performance of a system is represented by its measured levels of achievements in terms of one, or several, parameters that are chosen as indicators of the system's goal". This definition of performance suggests that there is a pre set of indicators that are used to show the achievements of the irrigation system in relation to its goals and objectives. This definition fits well with the irrigation system that have clear objectives and targets but in case of big multilevel irrigation system with no clear objective or targets the indicators are difficult to define, and so are the performance criteria.

[2] More recently, remote sensing has also been used as a tool to measure performance in terms of crop-evapotranspiration, and productivity of land and water (see Bastiaanssen and Bos, 1999; and Bastiaanssen *et al.* 1999)

Practically all these frameworks and indicators are related to the performance of main and secondary system level[3], and mostly developed either from a researcher or agency point of view. The performance of an irrigation system can be evaluated at different levels of an irrigation[4] system, and very often even defined differently from the perspective of different stakeholders. The Irrigation Department in Punjab Pakistan has their internal indicators for monitoring and evaluation of the system.They are more concerned about delivering water at the tail of the system and more proportional and equitable water distribution, in short reliability and equity is their major criteria for canal water supply. Whereas farmers are more concerned about their production and their input supply also including irrigation water. Nevertheless water users do assess the services of surface irrigation supply by the Irrigation Department through the availability of water at the farm-gate. For them, the system is performing well if they receive adequate water for their crops at the time the crops need it. They are not really concerned about equity, they are more concerned about the adequacy and reliability of the canal water supply.

Very often the views on performance of irrigation services of the water users, and the contribution in achieving these objectives of performance is neglected. Nevertheless there are a few attempts made to study farmers' perspectives on the indicators of surface water supply and groundwater quality (see Hoeberichts, 1996; Kielen 1996, Gowing *et al.*, 1996).

A different line of research has evolved to understand why and how different conditions of water delivery come into being through peoples' actions. These studies also involve measurements of water delivery, but these are often used to open up a broader inter-disciplinary understanding of why patterns of water use emerge. Levine (1982) first used the criteria of Relative Water Supply (RWS) both to look at the deficiencies in water delivery, and also to show how water supply could be a substitute for labour in irrigated production. Keller (1986) discussed how RWS could be used to explore social tensions, asserting that a low RWS is likely to cause higher social tension. Uphoff *et al.* (1990) developed an inverted U-shaped curve (∩-shaped) of Relative Water Scarcity to describe the scope of farmers' actions in the management of irrigation water. In the case of both 'absolute' scarcity and excess of irrigation water farmers' participation in the management activities will be negligible. Under extreme scarcity, strong authority is needed to ensure access to water and steer any negotiation. However, in case of 'relative' water scarcity, there is scope for collective action that can negotiate and facilitate improvements in water supply. The importance of availability of water in shaping farmers actions is clearly demonstrated by many authors, so that it became the key factor in the selection of the six sample watercourses, as outlined in Chapter 1.

Criteria like RWS are now called 'performance indicators' but can also be used for a very different exploration of the world of farmers' actions and the inter-disciplinary study of irrigation systems. This approach is used in this thesis.

[3] Though, a few like Kuper and Kijne (1992); and Strosser and Garces (1992) looked at the tertiary outlet (*mogha*) they did not go beyond it.
[4] Punjab Irrigation Department (PID) and farmers in the case of Punjab Pakistan.

2.2 INTERDISCIPLINARY APPROACHES: WHAT MAKES IRRIGATION SYSTEMS WORK, HOW IRRIGATION SYSTEMS WORK

To grasp the complexity of an irrigation system, an interdisciplinary approach is needed that keeps the technology in use as a central point while studying relations around it. Authors, such as Mollinga (1998), Pradhan (1996), Perry (1995), Murray-Rust and Snellen (1993), Jurriens and de Jong (1989), and Eggink and Ubels (1984), have all stressed the compartmentalisation of much irrigation research, which fails to show the inter-linkages actually present. An interdisciplinary or socio-technical approach to study irrigation systems, and what is called in this thesis their 'Water Delivery Environment' is proposed in this study (see Mollinga 1998, Pradhan 1996, Vincent 1997). In general, three clear frameworks for analysis of irrigation system management can be identified: one is provided by Murray-Rust and Snellen (1993), a second by Perry (1995), and a third by Mollinga (1998).

Mollinga (1998) developed a typology of water control to promote an interdisciplinary 'socio-technical' approach. He first argued that the different possibilities for irrigation activities - their different contexts - can be related to the agro-ecological system, the agrarian structure, and state and institutions of civil society, which in turn shape the inter-relations of water, technology and forms of organisation. This context is referred to in this study as the 'Water Delivery Environment' and discussed in detail for the research area in chapter 3. Mollinga made this schematic model dynamic by examining the practice of irrigation - in human agency through knowledge and capability, people's use of strategies and resources, their arenas and domains of interaction and their rules and routines - and looking at these through the concept of water control and its critical dimensions: the technical or physical dimension, organisational dimension and socio-economic and political dimension. Technical water control refers to physical control of water flow. In its organisational form, water control is the managerial control of water in which a group of people co-operate with each other in order to achieve effective management of irrigation water and are able to negotiate with other entities over the delivery of water to their group (see also Hunt 1990). Socio-economic and political control of water addresses the conditions of possibility of technical and managerial water control (Mollinga 1998: 28). Mollinga argues that a socio-technical approach rather than the performance-oriented approach is more relevant to study the dynamics of the irrigation system and water supply at any level. Only by understanding existing water management practices and the context in which they happen realistic interventions can be made. He also argues for an understanding of the everyday politics that shape outcomes in water supply.

Murray-Rust and Snellen (1993) developed the term 'design-management environment' to describe the combination of (i) the design of the physical infrastructure of the system (ii) the principles of water allocation (iii) organisational and institutional environment. Their conceptual model however, is designed specifically to contribute to the performance debate in giving a framework that could be used by irrigation managers. While influenced by the Small and Svendsen (1992) model of nested hierarchical systems to explore the social environment in which irrigation system operates, they conceptualise a view of irrigation system management as separate from the agricultural system and with a division between the roles of irrigation agencies and farmers. They viewed performance as having two dimensions: the attainment of a specific set of relevant objectives, and doing so with efficient resource use. They distinguished between operational performance and strategic performance. The former is related to the water delivery and the latter with the efficient decision making with the available physical, financial and human resources.

This three-fold framework is used to present the management structure of irrigation systems in the Punjab in the section 2.5, but it has limitations for studying the realities of local water management which are also reviewed at the end of that section.

Perry (1995) also used more or less the same conceptual framework to discuss successful irrigation system management: looking at infrastructure, water rights[5], and responsibilities in water supply. He differentiated between the 'functional' and 'dysfunctional' irrigation system and argues that performance assessment of dysfunctional systems could be misleading. His work provides a sort of framework but does not really refer to 'rules in use' and practice. He sees any deviations from rules and the politics as part of 'dysfunctionality' of the system.

2.3 TECHNOLOGY AND MANAGEMENT

Technology has great implications on the availability of water at different points within an irrigation system as is emphasised by many researchers including Horst (1996), Lankford and Gowing (1996) and Levine (1980). A number of typologies exist to describe irrigation infrastructure and systems of water control to deliver water according to different water supply principles and objectives (Plusquellec *et al.* 1994; Horst, 1996; Horst, 1998; Lankford and Gowing, 1996 and 1997); and Renault and Godaliyadda, 1999). While Horst (1996 and 1998), and Lankford and Gowing (1996 and 1997) write about the relationship between the system infrastructure and water delivery priorities, Levine (1980) emphasises the relationship between the design, operation and management of the systems through water and crops. The objective of the system, like equitable water distribution, or supply of adequate water for the pre-defined cropping pattern, defines the choice of the technology to distribute water. For instance if equity is the objective of the system, fixed proportional structures are likely to be used for water distribution. In the systems studied, fixed proportional structures are used for water distribution within a distributary, which implies that discharge at the distributary head is an important factor in the water availability at the watercourse level, if the dimensions of the tertiary outlets remain as designed.

Horst (1998) describes different irrigation water delivery systems and their implications on the water delivery. His book focuses on water division structures and how their operation can lead to dysfunctionality. He regards irrigation structures as 'technical artefacts' and calls for 'transparent' technology whose operation and significance can be understood. He states that division of water is not only a technical matter it also has a human dimension. The way farmers perceive these 'technical artefacts' may cause conflicts between the farmers if they are not satisfied with the quantity and timing of flow.

These conflicts may result in the farmers' intervention by damaging the structures and in the operation of the system. Horst's recommendations for transparent technology that should include a) general consensus by the farmers and agency on the allocation and distribution of water; and b) a system of canal and structures which enables farmers to understand the flows of water by their own perception (ibid: 74).

[5] Beccar *et al.* (2001) also argue along the same lines and says that the complexity of the water rights influences the operation of the irrigation system. Moreover, water rights constitute the fundamentals of the water distribution system. They define water rights as property rights which show links between the people and the source (water in this case); people and technology (infrastructure in this case) and people and people.

These interdisciplinary approaches also differ in the way technology is examined in relation to system management. Mollinga (1998) discusses the social dimensions of the socio-technical approach to study irrigation. He states that it can be studied in three ways: social requirements for use; social construction and social effects (ibid: 14). Different technologies require particular social conditions to use (ibid 14). He considers technology development and design as social processes, that include interaction between different actors and interests of these stakeholders to shape the technologies, therefore technologies are socially constructed (ibid 15). A third dimension is the social effect of technology; technologies influence people's livelihood through its effect on crop production, people's health and other things (ibid 15).

Lankford and Gowing (1997) differentiated systems in terms of water provision, water distribution and water partition which arise from management and engineering choices regarding design of system infrastructure, and configuration and operational procedures. In the 'water provision' systems, discharge is controlled mainly at the headwork and water flow measurement is usually absent in these systems. The 'water distribution' systems are further sub-divided into two: one, which has water control through the water level (cm, m) and the other with discharge control (l/sec/ha.). A wide range of technologies, from intensive manual methods to automatic control, is found in this type of irrigation system. In the 'water partition' systems, water supply is matched with the system demand. In this kind of system, water is considered highly scarce and a strict control of ratio of water supply to the area (l/sec/ha) is emphasised. Two modes of management, 'normal' and 'actualising' have been identified for these different kinds of irrigation systems. In the 'normal' mode, management is passive and is not done to improve long-term performance: the system is operated with routine daily activity. Actualising is an active mode of management to make a system work as it should and can be referred to the set of skills required to improve system management to enhance long-term performance. The practical actions of the managers, in such type of management, are based on the diagnostic analysis of the system. For example, the 'normal management' accepts the design of the system as it is whereas actualising questions the design and then takes practical actions by introducing trials and new designs, layouts, methods etc.

Renault and Godaliyadda (1999) proposed the typology of the gravity irrigation systems, particularly for the analysis of system operations, which could be applied to the whole irrigation system or sub-systems. They argue that the operation of a canal, regardless of the level of irrigation sub-system, is comparable to an industrial process in which inputs are transformed by machines[6] into outputs. The processes of canal operations include: internal and external constraints, characteristics of canal reaches, impact of quality of irrigation services on the system, and resources (inputs and efforts) needed to achieve a required level of performance given internal and external constraints. Based on these four processes a canal operational typology is developed, which has four levels of analysis: system and structures, networks, water, and consumer levels.

The first level, system and structures[7], addresses the technology of the irrigation system. This level is further subdivided into two categories, *system* sub-level and *structures* sub-level. The first describing the overall physical characteristics of the system and the second describing the local characteristics of the structures. Water control can be achieved by controlling water level or volumes through upstream or downstream water control mechanisms. Upstream

[6] Which are canals and structures in case of an irrigation system

[7] System and structures are considered to be analogous to the 'factory and machines' from the industrial process.

water control is common in the gravity irrigation schemes, in which the water level is maintained upstream of a structure (cross regulator) to prevent backwater effect in the upstream reach. Irrigation systems are considered to have two types of components: canal reaches - which are used for conveyance and storage of water - and structures - which are used to control water depth and deliveries. The actual physical condition of the structures and the properties of a canal reach influence the degree of control of the water and the speed with which the system responds to the incoming, scheduled or unscheduled, fluctuations. Three properties of a canal reach are considered important: 1) its topography - double bank canals, single bank canals and canal reaches with intermediate reservoirs respond differently to these water fluctuations; 2) control of water depth – a canal reach can operate in three situations: within backwater effect, has normal depth, and free flow or super-critical flow; and 3) seepage losses - lined canals have less seepage losses and low friction as compared to the unlined canals.

The second level of the typology, that is the networks, deals with the boundary condition of the irrigation system. The hydraulic network identifies the interfaces between the different networks including irrigation, drainage, runoff, natural streams, and rivers. Different sources of water - groundwater and surface water - are recognised at this level. The layout of the hydraulic network is used to differentiate between the systems, with and without drainage facilities.

Water, the third level of typology, is based on the hydrological context of the scheme. Water availability is considered to have large implications on the operation of the irrigation scheme. Three conditions of water availability are considered in this typology, which are water abundance, water scarcity, and seasonal variability of water. The sediment that enters the system with the surface water has a significant impact on the maintenance of the system. The surface water can be reused for irrigation by recycling of the water either through groundwater pumping or from the storage of drainage effluent. Conjunctive use of surface and groundwater provides better flexibility and additional availability of water for irrigation. However, the use of (marginal quality) irrigation water may have adverse environmental effects through increase of soil salinity and water-logging.

The fourth, and final level of typology is the level of the Consumer: the service provided to the users is analysed at this level. This level addresses the issues of multiple uses of water, policy and performance of the distribution system, and sociological and institutional aspects of the irrigation schemes. Here an irrigation system is again compared with an industry: the lower- value water, in the rivers and reservoirs, is transformed to higher-value, at the point of delivery to the user, through the operations of the irrigation systems. Therefore, like an industry, the operation of irrigation systems provides added value to the water by processing it through the irrigation system.

Murray-Rust and Snellen have evaluated fixed versus gated systems in terms of their potential achievement of Equity, Adequacy and Reliability objectives and the kinds of operational requirement they have.

In the terminology of Horst (1998), Fordwah is a system with proportional water distribution, with little 'transparency' and small 'operational flexibility'[8]. According to Lankford and

[8] Horst (1998) argues that the transparency of the irrigation systems in Punjab is low because *most of the modular offtakes are of the undershot type*. Therefore the degree of opening is not visible to the passerby. And

Gowing (1997) it has potential to perform well if management is fully actualised, but can face problems when badly managed. In the terminology of Murray-Rust and Snellen, the Fordwah system is a system with upstream control and is a fixed division system that has operational and maintenance requirements to work well.

According to the typology developed by Renault and Godaliyadda (1997) for the analysis of system operations, the important factors that should be considered to study any canal reach of the Fordwah canal are: its structures, physical characteristics, water availability, different sources of water and their impact on the environment, and the social and institutional aspects of the water delivery system. These factors are similar in scope to the irrigation context of Mollinga, and are described as the 'Water Delivery Environment' of this study in chapter 3.

2.4 WATER MANAGEMENT ACTIVITIES AND ACTIONS TO MEET SCARCITY AND SURPLUS

Management of irrigation water requires some essential activities that need to be undertaken: water has to be controlled, channelled and managed in order to irrigate the crops in the farmers' fields, which is the main purpose of all the irrigation systems. Researchers have proposed a kind of classification of the activities needed to manage water. Examples are Hunt (1989), Kelly (1983) and Coward (1979). In this study activities are referred to the range of things to be done (what) and actions are referred to the actual deeds (how and when). To explore the attempts at collective action (some successful and some not) chapter 4 looks at collective efforts of farmers.

Uphoff (1986) offered a more comprehensive set of water management activities that could be identified in any irrigation system. His cubic matrix shows linkages between the different management activities concerning technology, management, and organisation (see Appendix II). He proposes three groups of activities namely control structure activities, water use activities and organisational activities. Control structure activities include design, construction, operation and maintenance. Water use activities include water acquisition, allocation, distribution and drainage. To organise these activities, processes of conflict management, communication, resource mobilisation and decision making are needed.

However some researchers (see Vincent 1995) warn that expectations or design of a preset of water management activities may result in the standardisation of the water management activities that may not represent the actual situation in the field. Different kinds of stresses in a system lead to different emphases in the field. Vincent suggests to differentiate the tasks needed to make a system function as per design, and the actions of farmers to make a system operate as they wish especially if it is dysfunctional. The broader focus on actions in this study is taken to encompass these different kinds of management. Manzungu (1999) and Van der Zaag (1992) also criticise standardisation of irrigation management tasks and instead talk about 'contingency' management[9]. 'Contingency' management implies that there is more than one way to organise and manage a system and its management depends on the specific set of conditions at the scheme or system level (Manzungu 1999). This study also considers Uphoff's cubic matrix as starting point but adapts it to the situation in the study area, focusing on the water management activities. Uphoff shows the 'legal' tasks needed in a

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the operational flexibility is small because *the flow within the tertiary unit is divided on the basis of a time roster (warabandi).*

[9] However, Manzungu (1999) used Uphoff's cubic matrix as starting point.

functioning system. In dysfunctional systems a range of additional actions may emerge as farmers seek to control their water supply through different actions. Farmers actions in water management may be different from needs to keep system working. Therefore this study also looks at the 'water acquisition' and refusal of excess water, and then more broadly at 'farmers' actions.

These water management activities, which are considered to be needed for operation and management of an irrigation system, are mainly based on Uphoff's cubic matrix. However he considers maintenance as a control structure activity. Though maintenance is a control structure activity at the higher level of the irrigation system, at watercourse level it is done to ensure better use of irrigation water. Since the main focus of this research is to study impact of water management activities at the tertiary level, watercourse maintenance is considered as a water use activity. The main water management activities that exist at tertiary level in a water scarce system (like in Punjab, Pakistan) are described in the following paragraphs.

Water Allocation

Water allocation defines the water available to each farm in terms of time, thus if this time is different for farms of the same size, the allocation is not equitable. However in the *warabandi* system water allocation is not done by farmers, and is based on time allocated to the parcel of land rather than volume of water allocated to farmers. Hence the allocation is only on the name of landowners. (Re)allocation of this time is necessary in order to be able to accommodate tenants; this (re)allocation is done by farmers.

Water Distribution

Water distribution is based on a fixed (7 days) roster and any trade and exchange of canal water is illegal. The way (canal and tubewell) water is distributed within a tertiary unit considerably influences the performance (of water distribution). The trading (including exchange of canal water as well as buying and selling of tubewell water) of the irrigation water most likely improves the performance in terms of adequacy. Whereas, at the same time, it may also indicate the unreliability of the canal water.

Watercourse Maintenance

Watercourse maintenance is needed for better water conveyance. The maintenance, more specifically cleaning/desilting, of the watercourse will most likely improve (the performance of) water distribution (by reducing conveyance losses) in terms of more equitable water distribution to different farms, because it avoids surplus at one point and shortage at the other points.

Water Acquisition

In supply-based agency-managed irrigation systems, water acquisition is not considered an activity performed by the users of water. Farmers still try to acquire additional irrigation water (surface as well as groundwater). These activities reflect the unreliability of the surface water supply and the unsatisfactory irrigation supply available to the farmers. On one hand this will improve the water situation for the farmers who are able to undertake these kinds of activities, whereas on other hand it worsens the water situation of the farmers downstream in the system.

Drainage or Refusal to Surplus Water Supply

Drainage, though a very important activity in irrigation systems, exists in a different form in the irrigation systems that do not have drainage infrastructure. It is more a response to the surplus water supply at the time it is not needed by the crop. Farmers either close their outlet or take some other measures to get rid of this surplus water.

Most water management actions and activities are the result of a continuous process of communication and negotiation, but also collective action.

Organisation of different water management tasks also requires communication, negotiation and decision making at collective as well as at individual level. In case of groundwater supply schemes, Long (1989) found that farmers on commands with large discharge public tubewells tend to overirrigate much more than farmers with no control over irrigation supplies, and farmers who purchase private tubewell water or have their own private tubewell. Because of the unreliable water supply from these public tubewells due to electricity failure and cutbacks of the operation, farmers over-irrigated when supplies were available.

Farmers' actions for water availability

Coward (1991) notes that patterns of social interaction govern the use of irrigation facilities whenever an irrigation scheme[10] serves more than one person and these social arrangements may be formal or informal, and individualistic or collective, in nature. He also observes that institutions[11] and organisations are needed to perform irrigation tasks. Coward (1991) proposes three concepts – roles, rules, and social groups – to study institutional and organisational elements of irrigation tasks. There are rules[12] for performing tasks in an irrigation system, roles for those performing the tasks, and social groups that influence the rules and the performance of the tasks. The roles can have two dimensions: *role expectations* and *role performance*. The roles performed may or may not be the same as expected or 'ideal' roles[13]. The expected roles are associated with given functions, for example the role of a gauge reader or the role of a water user, whereas the role actually performed includes the human dimension: the actor who is playing the role has personal motives which influences the performance of the role he is playing. Giddens (1979) argues that it is not roles but practices, which constitute social systems: people produce and reproduce the social and material environment around them through regularised acts, which are referred to as practices. Long (1989) views people as knowledgeable and capable[14] actors who may act differently in varying situations. He says that '*in order to understand the complexities of intervention and actor strategies in the area of research we need to penetrate the life-worlds of different social groups and individuals who make up the complex mosaic of changing agrarian and social relations in the region*' (Long, 1989: 254).

This study is exploring farmers' actions as a dimension of human agency through the world of key actors and their interaction. Human Agency refers to the people's behaviour and their motivations to take actions (Giddens, 1984). Farmers have informal rules to organise group

[10] An irrigation scheme could be a canal irrigation scheme, a well irrigation scheme or any other type.

[11] Coward (1991) uses the word 'institution' to refer to ideal behavior and role expectations and as a generic concept for the variety of rules that help pattern social behavior: norms, folk ways, customs, conventions, etiquette and law.

[12] These rules may be formal and informal and may and may not be followed in the execution of the irrigation tasks.

[13] Coward (1991) explains that *role expectations* is the institutional aspect of the role and role performance is the social-organisational aspect of the role.

[14] Mollinga (1998) argues that knowledgeability and capability of actors does not imply that they can always do what they want to do. But their practices are constrained because of their positioning in the context they are operating. Hence *the relationships in which an actor finds him/herself constrain and enable his/her possibilities of actions*.

or collective actions for water management, which may and may not be followed in practice. Collective action refers to the actions undertaken by consent of most of the farmers. Not every farmer has to take part in the activity, however most of them agree to the plan of action and benefit from it. This study adopts Long's (1989) approach and studies the rules and the practices to organise farmers actions for water availability and the principal actors who are playing different roles in organising these actions, and hence influencing the water availability at *mogha* and at farm-gate.

Individual and Collective Action for water management
Irrigation systems by their very nature of scale and topography influence collective action for water management. Managing large irrigation systems may require more co-ordination and co-operation among the farmers as compared to small irrigation schemes (Uphoff 1986). Martin and Yoder (1988) suggest that a difficult topography may become a reason for farmers to take collective action since it would be difficult for individuals to acquire and manage irrigation water in that situation.

Farmers, in case of relative water scarcity with a room for improvement in the water supply, are more likely to opt for collective action for water management as compared to the absolute water scarcity or water abundance (Uphoff *et al.* 1990). Wade (1979, 1988, and 1990) also regards water scarcity or need of irrigation water as the main factor for emergence of collective action for water management. He defines water scarcity as a function of distance from the source - he writes *reliability worsens and hoarding behaviour increases as a function of distance form the source.* De Klein and Wahaj (1998) argue that the need for irrigation water is the major incentive for farmers to organise collective action.

Farmers who undertake this collective action also have their own motivations and vested interests in organising and participating in collective action. Ostrom (1993) suggests that farmers undertake collective action when they foresee their efforts for individual actions outweighing the efforts involve in organising and undertaking collective action. Their decisions to be involved in the collective action seem to be based on rational analysis of benefit/cost (Olson, 1971). However benefit or cost could not only be seen in the economic sense. It could also be in the sense of social gains of earning respect (known as '*Izzat*') and social loss by losing one's face value (Merrey 1986a). Another social factor that can overshadow the economic benefit is '*Zid*' (that means being stubborn): farmers do not undertake collective action because other farmers want them to do so (De Klein and Wahaj, 1998). These situations may result in conflicts between (individual and groups of) farmers that have to be resolved effectively in order to let materialise the collective action. Malik *et al.* (1996) proposed that effective conflict resolution would help in organising collective action. Some of the farmers will try to gain the benefit of collective action without participating. However there are mechanisms to control free riding. Uphoff *et al.* (1990) suggest that people who try to ride free and take benefit of other people's collective action will eventually find no role in the decision making process. Enforcement of sanctions for not participating in the collective action can also result in willingness of farmers to participate in collective action (Malik *et al.*, 1996; De Klein and Wahaj, 1998).

Some researchers, like Van Leeuwen (1998), opine that another way to look at the collective action is simply to accept that people also consider collective interests of the group and try to get collective profit. Koelen (1984, in van Leeuwen 1998) suggests that it is easier to organise collective action for preservation of a common resource (that means: 'taking less') than for producing a collective good (that means: 'giving'). He considers the quick results of the collective action as a good incentive for farmers to participate in collective action. Van Leeuwen (1998) studied collective and individual actions in the domains of water management though he took a village as the starting point instead of watercourse command area. He looked at the water management as domains of interactions that have institutions, which are described by networks. He also adapted Verschoor's (1997) thesis of translation into water management activities, and argues that individual actions do not mean that there is no agreement about the need to act collectively. The agreement on the need to perform an activity may exist but *translation* of the need to *networks of solution* may not be agreed upon by the farmers and therefore individual action is taken.

The reason why farmers opt for individual or collective action might not be influenced by the individual decisions for obtaining individual or collective benefit, but the result of the behaviour that forms them as group-members (Van Leeuwen, 1998). The choice for individual or collective action can be shaped by other factors besides relative benefit including reinforcement of identity and networks, and other collective objectives of a group (Mollinga, 1998).

Researchers have identified several factors and characteristics of a farmer group that promote collective action for water management. Mirza and Merrey (1979)[15] found that location of farms of powerful or influential farmers at the tail of a watercourse and a large percentage of farmers with land holding size between 2.5 to 10 ha. has a positive effect on collective action. They also found that it is easier to organise collective action in the watercourses with small number of farmers, and/or have farmers with relatively equal distribution of power. Mirza (1975), Malik *et al.* (1996) and Van Leeuwen (1998), on the contrary[16], found that it is easier for a group of farmers to organise collective action if they have a clear leadership. Mirza (1975) opines that decision making for collective action taken by the whole *Panchayat*[17] instead of influenced by an individual would support collective action. In that case farmers feel more obliged to participate in the collective action. Another factor that is considered by Mirza (1975), and Mirza and Merrey (1979), to have implications on the happening of collective action is the caste or *biradari*[18]. They found that majority of farmers from one *biradari* are more likely to have fewer problems in organising collective action. Malik *et al.* (1996) also found the presence of tenants in the area as affecting collective action. They suggest that a small number of tenants in a watercourse command area is most likely to facilitate collective action. Since tenants are not landowners and therefore may not cultivate the land for a long time, they are less interested in long term benefits of collective action. De Klien and Wahaj (1998) suggest that it is difficult to organise collective action if most of the farmers are involved in off-farm employment simply because of relatively less time availability. Their findings are based on field research on collective action for watercourse maintenance in 12 watercourses[19] in the Punjab, Pakistan.

[15] Their results were based on a study of 10 rehabilitated watercourses in the Punjab.
[16] However, Van Leeuwen research site was socially very different than the research site of Mirza and Merrey (1979).
[17] *Panchayat* is the traditional system of conflict resolution in which elders and respected people of a village take decisions
[18] *Biradari* is a kinship group based on the patrilineal descent and marriage.
[19] Six out of the twelve watercourses belong to this current Ph.D. study. The other six watercourses lie along 6-R distributary of Hakra branch canal that offtakes from Eastern Sadiqia canal.

2.5 OPERATIONS IN THEORY: THE 'DESIGN-MANAGEMENT ENVIRONMENT' IN THE IRRIGATION SYSTEM(S) OF PAKISTAN

This section outlines the design criteria, operational requirements and management of the irrigation system at different level of irrigation systems in Pakistan, following the three fields of influence proposed by Murray-Rust and Snellen (1993). It then shows the limitations of this approach as a prelude to the design of the research framework to look at farmers' actions to improve water supply at watercourse level. This section also describes the water rights of the farmers and the administrative set-up of the Irrigation Department[20].

2.5.1 Physical Infrastructure: Design Assumptions and Its Implication on Operation of the System.

The main features of the hydraulic design of the irrigation system in Punjab, Pakistan as described by Mahbub and Gulhathi, (1951) are:

- Irrigation channels were designed with Lacey's equation for non-silting and non-scouring, which was based on the Regime theory developed by British engineers (Ali, 1993)
- The flexibility factor for the secondary channels is 1 (or close to 1), which means that the fluctuation in the flow at the parent canal will be felt equally by all the outlets. However, one of the requirements for this condition is that the parent channel runs within a certain limits of the full supply level (FSL) (in most cases 75 % of the FSL). If this requirement is not fulfilled then the flexibility factor goes below one and the fluctuation is mainly felt by the outlets at the tail end of a distributary or a minor.
- Structures in the main system (i.e., primary and secondary canals[21]) are gated, whereas outlets at the tertiary level are designed as overflow structures[22] (Open Flume) and orifice (mainly Open Flume with Roof Block and Adjustable Proportional Module). This means that the structures at the distributary level are more sensitive to the water levels in the canal: large fluctuations in flow is created by small water level differences in the parent canal. While the structures in the main canals (including distributary gates) need careful operation and management. The head-discharge relationship for an overflow structure is described with discharge proportional to $H^{1.5}$ whereas for an for an undershot or orifice structures the discharge is proportional to $H^{0.5}$. The main assumption behind these design criteria was that the outlets would draw their share of water proportional to the area to be irrigated by adjusting the width of the weir or diameter of the pipe.
- Outlets are supposed to draw their share of sediment[23], because they are installed close to the bed of the distributary - the undershot outlets are installed at the 0.9 D of Full Supply

[20] Which, later in the thesis, will help in understanding the interaction between the farmers and the Irrigation Department Staff.

[21] In Pakistan a primary canal is called a main canal (or a branch canal) and a secondary canal is called a distributary.

[22] Some of the distributaries have a combination of Open Flume (OF) outlets (and/or Adjustable Proportional Module (APM)) and Pipe Outlets (PO) which have totally different hydraulic requirements. The Open Flume outlets are mostly towards the tail of the distributary, whereas, the pipe outlets are towards the head of the distributary. The reason for such a combination is that in case of fluctuations in the parent channel, the outlets at the tail still draw water proportionally, but can also carry excess flows more readily.

[23] However, this does not happen in reality, Sedimentation in the canals is one of the main problems faced by the Irrigation Department for achieving equitable water distribution. Sedimentation reduces the capacity of the canals, thus decreasing the water availability at the tail of the distributaries. Vander Velde and Murray-Rust (1992) and Vander Velde (1991) found that the desilting of the distributaries considerably improves water delivery to the watercourses along the tail end of the distributary.

Depth of a distributary and open flumes are installed at the bed of a distributary. This will prevent sedimentation in the parent channels thus reducing the maintenance requirement for the main system and help in maintaining the hydraulic integrity needed for the efficient running of the system.

- The system is designed to minimise the operation of the hydraulic structures with little or no cross-regulation.

The criteria for the hydraulic design have considerable implications on the management of the system. The rules to operate and manage an irrigation system are clearly stated in Manual of Irrigation Practice[24] (Govt. of West Pakistan, 1961). Among others, a few main features of the management and the operation of the irrigation system are:

- Distributaries are supposed to be operated at a certain supply level to achieve equity in water distribution and to prevent siltation. If the flow in the river is low, a 8 day rotation among the distributaries (and canals) is introduced. A rotational schedule among the distributaries is made according to a priority list[25]. The canal on first priority gets the full design discharge, the next priority canal gets water if there is enough water available in the parent canal to operate this distributary at 75 % of its design discharge. Similarly, the canal at the third priority is operated if the discharge in the parent canal is enough to operate it at the design level (see Malhotra, 1982; and Berkhoff, 1987).
- The Irrigation Department only sets targets for the water supply at the head of the distributary, since the outlets are supposed to draw their allocated share of water.
- Gates of the main and the secondary canals have to be operated according to the schedule made by the Irrigation Department. The gate also needs to be adjusted in case of unexpected discharge fluctuation in the parent canal. This requires a communication network between the different staff members of the Irrigation Department, like the Executive Engineer (XEN), Sub-Divisional Officer (SDO), Sub-Engineer and the gauge readers (gatekeepers).
- One of the implications of the design criteria was maintenance of the irrigation infrastructure. To keep the system functioning properly and achieve the design equity in water distribution, maintenance of the system is very important.
- Maintenance at the higher level of the irrigation system (main system level) is the responsibility of the Irrigation Department.
- To make management and operation easier for the Irrigation Department, responsibility to manage water (distribution and maintenance of the watercourse) below the outlet was given to the group of farmers within the watercourse command area. However, the basic rules (water allocation rules or water rights) for the distribution were already defined by the Irrigation Department.
- Time sharing (*warabandi*) system of water allocation and distribution was introduced to facilitate water distribution and to equitably divide the scarcity of water among all the water users of a command area.

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[24] The Manual of Irrigation Practice is mainly based on the Canal and Drainage Act, 1873 (Nasir, 1993), which details the rules, responsibilities and powers of the Irrigation Department.

[25] Each canal in a group gets first priority in one cycle. For example, if there are three canals, canal A, canal B and canal C, one rotation cycle will be of 24 days: Canal A will get first priority for first 8 days, 2nd priority in the next 8 days (from day 9 to 16), and 3rd priority in the last 8 days of the cycle (from day 17 to 24). After 24 days it will again be at first priority. Similarly water supply to the Canal B and C will also be prioritized in the same way.

2.5.2 Principles of Water Allocation: Water Rights and *Warabandi*

In Pakistan water rights are related to the land holding in the command area, and are practised in a distribution cycle called *warabandi*. This means that the time allocation in the *warabandi* is basically the right of a farmer to use water. People with no agricultural land cannot have any water right. However, people can still get access to irrigation water through a tenancy agreement and through the rights of other relatives. However, the water rights available to tenants depend highly on the type of tenancy agreements, and the social relations between the owner and the tenants. The landowners, when leasing out their land to the tenants, distribute their allotted water among tenants, which depends upon the social relationship between the landowner and each tenant (the lease agreement is much more flexible if the tenant is a close relative). Hence, in this way the inequity in water allocation is already permitted, which is contradictory to the objective of the *warabandi* system. Principally the water rights should also be transferred with the land on sale or death. Observations show that sometimes, when a father distributes land among his children for operational purposes, or when children inherit the right after the death of their father, they do not officially divide the *warabandi* turn. However, in practice they distribute the water turn among themselves without legalising it[26]. This makes the analysis of the entire situation more complex as this distribution is not very strict.

The British in Northwest India and Pakistan introduced *Warabandi*, a well-known water distribution system (see Malhotra, 1982, for evolution of the *warabandi* system). It is the only written form of farmers' water rights, which is also the water allocation principles, and it defines rules for the water distribution among a group of farmers. This type of water distributions system is based on the continuous water supply at the *mogha*. It enforces equitable distribution of scarce water over all the water users. *Warabandi* by definition is the method of allocating water or irrigation time proportional to land size (Bandaragoda and Rehman, 1995; Bandaragoda, 1998). Thus, in this case, the *warabandi* provides the rules to be followed during the actual distribution of water.

Under a *warabandi*, the rotation starts from the head of the watercourse and proceeds towards the tail of the watercourse. A farmer has a right to use all the water flowing in the watercourse during his turn. In Pakistan, two types of *warabandis* are recognised, '*pakka warabandi*' (official *warabandi*) and '*katcha warabandi*' (unofficial *warabandi*). In *katcha warabandi*, all the shareholders have to agree upon the turns and their schedule, and the Irrigation Department does not intervene unless they receive complaints from the farmers. Under *pakka warabandi*, once the rotation is started, it continues even if the distributary is closed during the irrigation turn, which means that there is no compensation for a farmer who loses his turn because of no water being in the distributary (Malhotra, 1982). Whereas, the *katcha warabandi* takes care of the unplanned canal closure. The irrigator on whose turn the canal was closed starts his turn again when the water starts flowing in the canal. The *katcha warabandi* is based on the agreement between the farmers whereas the *pakka warabandi* roster is prepared by the Irrigation Department. However, the basis to allocate time for canal water turn is the same. Total time in a week is divided over the total command area to calculate the allocation – time per unit area. The main difference in the two forms of *warabandis* is the time to complete one full cycle of roster. In the *pakka warabandi* one full roster is completed in a week, so if a canal water is stopped for certain period of time in that week, farmers having their *warabandi* turn in that time will lose their turns. They will get

[26] One reason for not legalising the water turn is that they can not do it until they legalise the distribution of land. And to do that they need to spend money to fulfil official requirements for registering the land in their names.

their *warabandi* turns again in the next week provided that there is water flowing in the watercourse. In the case of *katcha warabandi* the roster starts again with the same farmer in whose turn water was stopped. Therefore one full roster of *katcha warabandi* may be longer than 7 days. This sometimes makes it difficult for farmers to keep track, of their *warabandi* turns and time. One of the main characteristics of the *pakka warabandi* is that, by enforcing the water scarcity equally among farmers, it reduces the conflicts between the water users within one watercourse command area. However, at the same time, it may result in the inefficient use of irrigation water since the supply is more or less fixed and does not match the crop water requirement (Huppert, 1987 and Bhatti and Kijne, 1990). The reasons for the shift from *katcha* to *pakka warabandi* vary from one *chak*[27] to another (it may be the inequity created by the big landowners). The *warabandi* schedule is revised during the annual canal closure each year and the roster is changed by twelve hours (Bandaragoda and Rehman 1995), so that the farmers who had their water turn during the night the previous year can irrigate during the day time.

2.5.3 Organisational and Institutional Environment: Administrative Set-Up of the Punjab Irrigation Department

In Punjab, Pakistan the whole irrigation system is sub-divided into management/administrative units. A Chief-Engineer, who is responsible for one zone[28], is the highest officer (after the Secretary Irrigation of the Provincial government) of the Irrigation Department. The next officer in the hierarchy of the administration is a Superintendent Engineer, who is responsible for the Circle[29] office. An Executive Engineer (XEN) is in charge of a zone, which is the highest administrative unit of a canal, and the basic hydraulic unit of the Indus Basin Irrigation system. The XEN is mainly responsible for the operation and maintenance of the irrigation system. Each canal is then further subdivided into Sub-Divisions and the Sub-Divisional Officer (SDO) is in-charge of a canal sub-division. He is assisted by Sub-Engineers in technical matters and by revenue staff for the assessment and collection of the water tax (*abiana*)[30]. An important actor in the operation of the system is the gauge-reader (or gatekeeper), who is responsible for moving the gates of a distributary (secondary canal) under the supervision of the Sub-Engineer. The *Patwari* who has the lowest rank in the revenue staff also has close contact with the farmers, as he is responsible for assessing cropped area and the cropping pattern of the farmers and for making a *warabandi* for a watercourse.

2.5.4 Irrigation Management at the Watercourse Level

Water is supplied to the individual fields through the tertiary outlets (locally called *mogha*) and watercourses. It is the responsibility of the Irrigation Department to supply the designed quantity of water to each tertiary unit (*chak*) at the outlet. A *mogha* is, therefore, the contact point of the Irrigation Department and the farmers since the Irrigation Department is responsible to manage water up to this point and below this point a group of farmers takes care of the water distribution. Though they are not responsible to manage this water below the outlet, they are empowered under the Canal and Drainage Act of 1873 (Nasir, 1993) to take action in case this canal water is wasted. The Executive Engineer of the Irrigation Department can stop the water supply to a watercourse that is not properly maintained, (therefore resulting in wastage of canal water), or can penalise a person through whose

[27] Area irrigated from one tertiary outlet (*mogha*) is called a '*chak*'
[28] Whole Punjab Province is sub-divided into 7 zones
[29] A circle is comprised of 5 canal zones
[30] *Abiana* is the water tax that is based on the area and the crop irrigated. It is higher for the cash corps like rice and sugarcane as compared to the grain crops like wheat and maize.

neglect canal water is wasted. The actual management of water at this level remains farmers' responsibility, however.

2.5.5 The Reality Gap

In Pakistan the design assumptions and their implications on the management of the irrigation system at the different levels have an impact on the operation of the system. For example, water was provided for one third of the Cultural Command Area (CCA) and increased cropping intensity was not foreseen. Poor operation of the irrigation system led to problems like siltation in the canals, which result in increased bed level elevation, consequently changing the whole idea of proportional water distribution at the ungated secondary level. However, the attempts at rehabilitation of the systems by providing additional outlets to some areas changed the concept of the proportional water distribution (these outlets did not always have the same hydraulic requirement (Head-Discharge relationship) for operation). Even in the newly built systems the outlets are found not constructed and installed according to their design drawings, which has resulted in an in-built inequity in the water distribution (Murray-Rust and Van Halsema, 1998). These problems have been reported in terms of poor performance of the irrigation system by several researchers (among others Vander Velde and Murray-Rust (1992), Vander Velde (1991), Bhutta and Vander Velde (1992), Kuper and Kijne (1992) Strosser and Garces (1992)).

While the framework developed by Murray-Rust and Snellen (1993) is useful to describe the main system management of the Irrigation System of Pakistan, it is not practical to study irrigation system performance at the watercourse level. Since the Irrigation Department has no role in operation and management of canal water at tertiary level, they do not have any objective or target at this level. Hence, it is difficult to define performance at the tertiary level of the irrigation system in the absence of clear objectives and targets for the canal water supply. Moreover in the context of the irrigation system in Punjab, where groundwater is frequently used and provides about 40 % of the total irrigation water, one cannot separate the contribution of pumped groundwater in the crop production. Therefore a performance criteria is needed that includes groundwater use in performance evaluation. Moreover, their criteria to show the design and management inter-relationships are not very helpful to interpret at the watercourse level. These criteria do not show what farmers do, and only give results reflecting the situation after their negotiations.

Researchers like Lowdermilk (1990) look at the farmers' actions as 'anarchy' because they break rules. However, they often 'break rules' in an orderly way and the underlying assumption are that these actions improve the performance of the irrigation systems. Freeman (1990) and Keller (1990) write about the gap between the need required and the delivery of the irrigation water (which Keller called relative water supply). However, the model proposed by Keller is a schematic model and does not provide an analytical framework. Different actors (water users and agency staff) in an irrigation system adapt different strategies to achieve their objectives by mobilising resources (Mollinga 1998). Agency staff in their daily irrigation management activities encounter several difficulties that they have to cope with at short notice, for example demand for more irrigation water supply from farmers and breach of the irrigation channels. Farmers on the other hand try to adapt long term (planning) and short-term (operational) strategies[31] to improve water control. For instance a farmer acquires additional water for irrigation by installing a tubewell and hence goes for a long-term solution

[31] Short term strategies adapted by people to deal with the difficult circumstances in the daily irrigation-related activities are called coping strategies (Johnson 1992 quoted in Manzungu 1999).

to cope with the unpredictable canal water supply, while another farmer buys groundwater to cope temporarily with insufficient canal water.

Agency staff and water users, interact with each other to improve canal water availability, hence both play important roles in the dynamics of irrigation water management and appropriating water for a group of farmers. This interaction between farmers and agency staff is beneficial for both the agency staff and the farmers: the agency staff, through their rent seeking practices, get some economic benefit and farmers get better water supply. This study sets out to show the strategies adapted by the water users to manage irrigation water and their effectiveness, and explains interactions between farmers and agency officials.

2.6 RESEARCH QUESTION

The main research question of the study is:

> How and why do farmers intervene in irrigation water supply, what conditions shape their actions and what is the impact of their action on water delivery in a large scale irrigation system of Punjab, Pakistan?

To operationalise the main question following sub-questions are posed:

- How do conditions of water supply and infrastructure shape water availability and room to manoeuvre?
- How do different farmers take different actions for water management and why?
- What criteria can be used to study and demonstrate impact of farmers' actions on water delivery?
- How effective are farmers' actions in improving water availability at the farm-gate?

2.7 OPERATIONALISING THE RESEARCH FRAMEWORK

This section summarises and operationalises the research framework to study water management at the watercourse level. The research framework is outlined and the data collection set-up is described. The previous sections have shown the following issues to be significant in understanding outcomes of interaction between technology, people and water availability:

- technology and water availability: the physical characteristics of the terrain and irrigation infrastructure as well as their capacity to convey water
- the influence of the 'delivery environment' in shaping water management activities
- farmers responses to the water availability
- criteria to describe and assess outcomes of farmers actions in water management.

The study framework has developed a set of technical dimensions, farmers actions and water management studies that could be studied and compared across the sample watercourses, reflecting this review of conceptual literature, and also initial field study in the research area. Figure 2.1 shows the inter-relatedness of issues below the *mogha* and provides the research framework to study how farmers' actions at watercourse level reshape performance at the watercourse level. The different components presented in the diagram are discussed briefly in the following paragraphs.

Technology and water availability

In shaping a study of water availability below the *mogha*, discharge at the *mogha* is considered the primary entrance point of the study and part of the delivery environment (resource), as it shapes the uncertainty in water availability and the farmers' responses. Discharge at the *mogha* directly influences the total water available at the farm-gate, invariably affecting the adequacy and reliability of the canal water delivery.

The physical conditions[32] that are considered to play an important role in water management at tertiary level are: (i) design water allowance, (ii) shape and size of the *mogha*, (iii) length and slope of the watercourse, (iv) location of farm along the watercourse (v) presence of (private) tubewells, and (vi) quality of groundwater.

- **Design water allowance**: The design water allowance, expressed in discharge per unit area, determines the design discharge and hence provides basis for water allocation.
- **Shape and size of the *mogha***: This influences the discharge through the *mogha*, which in turn influences the water availability at the farm-gate.
- **Length of the watercourse**: It influences the water losses in conveying water to the tail of the watercourse. The conveyance losses in the lined watercourse will be much less than the conveyance losses in the unlined watercourse.
- **Slope of the watercourse**: The slope of the watercourse (together with the discharge available at the *mogha*), along with the channel cross section determines the velocity of the flow in the watercourse. This in turn, also influences the water available at the farm-gate.
- **Location of the farm along the watercourse**: Canal water availability to the farm located at the head of the watercourse is more likely to be higher than the canal water available to a farm at the tail of the watercourse because of more conveyance distance and therefore higher conveyance losses.
- **Presence of (private) tubewells**: The presence of (private) tubewells in the watercourse command area influences farmers' control over irrigation water in terms of adequacy and reliability. The location of the tubewell determines which farmers can possibly attain benefit from this water. If a farmer's farm cannot be irrigated from tubewell water (e.g., all the tubewells are downstream of his land), he either has to rely on canal water or install his own tubewell.
- **Quality of groundwater**: The quality of groundwater influences its use. Marginal quality groundwater can not be used very often, moreover, it has to be mixed with the canal water, and therefore its use is limited. However, it still increases the reliability and the adequacy of total irrigation water but to a limited degree.

[32] Some of these factors were also used in the selection of the sample watercourses.

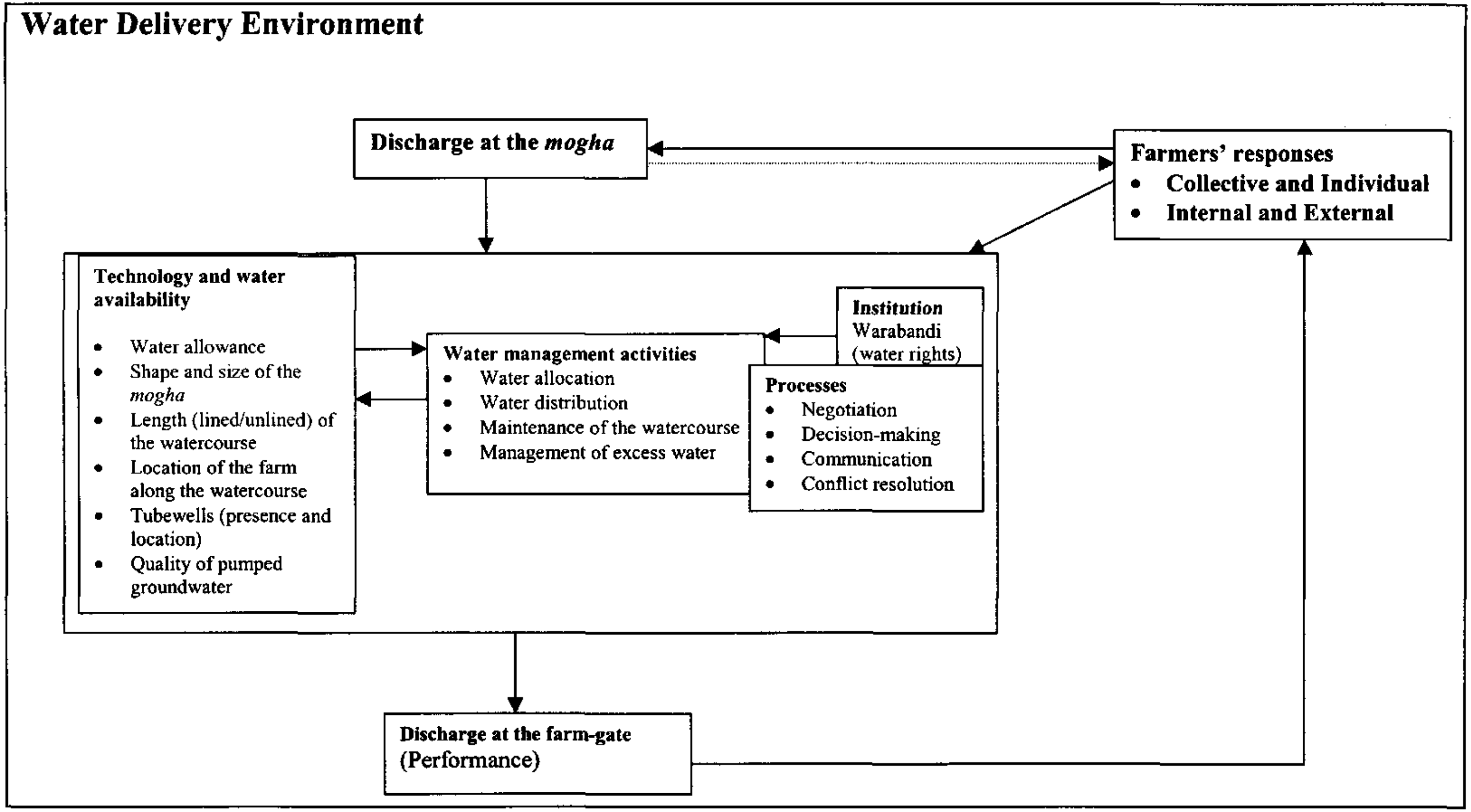

Figure 2.1: Research framework to study inter-relatedness of issues below the *mogha*

Water management activities

The main water management activities that are needed to be undertaken at tertiary level in a water scarce system (like in Punjab, Pakistan) are water acquisition, water allocation, water distribution, watercourse maintenance, and drainage of excess water (these activities have already been defined in section 2.4).

Farmers actions in the response to water availability

In Pakistan the Irrigation Department and farmers are involved in the management of different levels of an irrigation system in Pakistan. Farmers are the main actors[33] in the management of irrigation below the *mogha*, they continuously try to acquire more canal water at the *mogha* and manage available water as well. However, the arena of action is at different levels, some actions are taken collectively, others individually. Some activities are undertaken internally (inside the watercourse command) and others externally (above the watercourse). Subsequent chapters show what activities were undertaken collectively or individually, and what activities were negotiated internally in a watercourse and which required 'external' negotiation with staff of ID.

Criteria to describe and assess the outcomes of farmers actions

In a supply-driven big canal irrigation system like in Fordwah, tasks, responsibilities and targets of the irrigation managers at the main system level are related to the operation and maintenance of the main system[34]. Performance evaluation is mainly studied in terms of monitoring and evaluation (see Vander Velde (1991); Bhutta and Vander Velde (1992). The Irrigation Department has no role in operation and management of canal water at tertiary level therefore they do not have any objective or target at this level[35]. Hence, it is difficult to define performance at the tertiary level of the irrigation system in the absence of clear objectives and the targets for the canal water supply. However, it is the level where the results of poor performance at the main system level are obvious. The quantification of performance at this level will also help in comparing the management of the irrigation managers (engineers) at the main system level with the managers (farmers) at the tertiary level of the irrigation system.

Since the focus of this study is on the actions farmers take for water management the analysis is mainly based on the water delivery performance as shaped by the actual users of irrigation water. Figure 2.2 demonstrates the continuous process of performance evaluation, farmers' actions (or interventions) and improved performance. A farmer continuously monitors and evaluates water delivery to his farm based on which he takes individual or collective action to improve water delivery and to save the cost of operating tubewells for additional irrigation water.

[33] Though the supply of water at the watercourse level is also influenced by the ID staff, and day to day operation of the delivery system at higher level. Another very important actor for water availability at the farm-gate is the *patwari*.

[34] Here main system is referred to the main and secondary (distributaries) irrigation canals.

[35] The ID observes discharges at the main canal and the distributaries. They do not monitor discharge of the tertiary outlets (*moghas*), they are supposed to keep a record and check the efficiency of these outlets. If the actual data of the outlets matches the design then the outlets should draw their fair share of water supply and the sediment.

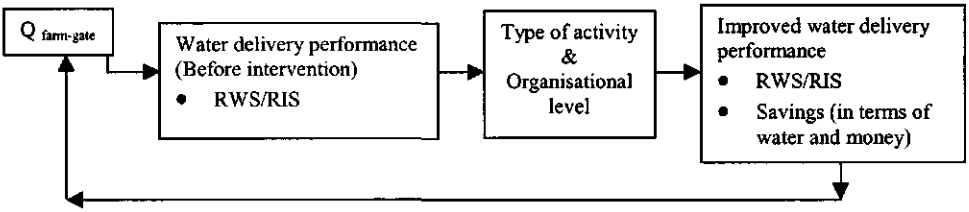

Figure 2.2: Water delivery performance as shaped by farmers' interventions

The literature on performance indicators is very rich (see Rao 1993 for review) however most of the performance indicators reveal the achievements of the irrigation system at the higher level of management and seem to overlook the role played by the farmers in these achievements. Hoeberichts (1996) studied performance indicators from farmers' perspectives, and gave qualitative indicators used by the farmers to assess surface water supply. Gowing *et al.* (1996) used fuzzy set theory to look at the performance at farm level from farmers' perspective. However none of them have quantified the impact of water management activities that farmers undertake which is the main thrust of the current study. Indicators are needed that could demonstrate the impact of water management activities on water delivery performance at the tertiary level sub-system.

To study operational management at the tertiary level it is important to understand that farmers do not compartmentalise the water delivery into performance indicators as such like the system studies do. They rather have a wholistic view of the water delivery; their main criterion is the amount of water delivered to them at their farm-gate - something that can aggregate the result of many interventions. Also, farmers themselves never measure the amount of water: rather they use their own indicators, like the area irrigated during one water turn as a proxy of water available at the farm-gate. These local indicators are analysed further during the study.

Since a primary concern of farmers is to match the total irrigation water available with the demand of the crop, discharge at the farm-gate and the Relative Water Supply or Relative Irrigation Supply seem good indicators to evaluate irrigation water delivery at the watercourse level. Both RWS and RIS is the ratio between the supply and demand with a difference that RWS considers rainfall as a part of supply while in RIS rainfall is deducted from the demand to get irrigation water requirement. The formulae to calculate RWS and RIS are:

$$\text{RWS} = \frac{\text{Total Water Supply}}{\text{Crop Demand}}$$

$$\text{RIS} = \frac{\text{Irrigation Supply}}{\text{Irrigation Demand}}$$

Total Water Supply	=	Net surface diversions, groundwater pumpage, and rainfall
Crop Demand	=	Potential crop water requirement
Irrigation Supply	=	Net surface diversions and groundwater pumpage
Irrigation Demand	=	Potential crop water requirement less effective rainfall

The variability of the discharge at the *mogha* is demonstrated by either plotting the actual daily discharges over time or by calculating the Delivery Performance Ratio (DPR) over time. Delivery Performance Ratio is the ratio of actual discharge to the target discharge (Bos *et al.*, 1994). As financial savings is also one of the concerns of farmers it has also been included in this analysis. The productivity in terms of yield (tons per ha.) is also calculated however since RWS can be used a proxy for productivity it is not shown in Figure 2.2. Besides productivity depends on other inputs (like fertiliser etc.) as well.

2.8 SETTING UP DATA COLLECTION

This research collected quantitative and qualitative data in order to understand farmers' intervention in the irrigation system and their influence on irrigation system performance. Most of the data is collected from primary sources (i.e., from the field either by measurements or from interviewing farmers). However, some of the data was also gathered from secondary sources, i.e., Punjab Irrigation Department (PID). On-going processes were monitored in the field and documented. Much information was obtained by informal interaction of the field staff. It was not difficult for the field staff to discuss about anything that was happening in the watercourses because of the good rapport they built with the farmers. The way collective action was organised was also part of the monitoring activity of the field staff. Whenever possible *Panchayat* meetings were attended by the researchers to observe the negotiation process and the outcome of the discussions among farmers. The following paragraphs give the data collected at tertiary level for each activity, the method of getting that information and the source.

Technology and water availability
Distributary level data (see table 2.2) was collected to show the variability of discharge two different the two distributaries.

Table 2.2: Canal water availability data collected at distributary level

Data	Method	Frequency	Sample	Source
Gate Operations	Gauging	Regular[1]	Two distributaries	Field Monitoring
Tail gauges	Gauging	Daily	Two Distributaries	Field Monitoring

[1]Whenever the gate was moved

The data collected to estimate water availability at the watercourse and farm-level is presented in table 2.3. This data helped in calculating daily discharges to the sample outlet and to individual farms. In addition, it also helped in showing how much water is more or less saved by desilting a watercourse or a portion of the watercourse, and thus could help in understanding the importance of the activity. The data also showed the daily variability of canal water supply to the tertiary units and to the selected farms, which indicated the equity of surface water among the watercourses and among farmers.

Table 2.3: Outlet type and canal water supply data at watercourse and farm level

Data	Method	Frequency	Sample	Source
Outlet type	Observation	Once	6 outlets	Observation and Outlet register
Discharge measurement for rating curve of the outlets	Current meter, cut throat flume	Start of the research[1]	6 outlets	Field measurement
Water level and actual discharge	Gauging	Daily	6 outlets	Monitoring in the field
Conveyance losses	Inflow outflow	Once every 3 months	6 watercourses	Field measurement
Canal dimensions: slope of the channel	Topographic survey	Once	6 watercourses	Field measurement
Discharge measurements at farm-gate	Current meter, Cut throat flume	Regular (for one season)[3]	15 farms[2]	Field measurement

[1]This was done once at the start of the research to calibrate the outlets of all the watercourses, and was repeated for the outlets, which were changed or tampered with during the research period.
[2] In three watercourses, MD 1-R, FD 84-L and FD 96-R, three farms, one in head, middle, and one in tail were selected. Whereas, in other three sample watercourses two farms, one in the upper half portion and one in the lower half portion of the watercourse, were selected.
[3]It was done for every *warabandi* turn of these farms for one cropping season

Groundwater pumpage

A summary of the data collection on groundwater is shown in table 2.4. In the study area groundwater is an important factor for farmers to plan and cultivate crops since it gives more flexibility in water application more certainty in terms of irrigation.

Table 2.4: Data collected about groundwater pumpage and use

Data	Method	Frequency	Sample	Source
Discharge	Trajectory method[1], cut throat flume	Regular (twice in an agricultural season)	88[2]	Field measurement
Groundwater table	Observation well	Regular (every two weeks)	18	Field monitoring
Groundwater pumpage	Monitoring of water distribution/Farmers interviews	Daily	88 Tubewells[2]	Farmers and Observation
Groundwater usage	Monitoring of water distribution/Farmers interviews	Daily	88 Tubewells[2]	Farmers and Observation
Groundwater quality	Chemical analysis	Once	20 Tubewells[3]	Soil Fertility, Pakistan

[1]Appendix III presents the Trajectory method to estimate discharge of the tubewells.
[2]Include all the tubewells in 6 sample watercourses.
[3]Chemical analysis of the tubewells that according to farmers had saline water was done by Soil and Water Laboratory, Bahawalpur. This laboratory is under Directorate of Soil Fertility, Pakistan

Irrigation water availability from other sources

A very small percentage of farmers, in the study area, used water for irrigation from a different source, like sewage water, and did not use canal water for irrigation[36]. The quantity of the water used by these farmers was not measured. However, information was gathered about their water management activities.

Water management actions and agency-farmer interactions

The data collected to study the different water management activities and agency-farmer interactions is summarised in table 2.5. Most of the data related to water management

[36] They sold their canal water turn

activities was collected by regular monitoring of the actual occurrence of the activity. Also actual processes of organising and performance of water management activities were observed. Data related to the agency-farmer interactions was needed to study the linkages between the farmers and PID Staff and the strategies they adopt to manage water.

Table 2.5: Information collected about water management actions and agency-farmer interactions

Data	Method	Frequency	Sample	Source
Pakka warabandi	Secondary data	Once	6 tertiary units	PID[1]
Agreed upon *warabandi*	Farmers interview	At the start of every season	6 tertiary units	Framers, Observation
Water distribution	Monitoring	Daily	6 tertiary units	Farmers
Desilting of the watercourse	Monitoring and Farmers' interviews	Regular	6 tertiary units	Farmers, Observation
Organisation of water management activities	Monitoring and Farmers' interviews	Regular	6 tertiary units	Farmers, Observation
Any interaction between farmers and PID[1]	Monitoring/ Observations and Farmers' interviews	Regular/every time it happened	6 tertiary units	Farmers, Observation
Farmers and PID[1] Staff Involved in these interactions	Monitoring/ Observations and interviews with farmers and PID[1] staff	Regular	6 tertiary units	Farmers, PID[1] Staff Observation

[1] Punjab Irrigation Department

Agrarian conditions

Data related to agrarian condition is presented in table 2.6.

Table 2.6: Information collected about agrarian conditions

Data	Method	Frequency	Sample	Source
Landholding size of owners	Farmers interview and Secondary data[1]	Once	6 tertiary units	Farmers and PID
Operational Landholding size of cultivators	Farmers interview	Once at the start of the research and afterwards every time it changed[2]	6 tertiary units	Framers
Tenancy Status	Farmers interview	Start of every season and afterwards every time it changed[2]	6 tertiary units	Farmers

[1] This is from *pakka warabandi* which is prepared by the irrigation department
[2] The basic data set were updated every time operational landholding size of a cultivator changed. This usually happens because of change in tenancy arrangements

Data related to water use, and production

Other data that was needed for the analysis of the water management activities is summarised in table 2.7. Meteorological data and other crop related data was needed to calculate demand of irrigation water, and to see the gap between demand and supply of irrigation water.

Table 2.7: Data related to water use and productivity

Data	Method	Frequency	Sample	Source
Rainfall	Rain gauge	Whenever happened	6 tertiary units	Field observation
Other meteorological data	Secondary	Monthly	Bahawalnagar area	
Cropping pattern	Walk through Survey	Seasonal	6 tertiary units[1]	Field observation
Yield	Farmers' Interview	Seasonal	250 farmers in 6 tertiary units	Farmers
Crop input data	Framers' interviews		52 Farms[2]	Farmers

[1] For all the farmers in six tertiary units

[2] This data was collected from 10 selected farmers from each watercourse except one that has only two cultivators

2.9 CONCLUDING REMARKS

It is not only infrastructure and water supply that determine irrigation performance below the *mogha*. The prevailing institutions and ultimately the users of this irrigation water also shape the irrigation that takes place. Irrigation systems are not only physical systems, different actors who interact with each other are also part of the irrigation system as they influence and are being influenced by the physical aspect of irrigation (Chambers, 1988). Farmers, being active recipients of the technology, evaluate and react to the irrigation services provided to them. Thus they take an active role in shaping the performance of the irrigation system. These different issues are inter-linked with each other and cannot be studied in isolation, as shown in the following chapters. These succeeding chapters will also demonstrate how farmers' actions make a difference in the Water Delivery Environment.

3 THE WATER DELIVERY ENVIRONMENT OF THE STUDY AREA: WATER DELIVERY, AGRARIAN CONDITIONS, AND PRODUCTION

This chapter describes the 'Water Delivery Environment' of the study area. As described in chapter 2 this is the context in which irrigation is taking place in the study area, drawing on the framework of Mollinga (1998) and Renault and Godaliyadda (1999): it shows the context of people, technology, and water supply in which farmers undertake actions for water management. To show how the system was performing at the time of study, some conventional performance indicators like Delivery Performance Ratio, and Relative Water Supply are also presented, but at the level of the watercourse and the distributary.

3.1 WATER SUPPLY CONDITIONS AT THE DISTRIBUTARY LEVEL

The two distributaries, Fordwah and Mahmood, selected for this study are quite different in their Water Delivery Environment: this was one of the reasons to opt for these two distributaries. These two distributaries are the last perennial distributaries at the tail of Chishtian Sub-Division, and therefore are considerably affected by any water shortage within the system (see Figure 1.1 for the location of the distributaries along the Fordwah Branch canals). Moreover, in the case of surplus water supply from upstream, these distributaries also have to carry higher discharges. Both these distributaries are perennial. The 3rd tail end distributary, Azim, is non-perennial and is not discussed further in this study. Differences in the water delivery of the two distributaries are summarised as following:

3.1.1 Size of the Distributaries

Fordwah is overall a bigger distributary as compared to Mahmood. It is longer, has a much bigger command area and thus much higher design discharge as compared to the Mahmood distributary. Table 3.1 gives the physical features of the two distributaries.

Table 3.1: Main features of two sample distributaries

Distributary	Length of the Distributary (km)	Design Discharge (m^3/s)	Culturable Command Area (CCA) (ha)	No. of Outlets	Water Allowance[1] (l/s/ha)
Fordwah	42.6	4.47	14940	88	0.25
Mahmood	3.6	0.23	825	7	0.25

[1] This allowance is based on the design discharge less the design seepage losses of the distributaries

3.1.2 Discharge of the Distributaries

Fordwah has a much higher design discharge than Mahmood as it serves a much larger area. However, Mahmood distributary nearly always receives much more than its design discharge, as compared with a much more variable level of supply to the Fordwah distributary. Figure 3.1a and 3.1b present actual and design discharges of both the distributaries during the study period. Discharge variation in both the distributaries is very high; however, Mahmood gets almost double its design discharge. During the study period, the average discharge of the Mahmood distributary was 14 ft^3/s (i.e. 396 l/s which is about 170 % of its design discharge).

For only 8 % of time (in days) in one year Mahmood did not receive any water, whereas for about 94 % of the time its actual discharge was higher than its design discharge. For about 34 % of the time it received 18 ft^3/s (509 l/s) or more canal water, which is double than it's design discharge. Whereas, Fordwah was closed for 16% of time and received equal to or higher than its design discharge for 50 % of the days. The average discharge of the Fordwah was 133 ft^3/s (3764 l/s), which is about 84 % of its design discharge. The highest discharge of the Fordwah distributary during the study period is 209 ft^3/s (i.e., 5914 l/s). The reasons for the higher discharge of the Mahmood distributary are firstly, that this distributary is very small therefore it hardly comes under rotation. When a very strict rotation was followed in *kharif* 1997, it was closed for one week and open for 3 weeks with full supply. The other tail end distributaries, Fordwah and Azim (the other non-perennial distributary at the tail of the Fordwah branch canal) had rotations with priorities - one week one distributary was operated with full supply and next week the other distributary would get full supply. Secondly farmers from Mahmood distributary have good relations with some of the Irrigation staff and most of the time they manage to get higher discharge in the distributary whenever it is needed. The reasons for the large improvements in flow in Fordwah distributary are discussed further in section 3.4.

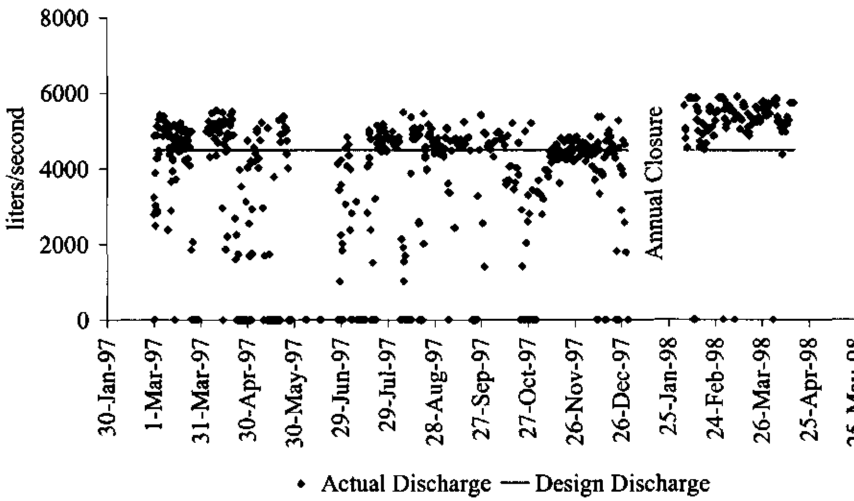

Figure 3.1a: Water supply to Fordwah distributary during the study period (March 1996- April 1998)

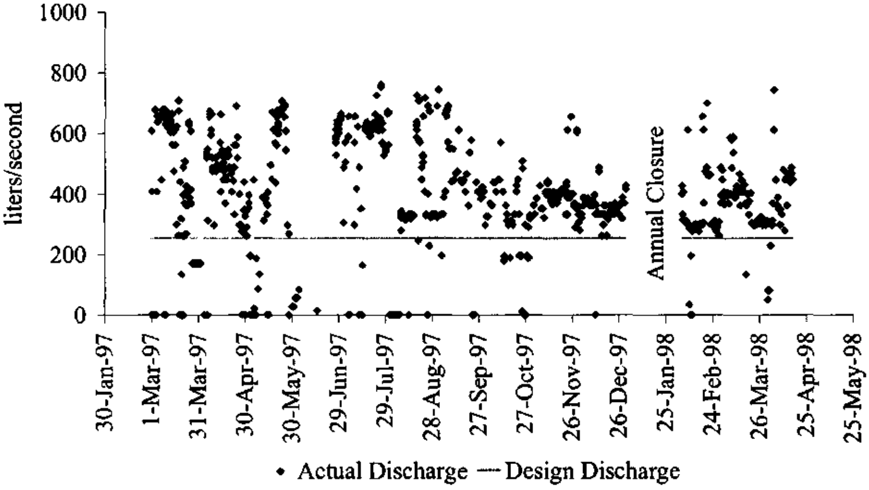

Figure 3.1b: Water supply to Mahmood distributary during the study period (March 1996- April 1998)

3.1.3 Water Situation at the Tail of the Distributaries

The water supply at the tail of the distributary indicates the functionality of the channel. The presence of one foot of water depth at the tail of the distributary is one of the internal indicators by which the Irrigation Department assesses the water delivery performance of the system. A dry tail of a distributary could either mean a low discharge at the head of the distributary or a reduced capacity of the channel to carry the design discharge. It could also mean that the outlets in the head and the middle reaches of the distributary are drawing more water than their designed share. In other words the proportionality of the system has been disturbed.

The water situation at the tails of the selected distributaries is very different. The tail of the Fordwah distributary hardly gets any water, whereas Mahmood's tail is always overflowing[1]. Figure 3.2 shows the water situation at the tail of both the distributaries. For the duration of the study period, the depth at the tail of the Mahmood distributary was greater than one foot for more than 70% of the time, whereas the tail of the Fordwah distributary was dry for most of the time. During the twelve months between April 1997 to April 1998 the tail of the Fordwah distributary was dry for about 52% of days. However for 77 % of the time it received more than 70% of its design discharge at the head. Which reveals that, even according to the Irrigation Department criteria, this channel is dysfunctional as the tail of the distributary is not receiving water for most of the time in a year. On contrary, the tail of Mahmood distributary was dry for only 19 % of the time in days and for 89 % of the time it received more than 70 % of its design discharge.

[1] In fact the tail of the Mahmood distributary also overflows because the Irrigation Department has increased the height of crest of the *tail clusters of the moghas* (there are 3 moghas at the tail of the distributary) while they did not increase the height of the walls of the open flume outlet.

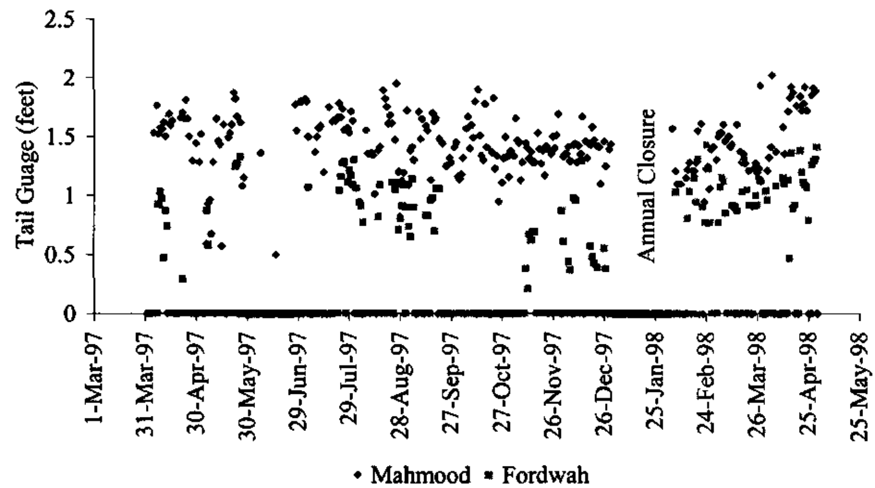

Figure 3.2: Water situation at the tails of two selected distributaries over time (April 1997-April 1998)

3.1.4 Desilting of the Distributaries

Mahmood distributary is desilted twice in one year, once during the canal closure (January) and once during summer (June/July). Farmers from the three tail watercourses organise and undertake the desilting activity of the whole distributary[2].

The last time Fordwah distributary was fully desilted by the Irrigation Department was almost 10 years before this study period. However, in 1992-93, it was desilted by farmers on a self-help basis. The then Government of Punjab, in a campaign, mobilised farmers throughout the province for desilting of almost all the distributaries. In the year 1997 part of the tail portion of the Fordwah distributary was desilted. Irrigation Department contracted this work to a consultancy firm in Pakistan. According to the Irrigation Department, lack of funding is the main reason for infrequent desilting of the distributaries.

3.1.5 Groundwater Use

The presence of a tubewell in an area is an indication of inadequate[3] and unreliable canal water supply. In the study area, the density of tubewells per 100 ha for the Fordwah distributary is 8.7 and for Mahmood it is 3. Moreover, the number of operational hours of the tubewells in Fordwah is much higher than in Mahmood. During the study period tubewells were operated for 10 % and 90 % in Mahmood and Fordwah sample watercourse respectively: that shows the relative importance of groundwater use for irrigation in the distributaries. Nevertheless, the quantity of pumped water depends on the discharge capacity of the tubewell. The ratios percentage of usage of total water pumped during the study period for Fordwah and Mahmood distributaries was 67: 33 that is also reflected in the total water use (see section 3.3.5).

[2] The Irrigation Department is officially responsible for the maintenance of the distributaries

[3] This inadequacy may also be the result of increased cropping intensities.

3.2 THE SAMPLE WATERCOURSES: WATER RIGHTS AND AGRARIAN CONDITIONS

The selected tertiary units are different in physical condition, but have more or less the same set of rules to perform water management activities. Before a description of the selected tertiary units it is important to describe different features of a typical tertiary unit in Punjab. Figure 3.3 presents a tertiary unit with different features and local names. The land demarcation in a tertiary unit or '*chak*' is based on the 'grid' system introduced by the British in early nineteenth century[4]. Under the grid system land was surveyed and divided into squares or '*murabah*' and Blocks. A Block is consisted of 16 squares and is numbered. A Square is also numbered consecutively starting from the Northwest portion of a revenue village[5] '*mauza*'. It is further subdivided in 25 '*killa*' – one *killa* is approximately equal to one acre - that are also numbered. Permanent concrete posts are used to mark the corners of the Squares. These posts are often used as a benchmark by farmers to find out the exact location of their *killas*.

A tertiary outlet a '*mogha*', connects a watercourse to a distributary channel. A watercourse[6] is a channel that conveys water from a distributary to the farmers' land holdings (Malhotra, 1982). It is generally an earthen channel and has several branches. A watercourse is usually constructed between the boundaries of the holdings (and boundary of a *killa*) to avoid conflicts among the farmers. The main official watercourse is called '*sarkari khal*': *sarkari* is referred to something owned by the Government and *khal* is a local word for watercourse or channel. The *sarkari khal* is designed by the ID Engineers and is constructed by the farmers. Farmers make their own farm and field channels to transport irrigation water within their farms. A watercourse provides at least one delivery point or a farm inlet to each land holding (or a farmer). A farm inlet, called a '*nakka*' could be earthern or a concrete structure. An earthen or '*katcha*[7] *nakka*' is basically a hole in the watercourse that could be closed by clay and bushes. Concrete structures with circular holes that can be closed with concrete lids are called *pakka*[8] *nakkas*. Every Square is officially provided with one *nakka*.

Farmers of a watercourse command area (a tertiary unit) are often referred to as 'shareholders'[9]. ('*pattidar*' in local language) by farmers themselves and Irrigation Department Staff

[4] Land demarcation according to such pattern was made compulsory to receive the canal water. It was easy to introduce this system in the new settlement schemes. However, farmers from the old settlement schemes were also forced to conform to this requirement (Hailey, 1907).

[5] A revenue village is a unit for collecting *abiana* (water tax) from a group of farmers. A *Numberdar* in a revenue village is made responsible to collect *abiana* from the farmers.

[6] Pakistan has about 88,000 watercourses that serve a CCA from 60 to 250 hectares.

[7] *Katcha* means earthern, weak, unofficial.

[8] *Pakka* means concrete, strong, official.

[9] They are sharing water from the same *mogha*.

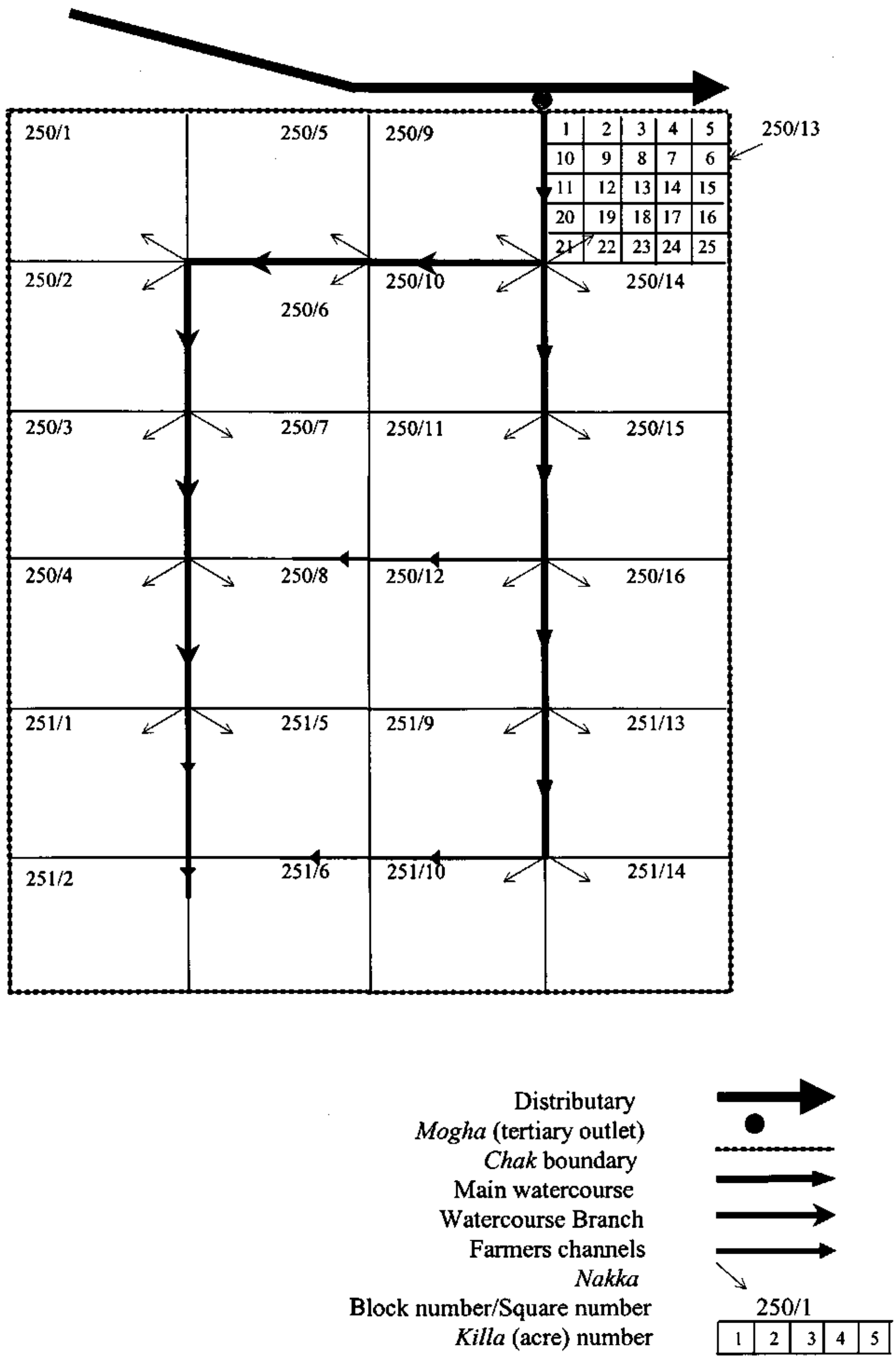

Figure 3.3: Layout of a tertiary unit (*chak*)

Main Features of the selected watercourses

The main attributes of the sample watercourses are summarised in table 3.2. Three kinds of outlets (*mogha*) are present in the sample watercourses. Three have an Adjustable Proportional Module[10] (APM), two have an Open Flume with Roof Block (OFRB) and one has Open Flume (OF). The implications of these outlet types and their dimensions on the discharge are discussed in section 3.3. The lengths of the selected watercourses range from 1.3 km to 3 km. These watercourses are also different in their physical conditions: the longest watercourse, FD 67-L is almost fully lined and has *pakka nakkas*, whereas the Mahmood watercourses are lined up to the first 390 meters. They have a few *pakka nakkas*. The other three selected watercourses are completely unlined with *katcha nakkas*.

Table 3.2: Main attributes of six selected watercourses

Distributary	Mahmood	Mahmood	Fordwah	Fordwah	Fordwah	Fordwah
Outlet	1030-R	11860-TC	38830-L	67160-L	84140-L	96692-R
Outlet Type	OFRB	OF	OFRB	APM	APM	APM
Design width of the outlet (b) (ft)	0.42	0.49	0.16	0.20	0.20	0.20
Design height of the outlet (y) (ft)	0.74		0.70	0.72	0.59	0.38
Actual width of the outlet (b) (ft)	0.42	0.49	0.16	0.21	0.21	0.22
Actual height of the outlet (y) (ft)	0.74		0.66	0.72	0.59	0.42
GCA (acres)	355	435	169	401	317	174
CCA (acres)	350	412	105	385	264	170
Water Allowance (ft^3/s/1000acres)	3.6	3.6	3.6	3.6	3.6	3.6
Design Q (ft^3/s)	1.26	1.48	0.38	1.38	0.95	0.64
Watercourse length (m)	1625	2798	1300	3000	2145	2015
number of TW	10	5	2	17	24	10
Warabandi type	*pakka*	*pakka*	*pakka*	*pakka*	*pakka*	*pakka*
No. of Owners[1]	77	78	3	44	86	48
No. of Cultivators[2]	71	74	2	57	48	29
No. of Tenants[3]	19	16	1	23	29	25
Allocated Irrigation time[4](min/acre)	29	25	59	26	38	56
Range of the Officially allocated water turn[5] (min/acre)	28-34	23-28		26-28	35-44	56-58

[1]Owner: who owns agricultural land
[2]Cultivator: who actually cultivates the land (includes owner and tenant)
[3]Tenant: a farmer who does not own land but cultivates it. He may sharecrop the land or rent it.
[4]Time calculated by *patwari* for the unit area in a watercourse command area.
[5]The range is not given for the watercourse FD 38-L because there are only two landowners

There is a link between the number of tube wells in the watercourse command area and the number of owners in the water scarce Fordwah distributary. Every farmer wants to be independent and flexible in use of irrigation water. In the Mahmood distributary more

[10] In fact a modified version, which is an Adjustable Orifice Semi-Module (AOSM), of APM is in use. However, since it is still referred to as APM in the record of Irrigation Department, the same name is used here.

tubewells are found in the head watercourses because of the choice for rice cultivation, that has a higher crop water requirement. However, the number of tubewells in Mahmood is still much less than in the Fordwah distributary, because of the availability of ample amounts of water. The quality of groundwater is also much better in the watercourses along the Mahmood distributary than in the watercourses along the Fordwah distributary since it is closer to an old riverbed.

The time to irrigate a unit land (allocated irrigation time for the unit area) is different for all the watercourses because it depends on the CCA and the design discharge of a watercourse, although the rotation cycle (*warabandi*) in all the cases completes in seven days. In theory, all farmers in one watercourse command area should get the same allocation for a unit area, that is minutes per acre. However, some small discrepancies were found when minutes per acre for all the landowners were calculated from the *pakka warabandi*. Some farmers are getting slightly more than the official allocation, while others are getting slightly less. The officially allocated *warabandi* turn is calculated by dividing the total irrigation turn time in minutes by the total command area of the watercourse written in the *pakka warabandi*. The allocation of each individual farmer is calculated by dividing his full water turn by his total area. The range of the allocated water turn of farmers within a watercourse is relatively big in the Mahmood watercourses and FD 84-L. Some of the reasons for these ranges are discussed in chapter 5 (section 5.4). Nevertheless these extreme values of allocated time per unit of area are few and the average time calculated using *pakka warabandi* schedule is very close to the official allocation presented in the table.

3.2.1 Settlement Patterns of the Watercourses

The study area, originally an arid region, was opened up to immigrants[11] for settlement and agriculture by the Sutlej Valley Project in the 1930's. People from different parts of Eastern Punjab (and also some people from other parts of the state, these people are locally known as '*Riasati*'[12]) shifted to this area. Today, the settlement pattern is composed of towns, villages and individual farmhouses. The first land allotment took place in 1930's after the construction of the project. A second land allotment was done at the time of Partition of United India, when many Muslims from Central India and East Punjab migrated to Pakistan (and Hindus & Sikhs moved out of the area). However, often people from one place of origin belonging to one caste, tried to stick together. Therefore in most of the settlement villages the population of farmers from one caste or one area of origin are found. Nevertheless, such patterns are not absolute since in the post independence period farmers also moved out and new farmers came in.

The main towns of the study area are Chishtian and Hasilpur. These towns provide employment opportunities, have processing factories, and provide market outlets to the agricultural produce of the area. Both the towns have populations of approximately 400,000. Chishtian town is a big market for cotton produce and other agricultural products of the area; it also has a sugar mill. Two of the sample watercourses, MD 1-R and MD 11-TC, are close to Chishtian and two, FD 84-L and FD 96-R, are very close to Hasilpur town. Fodder and vegetables grown in the watercourses FD 84-L and FD 96-R are sold at Hasilpur market. Fodder is also sold to the farmers having livestock farms. The milk from the cattle of these

[11] However, part of the area was cultivated, even before the Project started, especially during the flood season because of the inundation canal of the River Sutlej. People were living along the river as well.

[12] The State is called '*Riasat*' in the local language, therefore people from the state are '*riasati*'

dairy farms is sold to the milkmen, who sell it in the town. Farmers also sell cattle at the cattle market, which is organised from time to time on a regular basis. The watercourse FD 38-L is relatively more close to Chishtian than Hasilpur whereas FD 67-L is more close to Hasilpur.

In two of the sample watercourses, FD 84-L and MD 11-TC, cultivators live in villages[13] (which are also local administrative centres with schools). The cultivators in other watercourses live in individual farmhouses known as 'deras', which are usually constructed within their landholdings. These *deras* (houses) are spread over the whole watercourse command area. In the watercourse FD 67-L some houses are concentrated in one or two places in the watercourse command area.

Most of the farmers in the selected watercourses are settlers, and more than one caste is present in one village. There is only one watercourse, FD 67-L, with one dominant caste – 77 % of farmers from one caste - and another watercourse, FD 84-L, with two dominant castes – one with 52 % of farmers and other with 32 % of farmers[14]. The rest of the watercourses have farmers from many different castes, although, one or two castes are in the majority. In these cases, most of the farmers in one village have migrated from the same area even if the caste is different. It appeared in the study that caste seems to have an influence in the execution of some water management task in certain watercourses. For instance, in case of MD 1-R, work distribution to desilt a watercourse is done according to the castes. However, this research was not focused on caste to understand the relation between the caste composition of the village and water management activities. More research could be done on this issue. Other researchers studying irrigation in the Punjab, like Merrey (1983, 1986a, 1986b), noted that the roles and norms through which water management activities (which he refers to as irrigation tasks) materialise are imbedded in the larger social structure - especially the kinship-based *biradari* system. He analysed the effect of *biradarism* and kinship on the execution of water management tasks. In the villages he worked in, the conflicts between and within different *biradaris* were the main hindrance in the process of effective rehabilitation of the watercourse(s).

3.2.2 Agrarian Conditions

Land tenure pattern

The individual landholding size in the selected watercourses is reduced as a result of inheritance of the land from father to children. As the population has increased the landholding size has become smaller. Some of the landowners increase their operational land holding size by renting in more land. In this study the operational land holding size is taken as the land actually operated or cultivated by a farmer. Table 3.3 presents the average, minimum and maximum landholding sizes of the owners and the cultivators of the selected watercourses.

The watercourse FD 38-L has only three owners and two cultivators. Two of the owners are relatives, they are father and son and have leased out their land to one farmer. Hence the operational landholding size of the two cultivators is more or less the same. The presence of

[13] Farmers of the watercourse FD 84-L are in fact living in two villages

[14] Farmers from these two castes are related to each other by marriage.

one big landowner[15] in the watercourse FD 67-L has increased the average landholding size by 38 %. If that landowner is excluded the average landholding size becomes 2.1 ha. The watercourse FD 84-L has the smallest average landholding size of owners: this watercourse also has highest number of tenants.

The operational land holding size of the cultivators in sample watercourses, presented in Table 3.3, reveal that the watercourse FD 84-L has the smallest gap between the minimum and maximum land holding within the watercourse command area[16]. This may explain the fact that this watercourse has the most diverse tenancy arrangements, and also has the highest percentage of farmers having off farm employment. This suggests that the farm size is too small for livelihood of a family, therefore owners bring in tenants and seek off-farm employment themselves.

Table 3.3: Operational landholding sizes of the cultivators in six selected watercourses

Watercourse	Landholding size of the landowners			Operational Landholding Size in ha.		
	Average	Maximum	Minimum	Average	Maximum	Minimum
MD 1-R	1.7	14.2	0.1	1.96	14.17	0.10
MD 11-TC	2.0	11.1	0.2	2.11	11.13	0.20
FD 38-L*	12.8	19.4	9.5	19.23	19.43	19.03
FD 67-L	3.4	60.3	0.1	3.57	20.04	0.10
FD 84-L	1.2	8.8	0.1	2.15	7.70	0.20
FD 96-R	1.4	5.5	0.05	2.38	12.60	0.10

* This watercourse only has two cultivators with almost same operational land holding size therefore all the values are almost same.

Tenancy classes present in the selected watercourses are 'Owner-Cultivators'[17], 'Sharecropping'; and 'Renting'. 'Owner-cultivator' refers to the farmers who cultivate their own land.

Two main arrangements sharecropping exist: one is the sharecropping for 50 percent, in which both owner and tenant are equally responsible for the expenditures and get equal harvest of the crops. Each pays 50 % of the total expenditure and has a right to 50 % of the yield of all the crops cultivated. In the other arrangement of sharecropping owners get 75 % of the yield but provide all the inputs except labour, which is provided by the tenant. The tenant, who in this case, provides all the labour[18], does not pay for the inputs and gets 25 % of the total produce. In the third kind of tenancy arrangement, that is renting, an owner leases out land to a tenant for a fixed amount of money. A tenant, in this case, gets 'temporary' rights on land. He can cultivate the land, as he wants. The landowner cannot interfere with his cultivation practices. Appendix IV presents terms and conditions of different tenancy agreements. These contracts are usually made for one or two years, including two crop seasons *kharif* and *rabi*[19].

[15] This landowner is also an influential person in the watercourse command area.

[16] Although in all the watercourses except FD 67-L and FD 38-L, the operational landholding size of majority of the farmers is less than 5 acres (2.02 ha.) (Wahaj *et al.*, 2000).

[17] In this research, Landowners who are cultivating their lands themselves are considered a tenancy class in order to be able to compare them with the other tenancy classes present in a watercourse command area.

[18] The tenant is like a permanent labourer in this arrangement.

[19] This contract may be renewed after one or two years. In case of renting contracts, owners prefer not to lease out their land for more than 5 years, firstly because they want to increase the rent; and secondly because of the

In the selected watercourses, two watercourses, FD 84-L and FD 96-R, have more diverse tenancy arrangements. The reason might be that these two Fordwah watercourses are closer to the city where there are better opportunities for off-farm employment. Certainly off farm employment is also greater than in the other watercourses (see table 3.4). It has also been found that in some cases one cultivator is owner-cum cultivator on one parcel of land, is a sharecropper on another parcel of land and is a lessee on the third parcel of land. However, he must have enough manpower to cultivate all these parcels. Sometimes, a farmer owns small parcels of land in more than one watercourse, whose boundaries are not adjacent. In that case the farmer may only cultivate one parcel and rent in more land in the same watercourse (preferably adjacent to his own land) and lease out the parcel of land in the other watercourse. Or he may also lease out both the parcels and rents in land in a completely different watercourse (as in the case of one of the cultivators in the watercourse FD 38-L). However this strategy to consolidate area cultivated is not very common. The selected watercourses along the Mahmood distributary (MD 1-R and MD 11-TC) have a relatively high number of owner cultivators.

Table 3.4: Off farm employment in six selected watercourse command areas

Watercourse	Number of cultivators having off farm employment	% of cultivators having off farm employment
MD 1-R	1	1.3
MD 11-TC	7	8.8
FD 38-L	1	50.0
FD 67-L	6	13.9
FD 84-L	22	45.8
FD 96-R	12	41.3

More than 40 % of the cultivators in the watercourses FD 84-L and FD 96-R have other sources of income besides agriculture. Very often persons with a college education or university degree prefer to find a job in the Government sector instead of cultivation. Apart from higher income, these jobs also give some respect and influence within the community. In the case of the watercourse MD 1-R, there is only one cultivator with an off-farm job: he is Gauge Reader in the Irrigation Department. He leased in land because it is adjacent to his place of duty therefore he could easily keep an eye on the water level in the Branch and act accordingly. At the same time he earns some extra money from cultivation.

3.2.3 Social Relations and Leadership in Water Management

In almost all the watercourses one or more influential farmers are present who have more wealth and power than the rest of the farmers, and therefore are considered leaders or influential persons in the watercourse command. Prestige and power is not related only with land: nor do responsibilities of collective action always lie with the wealthiest farmers. In irrigation communities one can gain the authority by repeatedly initiating a task or organising a water management activity[20]. More details of the relation of responsibilities and roles in

fear of losing their land. In some cases renters tried to occupy this land legally by transferring it to their names (Terpstra 1998).

[20] Hunt (1989) identified the authority of a local water management organisation in an irrigation community. He recognises the size of an organisation and its influence, the source of legitimacy of authority, performance of the tasks of the organisation, the fulfilment of roles and the evaluation of their performance, and its financial viability and economic sustainability to be important and describe the authority of the organisation.

collective action are given in chapter 4 (section 4.5). Generally speaking one or more farmers are responsible for resource mobilisation within the watercourse command area or village, depending on the nature of the task. Similarly one or more farmers are considered helpful or unofficially responsible for the work needed to be done outside the watercourse, for example, negotiation with the Irrigation Department. These farmers are considered 'knowledgeable' and having more exposure to 'outside' world by the fellow farmers. Thus 'knowledge' and 'exposure' are also source of authority.

The influential and smaller farmers sometimes have a kind of dependency relationship. Influential farmers help others and in return get some labour input if needed or votes in case they are politicians. Or, small farmers get things, like fuel, on credit from the influential farmer and therefore do not object inequitable water distribution. These influential farmers could also use their influence in a negative way in order to show their power and to impress their opponent. Influential farmers are not always big landowners in the watercourse command area, they may also own a small piece of land in a watercourse command area. Or they may be tenants, who have rented in land or are sharecropping land in the watercourse command areas. In these situations, these tenants and small landowners usually have considerable amount of land in other, neighbouring watercourses. Thus, these tenants can have a higher socio-economic status as compared to some of the landowners of the watercourse.

Irrigation water management is mainly men's task and responsibility in the study area. Although women own land (through inheritance), often their male family members (father, husband or brother) cultivate the land. Or it is given on lease. Some women are involved in agricultural activities however they neither irrigate fields nor they are involved in organisation or performance of water management activities. Therefore, in this thesis a farmer is referred to as 'he'.

The forum that farmers use to discuss water related issues is the '*Panchayat*'[21]: although it does not have a legal status, it is a traditional method and is accepted by the water users. Farmers use the word *Panchayat* for any meeting to discuss issues and take decisions. While a formal *Panchayat* is not present anymore (at least not in the study area) it still works and elders of the village (or watercourse) and sometimes the *numberdar*[22] is present to discuss the issues. These elders of the village posses certain respect[23] because of their age or social status and may also be representing their *biradaris* and thus have higher social status within their *biradaris*. Similarly, in general any farmer can call for a *Panchayat* for any issue or dispute - for instance a dispute about the land between two farmers could be discussed in the *Panchayat*. If the dispute among the farmers involved could not be solved in the *Panchayat*, or one party is not satisfied with the decision, only then the concerned parties go to court, since it takes a lot of time before any decision is taken by the court. Besides it is expensive to

[21] In some parts of India formal *Panchayats* are present at village level and have legal status. These *Panchayats* also have a head (or a chairman) and other members.

[22] (or *lambardar*) the person responsible to collect *abiana* from the water users and give it to the Revenue Department. As compensation he gets some land for and he also doe not has to pay *abiana*.

[23] Religious leaders or *Imam* (person who leads prayers in the Mosque) are also respected by others because of their religious knowledge and religious tasks they perform. However, in the study area they are usually not involved in conflict resolution but they are involved in decision making related to water management if own or cultivate land in a watercourse command area.

go to the court. However the decision taken in the *Panchayat* could be used as evidence in the court (Terpstra 1998).

3.2.4 Interaction Between the Farmers and the Irrigation Department Staff: Location of Irrigation Staff and Means to Access Them

The main office of the Irrigation Department (ID) for the study area is in Chishtian town, where the Sub-divisional officer (SDO) sits with his administrative, maintenance and revenue staff[24]. The Executive Engineer (XEN) of Fordwah canal, who is responsible for the whole canal sits in Bahawalnagar - a bigger city, which is about 90 kms from Chishtian. The ID also has an office at the Sub-Engineer level in the Hasilpur town. The Gauge Reader, who is responsible to operate gates of Mahmood, Fordwah and Azim distributaries, is required to be present very close to the structure all the time. Therefore, a Gauge Reader lives next to this regulation point[25]. *Patwaris* do not have a permanent office, since they are required to be in the field for most of the time. Some of the maintenance field staff of the ID, the Mate and the Baildar, are also in the field for most of the time. They are responsible for small repairs and earthwork.

Farmers very often know where to find these ID staff. However, the most contacted ID staff are the Sub-Engineer for *mogha* remodelling, and the *Patwari* for a change in the *warabandi* or to save the *abiana* (water tax). *Patwaris* are the ones who assess the cropped area and therefore *abiana* for each farmer[26]. Farmers from the Mahmood distributary also contact the Gauge Reader very often to move the gates of the distributary. It is easier for them to contact the Gauge Reader and the SDO because of less distance as compared to the farmers of the Fordwah distributary. Appendix V presents main tasks and responsibilities of the ID staff contacted most by the farmers.

Some of the farmers who have also served Irrigation Department as a *patwari* or other lower level staff recognise the difficulties which ID staff faces in their day to day encounters with the farmers and the political leaders of the area, based on their own experience. But they also know the right persons to contact in the ID to get their work done. These farmers, who have worked for ID, accuse politicians for the bad functioning of the main irrigation system. Box 3.1 presents views of an ex-*patwari* who is cultivating his land now.

[24] Chishtian Sub-division is considered a difficult area for irrigation managers because of the high level of political interference. Therefore SDOs try to minimise their tenure –5 SDOs have been transferred in and out in 3 years (from 1993 to 1996) – whereas their normal tenure is 2 –3 years (Kuper, 1997).

[25] To earn some extra living, he has rented in land along the Mahmood distributary.

[26] However, they do not collect this abiana. It is collected by the *Numberdar* of the village. The *abiana* is based on the irrigated area and crop. It is highest for the cash crop like sugarcane vegetables and rice and cotton, since these are the crops, which need irrigation water most and are very profitable. *Abiana* for the main crops grown in the sample watercourses is:

Crop	Abiana per acre Rs/US$
Sugarcane	141/3.5
Vegetable	79/1.97
Cotton	77/1.93
Rice	73/1.8
Wheat	49/1.2
Fodder	31/0.8

Box 3.1: Views of an ex-*patwari* cum farmer on the problems faced by the ID staff and on the involvement of politicians in the management of the irrigation system

Farmer OID[1] 49, who owns 7 acres of land in one of the sample watercourses, was an ex-patwari with the Irrigation Department for 17 years from 1948 to 1965. At the beginning of his job he was happy and satisfied with his work, however with the passage of time he felt more difficulties in fulfilling his job as he felt that he had to keep both farmers and his bosses happy. According to him *patwaris* used to feel happy and contented even if someone (a farmer) would reward them with a small amount of money (Rs. 10) in good old days. He took early retirement after he felt that he could no longer perform his duties properly because of the political interference.

He feels that the management of the irrigation system has deteriorated since 1965, since when political interference of the big landlords has been increased. He is aware of the fact that ID officials get threats of transfers and sometimes even get suspended, if they do not co-operate with the big landlords and their tenants. In the worst cases ID officials have received life threats in case of non co-operation with these people. The whole system has entered into a vicious circle – small farmers steal water because they see big landowners doing and get away with it without paying any penalty. If these small farmers are caught while stealing water, by the ID staff, they seek help from either big landlords or the political leaders of the area. Political leaders of the area help these farmers because they are their vote banks. The effect of stealing of canal water appears in the form of water scarcity at the tail of the system where other farmers suffer. Every one blames everyone else for bad functioning of the system. The ID has a potential to manage this system very well only if political interference is minimised.

3.3 SAMPLE WATERCOURSES: OUTLET TYPES AND WATER SUPPLY DURING THE STUDY PERIOD

3.3.1 Outlet Type in the Selected Watercourses

The type and the design of an outlet has greatest impact on the water distribution, therefore it is of prime importance to the canal engineers and the irrigators (Mahbub and Gulhati 1951). It influences the equitable water distribution within a distributary and determines the discharge formulae to be used. The selected watercourses have three types of outlets[27] (See Appendix VI for sketches and other details):

- Adjustable proportional Flume (APM) or Adjustable Orifice Semi-Module (AOSM)
- Open Flume (OF)
- Open Flume with Roof Block (OFRB)

[27] Although there is one more type of outlet, pipe outlet, found in the selected distributaries. About 10 pipe outlets are installed along the Fordwah distributary, these pipe outlets are installed where the working head was not enough for the functioning of the semi-module (Hart, 1996). Along Fordwah distributary OFRB are present in the first half of the distributary (RD 0 to Rd 65) and APM/AOSM along the second half of the distributary (from RD 65 to 139). The tail of the Fordwah distributary has OFRD. Whereas along the Mahmood distributary first two outlets off-taking from the right side are pipe outlets and first two left outlets are OFRB. Three tail outlets (tail cluster) are open flumes.

The outlets were calibrated to obtain daily discharges of the watercourses. The Open Flume outlet however, was not calibrated with its formulae because it was always drowned under water, therefore the discharge formulae for an open flume could not be used for calibration, as the area of the flume through which water is flowing could not be determined. Instead, a section of a lined portion of the watercourse 50 meters downstream of the outlet was gauged, and this measurement was used as a calibration after consulting irrigation and hydraulic engineers. Only one outlet, that is the OFRB of the watercourse FD 38-L, needed to be calibrated for two flow conditions because of the higher elevation of the watercourse downstream of the outlet. The sediment deposition in the first hundred meters increases the bed elevation and therefore changes the flow condition from modular to submerged (or non-modular). The outlet of the watercourse MD 11-TC (outlet type OF) could also not be caliberated with its standard discharge formulae because it was drowned in water[28], for most of the time that resulted in continuous change in the actual area through which water was flowing. After discussions with some of the irrigation and hydraulic engineers it was decided to calibrate the lined section of the watercourse at the head by using empirical formulae. The discharge formulae used for calibration of the outlets for different flow conditions[29] are as follows:

Outlet Type(s)	Discharge Equation(s)	Sample outlet
Orifice (OFRB and APM) with semi-modular flow condition	$Q = CBY\sqrt{2gHs}$	MD 1-R FD 38-L FD 67-L FD 84-L
Orifice (OFRB and APM) with non-modular flow condition	$Q = CBY\sqrt{2g(Hu - Hd)}$	FD 38-L
Open Flume (non-submerged)	$Q = CBHu^{3/2}$	
Section of the watercourse	$Q = KD^n$	MD 11-TC

Where:

Q	=	Discharge
C	=	Discharge Coefficient
B	=	Breadth of the outlet
Y	=	Height of the outlet
Hs	=	Hu – Y
Hu	=	Upstream water level above the crest
Hd	=	Downstream water level above the crest
K	=	Discharge Coefficient
D	=	Depth of the water in the channel
n	=	Exponent

[28] The explanation given by the farmers and the irrigation department officials is that when the distributary was remodelled the height of the crest of the outlet was increased while the height of the side walls was not increased and therefore the outlet is most of the time drowned even with its design discharge. This was also found true but higher water supply was the main reason for this overflow.

[29] See Visser (1996) for different types of flow conditions for weir and orifice flow.

3.3.2 The Influence of Outlet Dimensions on Water Supply in Selected Watercourses

The size of an outlet determines potential discharge to a watercourse. Therefore it is critical in the supply of irrigation water for the farmers, and is a point where farmers intervene with the system and get benefit for the whole group within a watercourse command area. Sometimes farmers tamper with the outlet in order to acquire additional canal irrigation water.

At the start of the research, five out of six selected watercourses had almost the same dimensions as designed. However, one of the outlets was 21.6 % bigger than its design dimensions, hence the water it draws is 20 % more on average[30].

Later during the research farmers intervened and tampered with[31] another outlet, MD 1-R, a few times. First the farmers broke the outlet. When the Irrigation Department (ID) interfered and fixed it[32], farmers tampered with it again. Nevertheless it was fixed again by the ID within few days, but a compromise was made by increasing the Y (the elevation of the roof block above the crest) of the outlet by about 3 %. However this increase in the Y did not increase the discharge, in the sense that the discharge to the distributary was decreased.

The dimensions of another outlet FD 67-L were also changed by the Irrigation Department in *rabi* 1997-98; its width B was increased by almost 10 % and height Y was decreased by about 3 % that resulted in a total increase of 8 % in the discharge. The impact of these changes in *mogha* dimensions is discussed in detail in the chapters 4 and 6.

3.3.3 Water Supply During the Study Period

The study period that lasted for three agricultural seasons was special in terms of water supply. The first season that is *rabi* 1996-97, was normal but at the start of the *kharif* season one of the link canals that carry water from Balloki headwork to the Suleimanke headwork got damaged. Therefore the water, which according to farmers was already scarce, became even scarcer. This scarcity of water, in combination with the water theft[33] upstream in the system by big landowners, made the water situation even worse for the farmers at the tail end of the system. Water theft upstream is a factor that always influences water distribution in the Chishtian Sub-Division (personal communication with Irrigation Department staff). However, at the end of *kharif* season the link canal was repaired and canal water supply improved.

Another big incident that had influence on canal water supply of the study area was the visit of the Prime Minister (PM) of Pakistan to the area in July 1997. During the visit the PM witnessed cuts in one of the distributaries in the area by the bigger farmers. He suspended most of the Irrigation Department staff of the irrigation circle and also promised to take appropriate actions against the farmers who were indulged in water theft. Though such forms of water theft by the farmers were not occurring in the distributaries studied, the whole emphasis on equitable water distribution by the PM influenced water supply to the selected watercourses during the remainder of the study period.

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[30] This 20 % is the average of one year (April 1997-April 1998) daily discharges.

[31] They made holes in the walls of the outlets and also damaged the roof.

[32] The Irrigation Department interfered because of high awareness due to the visit of the Prime Minister. This is discussed more in section 4.1

[33] Here water theft also includes the use of power or influence to get a higher discharge than authorised.

The Delivery Performance Ratio (DPR) which is the ratio of actual supply to the design supply was calculated for all the sample watercourses. The DPR of the selected watercourses, presented in figure 3.4, shows that the water supply to the watercourses along Fordwah distributary was highest in *rabi* 1997-98 and lowest in *kharif* 1997. Average DPR during the study period was highest for the watercourse at the head of the distributary, followed by the one at the tail reach of the distributary; this is mainly because of the increased *mogha* size. Although the *mogha* of FD 38-L has the correct design dimension, it is still drawing more water than its design share. In theory, it should draw its design discharge. The only explanation of this is that, since the capacity of the Fordwah distributary to carry water has been reduced because of sedimentation, hence the water levels of the distributary are higher than the design water level for same discharge at the head of the distributary. Hence higher working head results in the increased discharge of the *mogha*. The water supply situation was improved considerably in *rabi* 1997-98 because i) one of the damaged link canal was fixed ii) distribution among the distributaries became more equitable after the PM's visit. However, the average DPR for the whole study period still remained well below 1 for the two watercourses, FD 67-L and FD 84-L, along the middle reach of the Fordwah distributary.

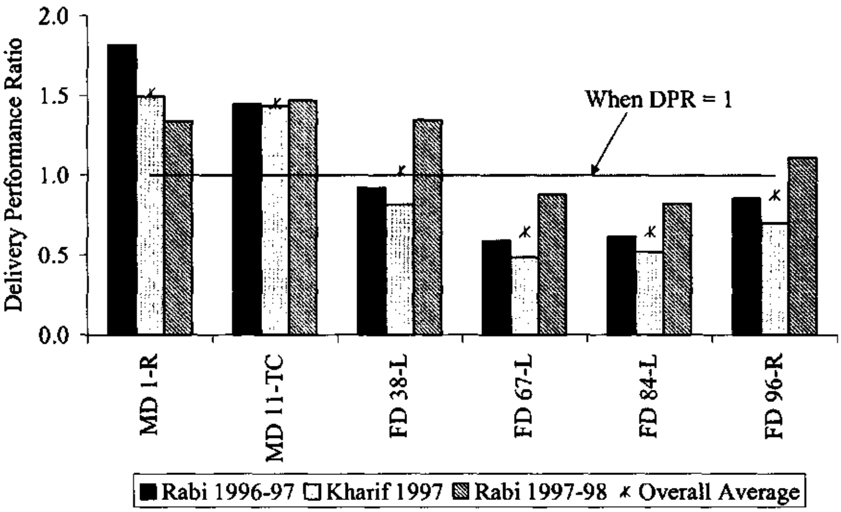

Figure 3.4: Delivery Performance Ratio (DPR) of the six selected watercourses along Fordwah and Mahmood distributaries during the study period (January 1997 to April 1998)

The watercourses along the Mahmood distributary show a different situation since the discharge of the distributary is usually much greater than its design share of water. Therefore both the selected watercourses (one at the head and the other at the tail of the distributary) have a DPR of more than 1 throughout the study period. The head *mogha* was receiving about 175 % of the design during *rabi* 1996-97: that reduced to about 150 % in *kharif* 1997 and to 137 % in *rabi* 1997-98. This change in the discharge of the *mogha* was due to the overall reduction in the discharge of the distributary after the PM's visited the area. According to these farmers the water supply has deteriorated. The privilege which the farmers of these watercourses have been getting in terms of higher water supply had become a right in their eyes: when it was taken back they felt deprived of their right. Some farmers even blamed the researchers (IWMI-Pakistan) for the reduced water supply: they said that since researchers had started measuring discharge, water supply had deteriorated. Nevertheless, one of the farmers who first blamed the researchers for poor water supply said that he realised that this reduction in the discharge of *mogha* was due to the fact that canal water is reduced, making the situation very difficult for them. In the words of a farmer:

"We are like fish that live in water and in past we never had any water shortage, we got water whenever we needed it but now when the *water is taken away from us we are suffering like fish would suffer without water. We know that it was not our right but we are used to get more water and now we have problems in surviving."*

In the selected tail watercourse of the Mahmood distributary the water situation remained more or less the same. One would expect a decrease in discharge and thus in DPR of this *mogha* as a result of the decrease in water supply to the distributary. But since the Irrigation Department downsized some of the upstream *moghas* to their design dimensions the discharge at the tail did not change. It remained more than 1 for all seasons.

The seasonal DPR shows the difference between the design and the actual discharge of the watercourses in a season. However it does not show the fluctuation in daily discharges, of these watercourses. Thus, the Coefficient of Variation (CV) - standard deviation/mean - of daily discharges of all the sample outlets are calculated, for the whole study period (18 months[34]), to show variability in canal water supply. The CV of daily discharges are 0.62, 0.64, 0.71, 0.64, 0.60, and 0.59 for the watercourses MD 1-R, MD 11-TC, FD 38-L, FD 67-L, FD 84-L, and FD 96-R respectively. These values, showing a high variation in daily discharges, cannot be used to show the general picture, since the canal water supply to the system was unusually disturbed due to some infrastructural problems in one of the link canals for one full month (in June 1997). Therefore the CV of daily discharge was calculated for the whole study period minus the month of June 1997. While this decreased the variability coefficient, it nevertheless was quite high. The new values of CV for the watercourses MD 1-R, MD 11-TC, FD 38-L, FD 67-L, FD 84-L, and FD 96-R are 0.55, 0.57, 0.63, 0.55, 0.51, and 0.49 respectively. These values show a high degree of fluctuation, and therefore unreliability in the canal water supplies to the watercourses. In the case of MD 1-R, this CV of discharge also includes the impact of farmers' action to refuse the surplus canal water supply by blocking the *mogha*[35] - the actual discharge during the days the *mogha* is blocked becomes zero. A CV of discharge for MD 1-R without considering the days when discharge was nil because of farmers interventions is even less, which is 0.5. An interesting observation is that the fluctuations in the last two sample watercourses along the Fordwah distributary are of more or less the same magnitude. The reason might be that they are physically very close to each other (the distance between these watercourses is about 3.8 kms). The highest fluctuations are felt in the watercourse FD 38-L, which can be explained by the depth at which the OFRB is installed in the distributary cross section. Since it is installed quite high in

[34] The period (4 to 5 weeks) when canals are closed for routine maintenance was not included in the analysis, because it is considered a part of the planning: for this period of time no water delivery was planned for the watercourses.

[35] Although it also happened in the sample watercourses along the Fordwah distributary, that farmers blocked the *mogha* when they did not need canal water, but for fewer days. Hence it did not influence the CV of the discharge. In case of MD 11-TC, farmers do not block the *mogha* to manage excess canal water supply, they rather drain it in the water-logged area. Therefore this activity does not effect the discharge at the *mogha*.

the distributary, a small reduction in the water level has a big impact on the discharge through this *mogha*[36].

3.3.4 Water Allowance Versus Supply

The water allowance defines the size of an outlet, and therefore provides the basis for design of a distributary channel (Mahbub and Gulhati, 1951; Govt. of West Pakistan, 1961). Generally, water allowance is expressed in cusecs (ft^3/s) per 1000 acres of Culturable Command Area (CCA). The water allowance for the selected distributaries' command areas and therefore of the selected watercourses command areas is 3.6 ft^3/s per 1000 acres. However, actual water supply (in $ft^3/s/1000$ acres) to the watercourses may be different from the water allowance (3.6 $ft^3/s/1000$ acres).

Principally the water supply to the official command areas of the watercourses should be equal to (or close to if not equal) their water allowance. In practice it is not the same, as shown here by the high discharge fluctuation. Another reason is that farmers, very often, do not cultivate one hundred percent of their command area but leave some land fallow[37]. In which case their actual supply should be greater than their water allowance. Table 3.5 shows the water supply (that is water delivered in $ft^3/s/1000$ acres) as calculated based on the designed Culturable Command Area (CCA), and the Actual Cropped Area (ACA). Water supply based on both the areas – CCA and ACA – was calculated using the following formulae:

Water delivered in ft^3/s /1000 acres of CCA = (discharge/CCA) * 1000
Water delivered in ft^3/s /1000 acres of ACA = (discharge/ACA) * 1000

Where discharge[38] is in ft^3/s, and CCA and ACA in acres

The table also shows the ratio between the water supply (in $ft^3/s/1000$ acres) based on both the areas (CCA and ACA) and water allowance – that is 3.6 $ft^3/s/1000$ acres. Theoretically this value should be 1 for CCA, however it is not so. For the first two seasons, *rabi* 1996-97 and *kharif* 1997, the ratio of actual water delivered based on CCA to the allowance was less than 1 for all the selected Fordwah watercourses and greater than 1 for the selected Mahmood watercourses. This shows the extent of water scarcity according to the design criteria. The ratio between actual water supply based on CCA and water allowance is below 1 even in case of the watercourse FD 96-R whose *mogha* was remodelled and enlarged. While the water supply remained higher than 1 for selected Mahmood watercourses in *rabi* 1997-98, the water supply of the two selected watercourses along the Fordwah distributary – FD 38-L and FD 84-L - also exceeded the theoretical value of 1.

In all the selected watercourses the water supply based on ACA is higher than the water supply based on CCA because the actual cropped area is less than the CCA. However the situation is more or less same when different watercourses are compared. The water supply based on ACA is very good in the selected watercourses along the Mahmood distributary: the

[36] Earlier studies (Visser, 1996; Wahaj, 1995) also show that the water distribution to the head outlets is more correlated to the distributary discharges than the tail outlets.

[37] This land is left fallow for several reasons including scarcity of canal water. In fact the system is designed with much less design cropping intensity (see section 3.4.2 for details). Note that water allowance is based on full CCA whereas design cropping intensity is the percentage of CCA.

[38] Note that the average discharge of the whole season was used in the calculations.

ratio between the water supply based on ACA is much higher than 1 showing no signs of water scarcity according to the design criteria. The situation is different in the selected Fordwah watercourses. Water supply based on ACA of two of the selected Fordwah watercourses – FD 38-L and FD 96-R - is greater than 1 in all the seasons. The watercourse FD 67-L received less than their water allowance in the first two seasons but the water supply improved – ratio of water delivered based on ACA and water allowance exceeded 1 - in the last season of the study period, i.e., *rabi* 1997-98. Water supply to one of the selected watercourses, FD 84-L, remained below 1 throughout the study period.

Overall, water supply situation to all the selected Fordwah watercourses became better after the water supply situation improved in late *kharif* 1997. Nevertheless the ratio between the water supply based on CCA and water allowance remained below 1 for two watercourses, FD 67-L and FD 84-L. The following chapters will show how do they manage this water scarcity.

Table 3.5: Actual water supply ($ft^3/s/1000acres$) versus water allowance (i.e., 3.6 ft/s/1000 acres) of six selected watercourses during the study period (January 1997 to April 1998)

		Watercourse					
		MD 1-R	MD 11-TC	FD 38-L	FD 67-L	FD 84-L	FD 96-R
Rabi 1996-97 ($ft^3/s/1000acres$)	Based on CCA[1] (acres)	6.45	5.32	3.34	2.11	1.59	3.22
	Based on ACA[2] (acres)	7.66	6.53	4.74	2.49	1.74	3.60
	Supply based on CCA/allowance	1.79	1.48	0.93	0.59	0.44	0.89
	Supply based on ACA/ allowance	2.13	1.81	1.32	0.69	0.48	1.00
Kharif 1997 ($ft^3/s/1000acres$)	Based on CCA[1] (acres)	5.55	5.15	2.95	1.74	1.88	2.64
	Based on ACA[2] (acres)	7.11	6.74	4.43	2.42	2.11	3.68
	Supply based on CCA/allowance	1.54	1.43	0.82	0.48	0.52	0.73
	Supply based on ACA/ allowance	1.98	1.87	1.23	0.67	0.59	1.02
Rabi 1997-98 ($ft^3/s/1000acres$)	Based on CCA[1] (acres)	3.99	5.69	5.07	3.23	3.00	4.25
	Based on ACA[2] (acres)	4.60	6.75	8.20	3.95	3.33	4.72
	Supply based on CCA/allowance	1.11	1.58	1.41	0.90	0.83	1.18
	Supply based on ACA/ allowance	1.28	1.88	2.28	1.10	0.93	1.31

[1]CCA is Culturable Command Area
[2]ACA is Actual Cropped Area

3.3.5 Conjunctive Water Use

Farmers in the study area frequently use groundwater to irrigate their crops. Figure 3.5 gives an overview of the percentage of volume of groundwater, canal water and rainfall during the study period. Groundwater provided approximately 22 % of the total volume of water available in the selected watercourses during January 1997 to April 1998. Particularly in the month of June when canal water was scarce, most of the water was provided by rain and groundwater pumpage. Note that in *kharif* 1997, the link canal conveying water to Fordwah irrigation system was damaged, therefore groundwater pumpage was relatively higher than previous *kharif* seasons[39].

Groundwater use in the watercourses along Fordwah distributary (that has a relatively lower canal water supply) is much higher than the watercourses along Mahmood distributary that has better canal water supply. However, within the Mahmood distributary groundwater is used more in the head watercourses because of more rice cultivation there. Similarly along the Fordwah distributary groundwater pumpage is greater in the watercourses with lower canal water supply.

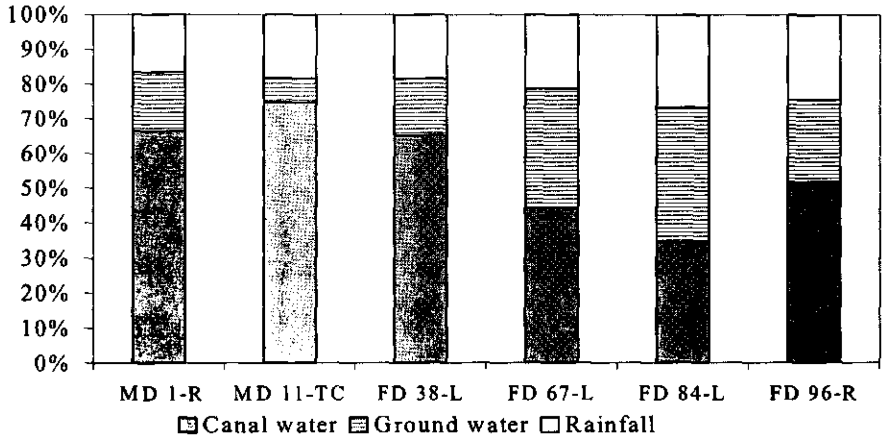

Figure 3.5: Percentage of canal and groundwater used in six selected watercourses during study period (January 1997 to April 1998)

The use of groundwater is an indicator of adequacy and of reliability of the canal water supply. A higher amount of groundwater use indicates that the canal water is not sufficient for the crops grown in the area, whereas a higher frequency of groundwater pumpage would mean that the canal water supply is not reliable.

Groundwater exploitation was seen as the source for additional irrigation water as farmers were pressurised by the increased need of irrigation water resulting from increased cropping intensity. In the study area tubewell installation started in 1960, though a clear trend of increased groundwater exploitation set in during the 1980s (see Figure 3.6a). Almost all the farmers are using groundwater for irrigation in the study area: however, the frequency and amount is higher in the Fordwah distributary than in the Mahmood distributary.

[39] Data from the previous *kharif* seasons was not available. This statement is based on the discussions with the Irrigation Department staff and farmers.

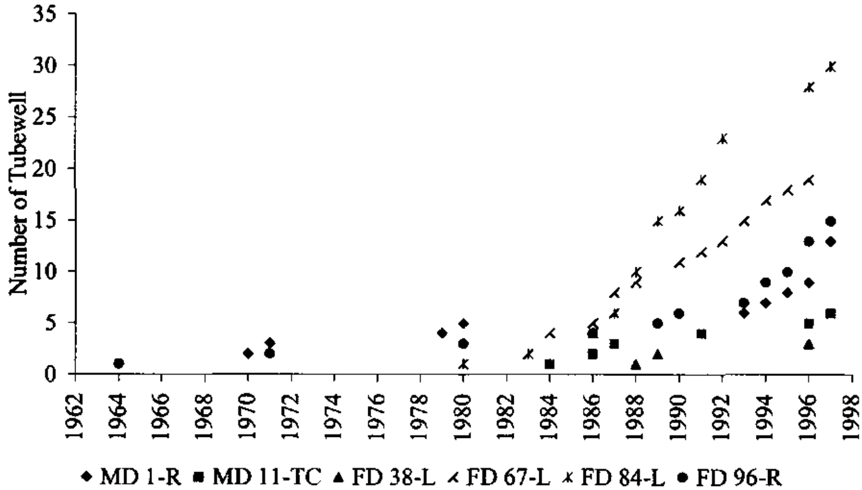

Figure 3.6a: Tubewell installation patterns in the six selected watercourses along the two distributaries

Observation wells were used to observe groundwater table depth in every selected watercourse during the study period. Three observation wells at head, middle and tail of every watercourse were installed and readings were taken every fifteen days. Figure 3.6b shows the fluctuations in groundwater table over time. The groundwater depth values presented in the graph are the average of the values obtained from three observation wells. Overall average groundwater table depth increases as one moves downstream in the distributaries. Average groundwater depth for the selected watercourses in meters is 1.56, 1.88, 2,06, 3.06, 4.31, 4.89 in MD 1-R, MD 11-TC, FD 38-L, FD 67-L, FD 84-L and FD 96-R respectively. The depth to groundwater table increases as the distance of the watercourses from the distributary head increases. Over time, the fluctuations in the groundwater table depth are more obvious in the watercourses along the Mahmood distributary because of relatively higher groundwater pumpage in *kharif* 1997. However, in almost all the watercourses, the groundwater table fell in *kharif* but rose again in *rabi* because of less groundwater pumpage and better canal water supply. That may be keeping the balance of groundwater table in the area. January is another time of the year when groundwater table depth decreases, when the canal water supply is stopped for regular maintenance of channels. Farmers rely only on groundwater in that month hence groundwater levels fall, but again the groundwater table restored once the canal water supply is resumed. Unfortunately groundwater level data was only available after June 1997 hence water balance for one year could not be done.

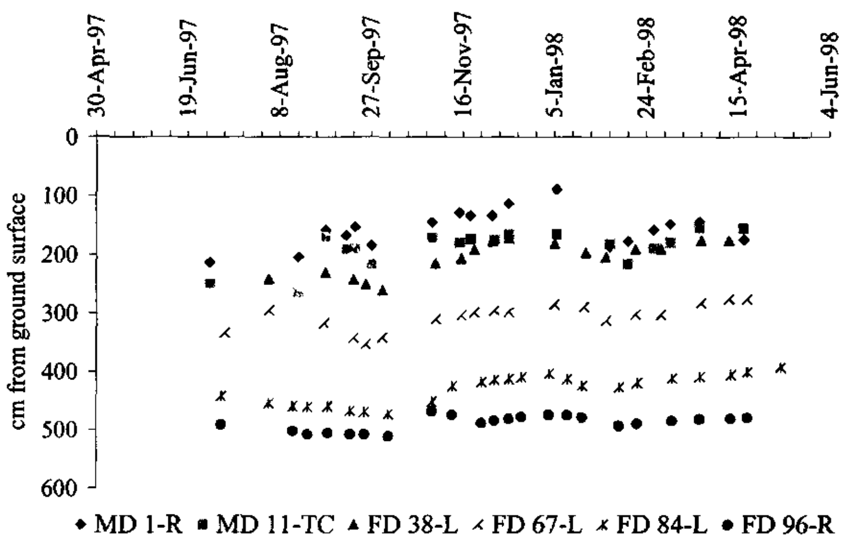

Figure 3.6b: Average groundwater table in the six selected watercourses over time (April 1997 to April 1998)

3.4 CROP PRODUCTION, IRRIGATION WATER REQUIREMENTS, AND WATER DELIVERY

3.4.1 Cropping Pattern

The cropping pattern differs between the two distributaries in relation to available water supply. In the Fordwah distributary the main crops are wheat, cotton, sugarcane and fodder. Whereas, the main crops cultivated in the Mahmood distributaries are wheat, sugarcane, rice and fodder. Vegetables are also grown specifically at the head of both the distributaries. In the Mahmood distributary farmers cannot really grow cotton because of the higher groundwater table. The percentage of cultivated area under major crops in the sample watercourses is presented in table 3.6 (a and b). One of the reasons for the high percentage of sugarcane cultivation in three of the selected watercourses is that these watercourses are close to the sugar mill making it easier for farmers to sell their produce.

In the watercourses along Mahmood distributary the percentage of area under sugarcane is even higher than the percentage of area cultivated under wheat that is considered the main *rabi* crop of this climatic zone. Moreover in *kharif* rice is the second biggest crop along the head watercourse of Mahmood distributary. This is a clear indication that water availability is not a limiting factor for the farmers having land along this distributary. Whereas, looking at the watercourses along Fordwah distributary, the percentage of area cultivated under sugarcane decreases along the distributary. Wheat, on the other hand covers more than fifty percent of total cultivated area in all the selected watercourses along the Fordwah distributary. In *kharif*, cotton is the main crop whereas there is hardly any rice along this distributary. Rice, in the selected watercourses of Fordwah distributary, is grown mostly for domestic consumption.

Table 3.6a: Cultivated area under major crops in six selected watercourses in *rabi* 1996-97 and *rabi* 1997-98. *Rabi* 96 and *Rabi* 98 refer to the seasons *rabi* 1996-97 and *rabi* 1997-98 respectively

Watercourse	Wheat				Sugar Cane				Fodder			
	Area (ha.)		% of total cultivated area		Area (ha)		% of total cultivated area		Area (ha)		% of total cultivated area	
	Rabi 96	*Rabi* 98	*Rabi* 96	*Rabi* 98	*Rabi* 96	*Rabi* 98	*Rabi* 96	*Rabi* 98	*Rabi* 96	*Rabi* 98	*Rabi* 96	*Rabi* 98
MD 1-R	42	41	35	33	43	52	36	42	29	27	24	21
MD 11-TC	54	55	40	41	58	48	43	36	22	29	16	22
FD 38-L	16	12	52	46	9	13	30	48	3	2	10	6
FD 67-L	92	94	70	74	15	6	11	5	13	12	10	10
FD 84-L	65	68	67	74	7	2	7	2	15	13	15	14
FD 96-R	30	35	49	57	0.5	0.1	0.8	0.2	17	15	28	24

Table 3.6b: Cultivated area under major crops six selected watercourses in *kharif* 1997

Watercourse	Cotton		Sugar Cane		Rice		Fodder	
	Area (ha)	% of total cultivated area	Area (ha)	% of total cultivated area	Area (ha)	% of total cultivated area	Area (ha)	% of total cultivated area
MD 1-R	4	3	49	44	43	39	14	13
MD 11-TC	22	17	72	57	11	4	27	21
FD 38-L	9	32	16	56	0	0	2	8
FD 67-L	72	64	15	13	5	4	11	10
FD 84-L	65	68	7	7	0.2	0.2	16	17
FD 96-R	28	56	0.5	1	0	0	15	31

3.4.2 Cropping Intensities

The system was designed for 80% annual cropping intensity – (Cropped area/Cultuturable Command Area)*100 - with 32 % in *rabi* and 48 % in *kharif.* Design engineers envisaged lower cropping intensity in *rabi* as compared to *kharif*, which is not the case at present. The cropping intensities have increased tremendously mainly because of need for more food and income due to an increase in the population and more commercial activity. Only 4 % of the total population of farmers in the selected watercourses cultivate one crop in a year leaving the farm completely fallow for one full season. The cropping intensities of the watercourses studied are presented in table 3.7. Besides considerable increase in the annual land cultivated as compared to design cultivated area (60 to 90 % of CCA rather than 32 % in *rabi* and 48 % in *kharif*), farmers generally cultivate more area in *rabi* than in *kharif* mainly because of the lower water requirement in *rabi*[40]. The lowest cropping intensity is in the smallest watercourse (in terms of area and number of farmers both) FD 38-L. Some of the land for which water was allocated cannot be used for cultivation because of the high degree of salt in the soil. In the remaining watercourses, annual cropping intensities are twice the design cropping intensities.

[40] Though in non-perennial distributaries the cropping intensity in *kharif* is still higher than the cropping intensity in *rabi* since they only get canal water supply in *kharif.*

Table 3.7: Cropping Intensities of the sample watercourses during the study period (*rabi* 1997, *kharif* 1997 and *rabi* 1997-98)

Watercourse	Cropped Area (hectares)			Cropping Intensity (%)		
	Rabi 1996-97	*Kharif* 1997	*Rabi* 1997-98	*Rabi* 1996-97	*Kharif* 1997	*Rabi* 1997-98
MD 1-R	121	111	125	85	78	88
MD 11-TC	136	127	133	82	76	80
FD 38-L	30	28	26	70	67	62
FD 67-L	132	112	127	85	71	82
FD 84-L	97	95	91	91	89	85
FD 96-R	61	49	62	89	72	90

3.4.3 Irrigation Water Demand and Water Supply in the Selected Watercourses: Matching Supply with the Demand

The annual potential evapotranspiration of the selected watercourses was 1787 mm for the year April 1997 to April 1998 (two agricultural seasons, *kharif* 1997 and *rabi* 1997-98), whereas rainfall in this period was 302 mm[41]. This shows the great need for irrigation in the area. Irrigation water requirements was calculated using software CROPWAT 4.0 for windows. Figure 3.8 a and 3.8 b present irrigation water requirements and conjunctive water use at the farm-gate in selected watercourses of the study area. On the supply side conveyance losses for every watercourse were deducted from the total canal water supply. Rainfall is deducted from the demand. The canal water supply situation was very bad in *kharif* 1997 that is also shown by high amount of groundwater use, yet the gap between the supply and demand is still enormous. MD 11-TC has highest deficit, 312 mm, whereas FD 84-L has the least deficit, 97 mm, because of high groundwater use and lower water demand. In this watercourse farmers are managing demand very well by keeping it low: they are growing crops with relatively less water requirement. The gap between demand and supply is less in *rabi* 1997-98 for all the selected watercourses.

The Relative Irrigation Supply (RIS), which is the ratio between the irrigation water supply and irrigation water demand (Perry, 1996) of canal water and conjunctive water use, is separately estimated for all the selected watercourses. The values presented in table 3.7 reveal that the demand for canal water for irrigation was much higher however, the gap between demand and supply was decreased tremendously with the use of groundwater in *kharif* 1997. For example RIS improved from 0.24 to 0.86 in case of FD 84-L. In *Rabi* 1997-98 RIS is much better even with use of only canal water, it is more than 0.5 for all the watercourses. This also suggests that the groundwater was the major contributor in achieving reasonable levels of RIS in all the watercourses. In FD 38-L and MD 11-TC RIS is even greater than 1. RIS with conjunctive water use is higher than 1 for all the selected watercourses in *rabi* 1997-98. These patterns are analysed further in chapter 6.

[41] Data used to calculate evapotranspiration was obtained from Meteorological stations located in Bahawalpur (about 90 kilometers West from the field area) and Bahawalnagar (about 40 kms East of study area). Rainfall was measured with rain gauges in all six selected watercourses and then the average of each month is taken and summed up for a year. This year rain in the area was much higher than the normal rainfall. Farmers and researchers both observed that in the year 1997 it rained more than the usual.

Table 3.8: Relative Irrigation Supply (RIS) of six selected watercourses in *kharif* 1997 and *rabi* 1997-98. RIS is calculated for both canal water supply only and total irrigation (canal + ground) water

Watercourse	RIS in *kharif* 1997		RIS in *rabi* 1997-98	
	Canal water	Conjunctive use	Canal water	Conjunctive use
MD 1-R	0.51	0.92	0.88	1.05
MD 11-TC	0.57	0.68	1.22	1.29
FD 38-L	0.41	0.71	1.37	1.37
FD 67-L	0.29	0.72	0.75	1.06
FD 84-L	0.24	0.86	0.50	1.04
FD 96-R	0.36	0.86	0.72	1.16

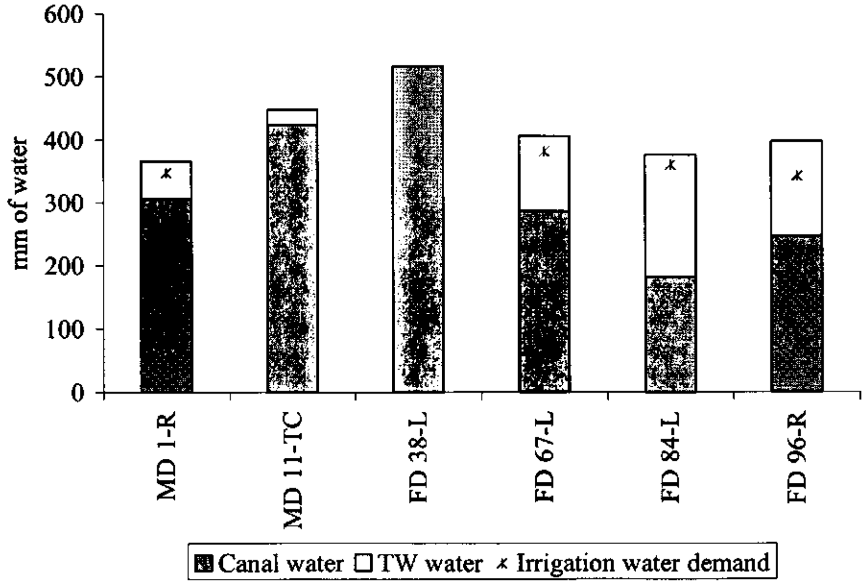

Figure 3.7a: Irrigation water requirement and conjunctive use of canal and groundwater for *kharif* 1997 in the six selected watercourses

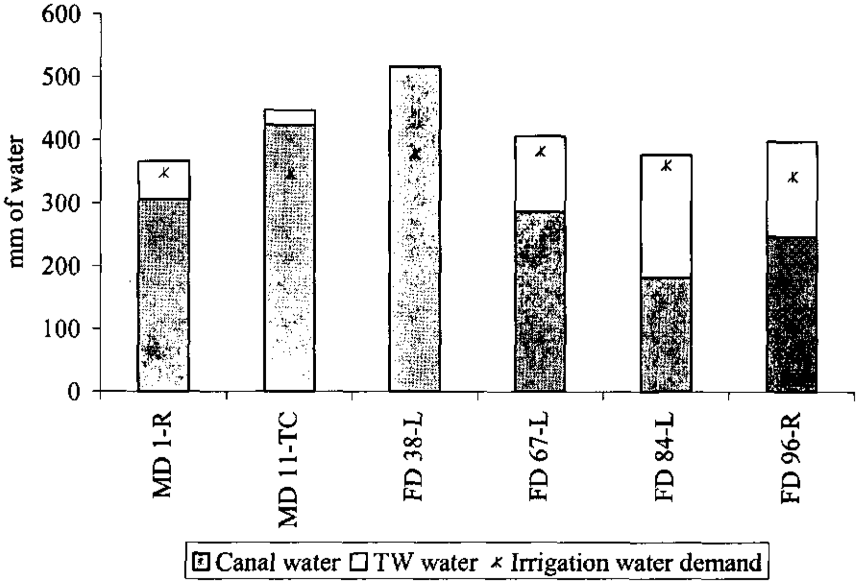

Figure 3.7b: Irrigation water requirement and conjunctive use of canal and groundwater for *rabi* 1997-98 in the six selected watercourses

3.4.4 Yield

The crop yield for every farmer in the selected watercourse has been obtained through interviews at the end of every season studied (see table 3.9). Average yields of wheat and sugarcane in the selected watercourses are in line with the average yield for Punjab, published by Government of Pakistan (1999). The average yield of cotton in the selected watercourses is significantly lower than the average yield of Punjab. This may be the impact of bad canal water supply during *kharif* 1997. The yield of rice is higher in the selected watercourses than for Punjab, which may be taken as the indication of better irrigation services - however use of groundwater played a vital role in achieving these yields. Wheat as a major *rabi* crop in the area was very good mainly because of the adequate canal water supply. In *rabi* 1997-98, canal water supply to all the watercourses was quite good (DPR ranged from 0.82 for FD 84-L to 1.47 for MD 11-TC). During *kharif* 1997 it was best for MD 1-R, which has the highest yield for rice.

Table 3.9: Yield of major crops in six selected watercourses

Watercourse	Average watercourse yield in tons/ha.			
	Wheat	Sugarcane	Cotton	Rice
MD 1-R	2.3	45	1.1	3.0
MD 11-TC	2.0	34	0.9	2.7
FD 38-L	2.4	55	1.0	
FD 67-L	2.0		1.1	2.2
FD 84-L	2.5		0.8	
FD 96-R	2.6		0.8	
Average	2.3	44.6	0.95	2.6
Punjab	2.3	40	1.5	1.4

3.4.5 Soil and Water Quality

The soils in the selected watercourses are moderately coarse and coarse in texture. The watercourses along the Mahmood distributary (MD 1-R and MD 11-TC) have more of moderately coarse soils. Whereas, coarse soils are found more in the watercourses FD 67-L and FD 96-R. According to Doorenbos and Kassam (1979) a variety of crops (including wheat, cotton, rice, sugarcane, potatoes, water melon, etc) could be cultivated on these kind of soils. However, the level of salinity and sodicity can significantly effect the yield of these crops. Cotton is tolerant, while sugarcane, wheat and potatoes are moderately tolerant to soil salinity (Doorenbos and Kassam, 1979).

Kuper (1997) has described a gradual decrease in moderately and severely salinity affected areas in the Chishtian sub-division[42] through appropriate measures taken by farmers. Strosser (1997) gave the salinity affected area as 10 % of the CCA (Strosser, 1997). The sodification of the soils resulting from the increased use of marginal quality groundwater may completely damage the soils so much so that they cannot be reclaimed any more (Strosser, 1997). However in the selected watercourse FD 38-L farmers have lost about 10 % of the total CCA because of soil degradation resulting from salinity and sodicity problems. However in other watercourses these problems have not yet cost any valuable agricultural land. Farmers take a range of water management and other actions as salinity and sodicity control measures (Kielen, 1996; Kuper, 1997). Some of these water management actions include maximum use of canal water for irrigation, blending tubewell and canal water, and a large pre-irrigation (*rouni*) for leaching. The use of gypsum is also very common for salinity control.

The quality of groundwater in the study area is highly variable - it is often saline with relatively high concentrations of sodium and bicarbonates (Kuper, 1997)[43]. The selected watercourses along the Mahmood distributary generally have better quality groundwater, with the average EC of 1.1 dS/m, since this was the old riverbed of the River Sutlej. The average EC of groundwater in the selected watercourses along the Fordwah distributary is a bit higher, which is 1.6 dS/m[44]. Recent studies (Kuper 1997, Kielen 1996, Hoeberichts 1996) have shown that farmers of the study area are well aware of the problems caused by the use of marginal quality groundwater and have their own indicators and criteria to judge the quality of groundwater[45]. Some farmers in the selected watercourses of Fordwah distributary complained about the poor groundwater quality. Water from a few tubewells in the Fordwah selected watercourses was found unfit for irrigation (see section 5.2).

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[42] The selected watercourses of the current study are part of the Chishtian Sub-division. This statement of Kuper (1997) is based on the results of series of surveys conducted by some Government agencies (including Water and Power Development Authority, WAPDA). The salinity was determined through visual observations. The total non-saline area found in the survey conducted in 1978 was increased to about 80 % from 55 % non-saline area found in the survey conducted in 1960.

[43] Kuper (1997) studied the irrigation management strategies for improved salinity and sodicity control. Sample from 500 tubewells of the Chishtian sub-division were analysed under the study. The water was tested for three indicators - *electrical conductivity* (EC); *sodium adsorption ratio* (SAR); and *residual sodium carbonates* (RSC). The average EC of the of the pumped water was 1.1 dS/m, average SAR was 3.8 $(mmol/l)^{0.5}$, and average RSC was 0.4 meq/l.

[44] The highest average EC was found for the watercourses FD 96-R, with an average value of 1.9 dS/m. According to the water quality criteria used by WAPDA it is of marginal quality.

[45] Kuper (1997) has even shown that the criteria used by the farmers (based on their perception) to judge tubewell water quality is stricter than the classification of WAPDA (based on laboratory measurements).

3.5 CONCLUSION

This chapter described the 'Water Delivery Environment' of the selected watercourses looking at their water supply, water technology, agrarian conditions and irrigation outcomes. Some basic performance indicators were also calculated to show the level of functionality of the system. The monitoring of tail gauges of the Fordwah distributary showed that it is dysfunctional even from the Irrigation Department's criteria of monitoring of water supply, whereas Mahmood distributary is privileged with good water supply. While for more than half of the time, during the study period, the tail of the Fordwah distributary did not receive any canal water. The water level at the tail of the Mahmood distributary was more than double its design water level.

Discharge to the watercourses is highly variable and not matching the respective design discharges: the overall average DPR of the Mahmood watercourses during the study period was greater than 1, whereas it was less than 1 for the sample watercourses along the Fordwah distributary.

The cropping intensities of the watercourses are more than double the design cropping intensities, that is a major cause for acquiring additional irrigation water. This additional water has to come either from exploiting the groundwater resources or by higher discharge in the whole distributary. The former is a more common way of water acquisition in the Fordwah distributary and the latter is more common in the Mahmood distributary. High water demanding crops, rice and sugarcane, are grown in three of the selected watercourses, two watercourses along the Mahmood distributary and one, FD 38-L, along the Fordwah distributary.

The research site is transforming through population growth, and urban employment. Off-farm activities and markets shape production and market choices as well as water supply. However despite these changes some social institutions like *Panchayat* abide.

It was also shown that even in a dysfunctional system, farmers manage to get reasonable yields of the major crops. However, the yield of the high water demanding crops, sugarcane and rice, was better for the watercourses with relatively better canal water supply. The following chapters will explore in detail the way farmers manage water scarcity and water abundance to achieve this production and yields.

4 COLLECTIVE EFFORTS TO CHANGE THE WATER DELIVERY

Premeditated water scarcity of protective irrigation supply in the large irrigation systems of Pakistan, together with the increased cropping intensity and unreliable irrigation water supply has resulted in efforts by farmers to acquire more water for irrigation and hence increase control over irrigation water. Farmers on the one hand make individual efforts like installing tubewells to improve adequacy and timely availability of water and on the other hand make collective efforts to maintain watercourse and to increase amount of surface water for irrigation. This chapter deals with the water management activities that are organised and performed collectively at watercourse level. These activities are identified and their organisational arrangements are discussed. Factors influencing collective action for water management in the selected watercourses are identified and discussed in the conclusions. The relative impact of these actions on water availability is presented in chapter 6.

At the start of the research no distinction was made in terms of activities undertaken at different levels of organisation. However, with the time spent in the study area it was learnt that two water management activities, water acquisition and watercourse maintenance are the most important as far as collective action is concerned. The actions[1] undertaken under these activities are:

- Water acquisition: acquiring more water for all shareholders in the watercourse command area by: (i) lobbying for increase in discharge, (ii) physical interventions, and (iii) institutional arbitration
- Watercourse maintenance: keeping the geometry of the watercourse in good shape by desilting of the main watercourse and other maintenance work.
- Other actions to improve water availability and to reduce 'hassle' in irrigation, like (i) relocating infrastructure, (ii) lining of the main watercourse.

In this research these activities are assumed to be effective and having an influence on the water delivery environment of the watercourse command area.

4.1 WATER ACQUISITION: ACQUIRING MORE WATER FOR ALL SHARE HOLDERS IN THE WATERCOURSE COMMAND AREA

Additional water for irrigation could be acquired from two sources, ground or canal water. Groundwater is mainly an individual strategy to increase flexibility in amount and timing of water use. Canal water is more difficult for an individual farmer to acquire hence collective action is preferred. Farmers either intervene with the system physically for short- term benefit or try to institutionalise their physical interventions for relatively long-term gains.

[1] Mollinga (1998) also found similar kind of actions regarding water acquisition in Tungabadra canal irrigation system in South India.

4.1.1 Lobbying for an Increase in Discharge

Farmers try to contact Irrigation Department (ID) staff of different levels (including XEN, SDO and Gauge Reader) collectively to complain about the shortage of surface irrigation water and to request an increase in the discharge of their distributary. Since the outlets are ungated, farmers can only request for an increase in discharge of the distributary. The staff visited depends on the nature of the complaint or request to be made. For example, requests regarding the increase of discharge or *mogha* dimensions are made to the SDO or Sub-Engineer and requests regarding the increase of discharge in the distributary are made very often to the Gauge Reader. However generally the efforts made to get higher discharge in the distributary are from farmers having land along a smaller distributary. Most often influential farmers or farmers with better negotiating abilities would go on these so-called 'missions'. These negotiators may also be influential persons, who are involved in the local politics and have contacts with the Members of Provincial Assembly (MPA).

Sometimes farmers seek the help of MPA(s) of their area to lobby for increased water supply to their distributary. To arrange additional water, an MPA usually talks to the senior staff of the ID (XEN or SDO level). Sometimes he (MPA) also tries to order junior staff in the ID (Gauge Reader, Sub-Engineer). Junior irrigation staff obey the orders of an MPA to save their own jobs or to please him to get some benefits later on. However doing so can also put their jobs at stake sometimes (see Box 4.1).

4.1.2 Physical Interventions

Usually physical interventions are illicit practices and include a certain risk factor in undertaking them: that may also be one reason why farmers perform this activity collectively. Actions taken to intervene physically with the system are also based on the urgency of the matter. For instance, collective action is organised quickly in response to sudden decrease in water supply as a result of change in strategies of operational management of the ID. Box 4.1 also outlines the actions taken by the farmers of the Mahmood distributary during July 1997 and August 1997 to collectively acquire their perceived right of water. This could also be regarded as successful collective action that is possible in the case of a smaller distributary. However, this successful collective action still means less supply of surface water to some of the watercourses in other distributaries and problems for some of the ID staff in fulfilling their duties. Farmers physically intervene with the system at two levels, distributary level and watercourse level. At the distributary level physical action is pursued through the Gauge Reader by putting pressure on him to increase the discharge in the distributary and thus the watercourse. Whereas at watercourse level it is more direct physical intervention by tampering with the *mogha.*

Box 4.1: Collective action for water acquisition in response to the decreased surface water supply in the Mahmood distributary

Farmers at the tail of the Azim distributary, one of three tail distributaries of the Fordwah branch canal, have not received any water since a long time, because big landowners take all the canal water by force. These farmers have been trying to get some canal water. Finally they decided to talk to the Member of Provincial Assembly (MPA) this time. The MPA complained about this water scarce situation to the Prime Minister (PM) who visited the area in the third week of July 1997. The Prime Minister, some ID officials and the Provincial minister of Agriculture witnessed a cut in the distributary. The PM ordered to arrest the culprit and suspended the whole Irrigation staff of the circle, except an Executive Engineer (XEN) recently transferred to this area. In response to the Prime Minister's visit the ID's staff became very careful and took some measures to deliver water to the tail of the distributaries. One of the actions they took was to downsize the *moghas* to their design dimensions. Another measure was to decrease the discharge of the Mahmood distributary, since it was much higher than its design share. Farmers along the Mahmood distributary, who were used to receive abundant water, got extremely angry with the ID and threatened to kill the Sub-Engineer who they thought was responsible for the decrease in discharge. Shareholders from the different watercourses reacted differently as discussed below.

Watercourse MD 1-R

Direct physical intervention: Tampering with the mogha

Sharecroppers of watercourse MD 1-R were used to get on average 60 % higher discharge than its design share before the visit of the Prime Minister in *kharif* 1997. This privilege of plentiful water was considered a right by these farmers, who had received this for many years. After the visit of the Prime Minister, who also clearly instructed the ID staff to provide water to the tail end farmers in the system, the ID staff tried to keep the discharges of the distributaries to their design share. As a result discharge to the Mahmood distributary was reduced. Water users of the watercourse MD 1-R got angry at this intervention of ID and tampered with the *mogha*, by breaking bricks thus creating a hole in the wall of *mogha* on one side, in the third week of August 1997. The ID repaired this within a few days, but the new *mogha* was now downsized, which was not acceptable to farmers since the water supply was not enough to irrigate rice and sugarcane. Therefore the farmers again broke the wall. This time the ID made a compromise and the dimensions of the *mogha* were increased as compared to the one in the normal conditions. The height of the opening was increased by 2.7 %; the width was not increased though. However, the discharge of the *mogha* still decreased by 30 % because of the total reduction in the discharge of the distributary. The *mogha* would have drawn 2 % less than the present discharge if the height of the *mogha* (Y) had not been increased.

Tail clusters of Mahmood distributary

Lobbying for increased water supply

Shareholders from the tail cluster of watercourses went to the Gauge Reader first to get more water into the distributary since tampering with the *mogha* would not have solved their problem (their *moghas* are at the ultimate tail of the distributary). The Gauge Reader was instructed not to leave more water than the design in Mahmood distributary hence he refused to increase the discharge and explained the situation to the farmers. The farmers got angry with him and went to the MPA of the area and complained about the Gauge Reader's refusal. The MPA summoned the Gauge Reader and asked him to entertain the request of farmers, he also gave his visiting card to the Gauge Reader and said he would talk to the officers himself. The Gauge Reader came back and increased the discharge to Mahmood distributary. The XEN of the zone visited the site and found that the discharge to the Mahmood distributary was much higher than its design. He got angry with the Gauge Reader and suspended him. The Gauge Reader was still suspended by the end of this research period.

4.1.3 Tampering with the *Mogha*

Farmers tamper with the *mogha* by making a hole in the sidewall of the *mogha* to increase the discharge for the whole watercourse command area. This is mainly done in the *kharif* season when demand for irrigation water is at its peak. The *mogha* may have been tampered with by only one or a number of farmers but the plan of action is discussed and agreed upon by all the farmers. Once a *mogha* is tampered with by farmers(s) it is usually not repaired before the canal closure. Therefore if farmers undertake this action during the start of the year (after January) or at the start of *kharif* season (after April), they can use the large flow for the rest of the year until beginning of January. The farmers do have to pay[2] the fine for damaging the *mogha* but when divided among the shareholders this is minimal as compared to the benefit they get with the additional water. Sometimes this action is even taken in consultation with the ID officials (SDO according to many farmers). In addition to this penalty, farmers also have to pay some money to the officer consulted[3]. But in this case the penalty is not high since the amount of penalty depends on the officer[4].

During the whole study period only one *mogha* (*mogha* type OFRB) of the watercourse MD 1-R was tampered with by the farmers (see box 4.1 for details). Another *mogha* (*mogha* type: APM) was tampered with and replaced just before the data collection was started[5]. Shareholders of the Watercourse FD 67-L are very well organised in undertaking this action for acquiring additional canal water. They have been doing it time and time again in the past and do not hesitate to undertake it.

4.1.4 Institutional Arbitration

Remodelling the outlet: Change in mogha dimension

A more sustainable way to acquire additional canal water is to get the dimensions of the *mogha* enlarged. This can only be done with the help of the ID officials. Therefore farmers have to first discuss the situation among themselves, then negotiate with the ID and then collect some funds to pay for the so-called service provided by the Department. The ID staff contacted for this reason depends on the ease with which the farmers could approach them. For instance if a farmer has a relative or a friend who is a higher level officer (SDO or XEN) he would rather directly talk to him. Nevertheless most often a Sub-Engineer is the contact person for these kinds of arrangements since he is responsible for checking the dimensions of the outlet and construction work in the field. One of the duties of a Sub-Engineer is to

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[2] According to the Canal and Drainage Act the Divisional Canal officer is, after holding an inquiry, responsible for levying charges according to the rules. Section 33 of Canal and Drainage Act 1873 (Nasir, 1993) substituted by the Punjab (Amendment) Act XXXII of 1975, '*.....provided that where the water so used has been supplied through a watercourse, the charges shall be levied: from the person by whose act or neglect such use has taken place, or if such person cannot be identified, from the person on whose land the water has flowed and such land has derived benefit therefrom; or if such person cannot be identified or the land on which the water has derived no benefit there from, from all persons chargeable in respect of the water supplied through such watercourse*'.

[3] Farmers usually consult the Sub-Engineer or the SDO.

[4] The penalty could be from three to six times of the water tax (*abiana*) of the crops irrigated from the stolen water. In the case of involvement of all the farmers in tampering with the *mogha*, total *abiana* for the watercourse is considered since all the farmers have benefited from this intervention and all the crops are irrigated with this additional water (Canal and Drainage Act, 1873).

[5] According to the Check Outlet Statement of Hasilpur section for the year 1997-98, 29 out of 88 outlets (about 33 %) along the Fordwah distributary differ significantly from their design dimensions:

- Out of these 29 outlets 15 are APM, 10 are OFRB and 4 are pipe outlets.
- 10 of these outlets lie in the head reach, 10 in the middle reach and 9 in the tail reach of the distributary.

periodically check[6] and record the outlet dimensions and the working head of the outlet in a register called the 'H-Register'. Particularly when a Sub-Engineer is transferred to an area, he has to check all the outlets in the distributary (or a section of a distributary) for which he is responsible and prepare a statement called 'check outlet statement'. *Moghas* are downsized and brought back to their original design dimensions if they deviate from design data. This makes farmers always suspicious about the motives of new Sub-Engineers transferred to the area for checking the *mogha* dimensions. They fear that the Sub-Engineer wants to get some money and that they check the outlets for personal gains and not because of their duty[7].

In the selected watercourses one of the *moghas* had enlarged dimensions at the start of the research, while the dimensions of the rest of the *moghas* were approximately according to their design. The watercourses along the Mahmood distributary and watercourse FD 38-L were not enlarged because of good canal water supply. Watercourse FD 67-L was downsized and repaired just before the research started. Watercourse FD 84-L was not enlarged because of lack of consensus among the shareholders over collecting funds. Nevertheless towards the end of the data collection, the dimensions of FD 67-L and MD 1-R were also changed. MD 1-R has already been dealt with in section 4.1.1 whereas FD 67-L is discussed later in this section.

The *mogha* of the watercourse FD 96-R was enlarged about one year before the start of the current study. Farmers decided to have this change and discussed it with the Sub-Engineer of the area who was willing to help them but also charged money for the service he provided. Farmers paid Rs 16000/US$ 400 in total. The width of the outlet, B, was increased by 10% and the height of the opening, Y was increased by 10.5 % with an overall increase in area of 21.6 %. This intervention resulted in an increase of average daily water supply to the watercourse of 20 %. Figure 4.1 shows the difference between the discharges calculated using the design[8] dimensions and actual dimensions of the outlet FD 96-R. Although the variability in the water supply would have remained the same, the total amount of water delivered to this watercourse has substantially increased because of the increased *mogha* dimensions. A rough estimate reveals that farmers would have to spend Rs. 48000 (US$1200)[9] in order to pump the same amount of water for one year (from December 1997 to December 1998). This estimate was made using a tubewell with a discharge of approximately 19.5 l/s and the price to pump water for one hour as Rs 40 (about US$ 1) that is commonly used in this watercourse. Therefore farmers together saved about Rs 32000 (US$ 800) in one year[10].

[6] Although, in practice this duty is not performed periodically, only when a Sub-Engineer is transferred in does he prepares a check statement.

[7] In fact, to some extent farmers are justified to doubt the motives of the Sub-Engineer (see footnote 28).

[8] The discharge is calculated using the design dimensions but actual water level in the distributary, to get an idea of the discharge in case the *mogha* was not enlarged.

[9] The conversion rate of US dollar to Pakistani Rupee was 40 Rs. to a dollar in January 1997, which dropped to 44 Rs to a US dollar in January 1998. The conversion rate used in this thesis is 40 Rs to a Dollar to keep the comparison simple.

[10] Since the *mogha* was not downsized to its design dimensions for more than two years, the benefit is even higher.

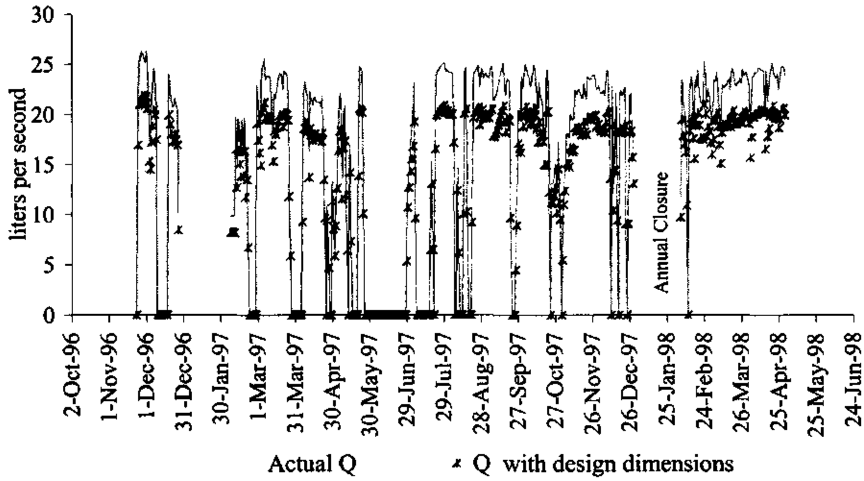

Figure 4.1: Daily discharges (Q) of FD 96-R with design dimensions and actual dimensions of the outlet (November 1996 to November 1998)

Water users in the watercourse FD 67-L were receiving only 50 % of the design discharge and were not happy with the situation. They were talking about tampering with the *mogha* and getting the size of the *mogha* enlarged. However, after the Prime Minister's visit when the new Sub-Engineer was transferred to the area, he checked all the outlets and downsized those with bigger dimensions than their design, and upgraded the ones that were smaller than the design. According to farmers, one day the Sub-Engineer changed their *mogha* as well. They thought it was downsized and therefore became very angry. They also asked about this change to the Sub-Engineer who told them to wait and see. The Sub-Engineer said that the change was for the good and that it would have positive impact on water delivery. The area of the orifice was increased by about 5 % with 9.5 % increase in the width, B, and 4.1 % decrease in height, Y, of the *mogha*. This increased the discharge by about 8 % provided that there was water in the distributary. Figure 4.2 shows the actual discharge and the discharge if the *mogha* had not been enlarged. Farmers were not satisfied with this increase of the discharge and were talking about getting the *mogha* enlarged for next year if canal water supply does not improve.

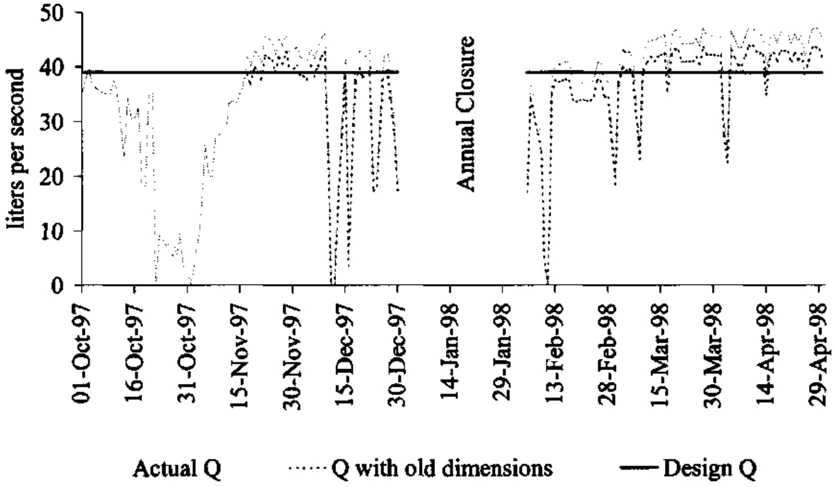

Figure 4.2: Daily discharges (Q) of the watercourse FD 67-L for both new and old APM outlet (October 1997-April 1998)

Inclusion of more command area to increase the discharge

If the watercourse command area is increased by 10% of its existing command area the outlet has to be enlarged in order to supply the water allowance. The delivery time in minutes per acre is reduced however. Assume a watercourse with a CCA of 300 acres (121.5 ha.) that has 50 farmers and a design discharge of 1.08 ft^3/s (30.6 l/s). The irrigation time per acre will roughly be 33 minutes per acre. If the CCA of such a watercourse is increased by 10 % and becomes 330 acres, the design discharge will be increased to 1.19 ft^3/s (33.7 l/s) but the time to irrigate one acre will decrease to about 30 minutes per acre. However, with a stable discharge the depth of water supply over a given period will remain the same. According to farmers, in the past when the water supply was still reasonably reliable the strategy to increase the command area of the watercourse in order to increase discharge capacity of the *mogha* was adopted. However now farmers do not go for this option. Box 4.2 shows lack of agreement on increasing the watercourse command area since some of the shareholders perceived it as loss of water as a result of less time available for irrigation. This also shows the distrust of the farmers with regard to the services provided by the ID. Collective decision was not taken as the proposed change may have negative impact for some farmers

Box 4.2: Resistance to the acquisition of water by increasing the command area of the watercourse

An ex *Patwari*, OID 43, has land in two adjacent watercourses FD 67-L and FD 68-L. It is difficult for him to irrigate his land in the tail section of watercourse FD 68-L because of some physical constraints: slope of the watercourse at the tail section was minimal. Therefore he wanted to include that part (36 acres or approximately 15 ha) in the command area of the watercourse FD 67-L from where his land is accessible for irrigation. To shift some area from one watercourse to the other he had to take shareholders of the potential increased watercourse command area into confidence so that they do not object when asked by the ID. Officially he has to make a request for the change in the source of the canal water supply to the ID official, who will visit the area and inquire among other farmers about their views on inclusion of the new area. Hence the ex *Patwari* had to discuss this issue with other shareholders. He asked for a *Panchayat* a few times and tried to convince fellow shareholders that this inclusion of 10 % more area would also result in an increase of the discharge capacity of the outlet by 10 %. According to rules if 10 % of the total command area is increased the outlet has to be remodelled and discharge is increased. The *numberdar* of their village who is living a bit farther along another distributary and is considered a respectable person also joined the meetings once and gave arguments in favour of the ex *Patwari* but it did not work. The argument against this change put forward by a number of shareholders was the reduction in irrigation time in terms of minutes per acre. Some of the farmers said that they had already lost 3 minutes per acre as result of increase in the command area at different times in past: this time 6 more minutes had to be deducted, which was not acceptable. The canal water supply is fluctuating and the discharge is not guaranteed, which could result in a smaller volume of canal water per unit area. The *Patwari* told the farmers that he would get this change made one way or the other because he has good contacts with the ID people. However, by the time fieldwork for this research was completed nothing had happened; some farmers were still opposing the increase in command area while some others were convinced that the change would not reduce total quantity of water per unit of area.

4.2 WATERCOURSE MAINTENANCE: KEEPING GEOMETRY OF THE WATERCOURSE IN GOOD SHAPE TO REDUCE LOSSES

The watercourse is of vital importance to the farmers since it carries water from the source - that is the *mogha* in this case - to the individual field. If it is in bad shape conveyance losses are higher and precious water is lost. Conveyance losses are much greater in the unlined watercourse as compared to the lined watercourse, between 30 to 40 % of water entering the unlined watercourse is lost in conveyance (Trout, 1979). Thus maintaining watercourse in good shape is as good as acquiring additional water for irrigation.

Farmers are responsible to maintain watercourses. The Canal and Drainage Act of 1873 (Nasir, 1993) states "*The Government is not responsible for the maintenance of the watercourse, but that is the responsibility of those who use it, whether on existing Government, or private land.*" The ID can only interfere and take action if they consider that farmers are not keeping the watercourse in good shape, such that it is causing water loss. In this case the ID can stop water supply to the watercourse until the watercourse is improved. However, it had never happened in the sample watercourses.

Watercourse maintenance includes desilting or cleaning of the watercourse, repair of the watercourse banks, repair and installation of *nakkas* and construction and repair of culverts. Desilting is done periodically and the rest is done once in a while. Farmers consider desilting as one of the most important water management activities since it requires resource mobilisation in the form of labour - and it is hard work. Cleaning or desilting includes removal of weeds and sediment from the bed and the banks of the watercourse and strengthening of the watercourse banks. In the lined watercourses with a good slope, less sediment is deposited and thus these tasks become relatively easier (De Klein and Wahaj, 1998). Sometimes when farmers start irrigation, and patrol along the watercourse, they remove some hindrances. That is also a kind of watercourse cleaning, but farmers do not really regard it as such. Moreover it is not done in planned or organised way and to keep track of this kind of activity is also difficult: therefore it is not dealt with in depth in this thesis. In some cases farmers also desilt the distributary. Box 4.3 describes some of the processes of collective action for desilting of the distributary.

4.2.1 Farmers Perception on Frequency of Desilting of the Watercourses

Farmers have an idea of the number of times that a watercourse should be desilted during a year - which they do not always follow. In the current research, farmers were asked about their perception of required frequency of the desilting activities in each of the selected watercourses. Later, the number of actual desiltings was monitored and thus 'deferred maintenance' was calculated as the difference between the ideal and the actual number of desiltings. Table 4.1 presents the desilting events that happened during the study period in the selected watercourses. The timing and the number of the actual desiltings were different for all the watercourses. The need to maintain - or more precisely to desilt - the main watercourse seem to be better met in the watercourses along the Fordwah distributary as compared to the Mahmood distributary (see table 4.2). Farmers of the Fordwah watercourses seem to be more practical in assessing the need to desilt the watercourse[11]. Several reasons were explored for the differences. The first is the better water supply in terms of DPR. The second was the number of water users. The water supply to the watercourses along the Mahmood distributary was better than to the watercourses along the Fordwah distributary; therefore the need to desilt the watercourse to improve water availability at the middle and tail reaches was less strong than for the Fordwah watercourses. Moreover, these sample watercourses (along the Mahmood distributary) were desilted at the time of peak water requirement. A relationship between the deferred maintenance and canal water delivery and deferred maintenance and number of shareholders in a watercourse command area was tested. The correlation between the deferred maintenance and the number of shareholders in a watercourse was stronger (R^2 = 0.71) than between the deferred maintenance and DPR (R^2 = 0.59). Figure 4.3 shows the relationship between the number of shareholders and the deferred maintenance. De Klein and Wahaj (1998) found that the number of shareholders was less than 30 in the watercourses with little or no maintenance gap. Their results were based on in-depth study of twelve watercourses in Southeastern Punjab[12].

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[11] Perhaps because farmers of the Mahmood distributary cultivate crops with high water requirement, they perceive a greater need for cleaning their watercourses than they actually perform.

[12] Six of these twelve watercourses are part of this Ph.D. study.

Box 4.3: Successful collective action for desilting of the Mahmood distributary

Desilting of the distributaries is a responsibility of the ID. Generally speaking most of the distributaries in Punjab are in bad shape in terms of maintenance. In the late 1980s farmers started desilting the distributaries in a campaign of "self help" initiated by the then Provincial Government, but it did not last long. The parts of the distributaries that need reinforcement are temporarily strengthened in case of a breach.

In the studied distributaries, the ID last carried out desilting more than ten years ago, because of the lack of funds provided by the Provincial Government. In the year 1997 part of the tail reach of Fordwah distributary was desilted. Nevertheless the Mahmood distributary is desilted by the farmers from tail clusters twice a year. This happens once in January/February during the canal closure, and a second time in June or July when a lot of sediment comes with the water and evapotranspiration is at its peak. Sometimes it gives problems to farmers upstream when done in June/July. During the canal closure there is no problem in desilting the distributary.

Farmers from three watercourses at the tail of the distributary organise for desiltings. Three persons, one shareholder from each watercourse, are responsible for organising the activity. When organised during the canal closure, date and time is first discussed among a few farmers, mostly among the *numberdar* of MD 11-TC and three other influential farmers (one from each watercourse of the tail cluster) and then communicated to other farmers. When it has to be done during the supply period (in June/July) permission to close the distributary for a day or two has to be asked from the SDO of the ID since it is not possible to desilt the distributary when it has water flowing in it. One of the leaders writes an application and gets it signed (or takes a thumb impression) by at least 15 farmers and the Sub-Engineer of the area and submits it to the SDO for approval. Afterwards the time and the date for desilting are announced in the Mosques by loudspeakers to inform all the farmers.

Sometimes farmers from upstream try to stop this desilting activity since the distributary has to be closed and they are not affected by the sedimentation. A few times they tried their best to get the approval to close the distributary cancelled but they did not succeed. Once they even requested the MPA of the area to interfere. The leaders who organised the activity suggested to the SDO to go to the head office, which is in another city, on the day this activity had to be performed. This way he does not have to deal with the MPA - since if an MPA asks an SDO for cancellation of the order to close the distributary he will have problems in resisting the request. The SDO took the advice and did not come to his office that day and the activity was performed successfully.

The distributary is divided in three equal parts to be cleaned by the farmers of three watercourses. One farmer from each watercourse then distributes the work according to the land holding size of the farmers. During the desilting activity farmers try to maintain a smooth slope in the distributary bed and keep distributary width as in design, which they learned form the Sub-Engineer of the area, although they do not measure it with a measuring tape.

Table 4.1: Desilting events that took place in the six sample watercourses during the study period (November 1996 to April 1998)

Month	MD 1-R	MD 11-TC	FD 38-L	FD 67-L	FD 84-L	FD 96-R 1st half	FD 96-R 2nd half
Nov-96	■						
Dec-96						■	■
Jan-97	■				■		
Feb-97		■	■				
Mar-97							
1-14 Apr-97							■
15-31 Apr-97			■			■	
May97	■	■					
Jun-97	■	■	■			■	
Jul-97					■		■
Aug-97			■			■	■
Sep-97					■	■	■
Oct-97			■				
Nov-97			■	■			
Dec-97							
Jan-98	■						
Feb-98		■	■		■		
Mar-98						■	■
1-14 Apr-98	■		■				
15-31 Apr-98							
Total	6	4	8	1	4	6	6
Per Year 15 April 97 to 15 April 98	4	3	7	1	3	5	4

Table 4.2: Gap between the watercourse desilting required and actual during one-year (two crop seasons: *kharif* 1997 and *rabi* 1997-98)

Watercourse	Required number of desilting	Actual number of Desilting[1]	Deferred maintenance[2] (%)
MD 1-R (partially lined)	9	4	55.5
MD 11-TC (partially lined)	9	3	66.6
FD 38-L	9	7	22.2
FD 67-L (almost fully lined)	0[3]	1	
FD 84-L	4	3	25.0
FD 96-R (average of the two halves)	6	5	16.6

[1] The Annual number of desilting events taken between 15 April 1997 to 15 April 1998.

[2] Deferred maintenance = ((required number of desilting-actual number of desilting)/ required number of desilting))*100

[3] This watercourse was lined two years back and since then farmers have not desilted it. Therefore farmers thought that it did not need to be desilted at all. However, later they realised that the desilting was required.

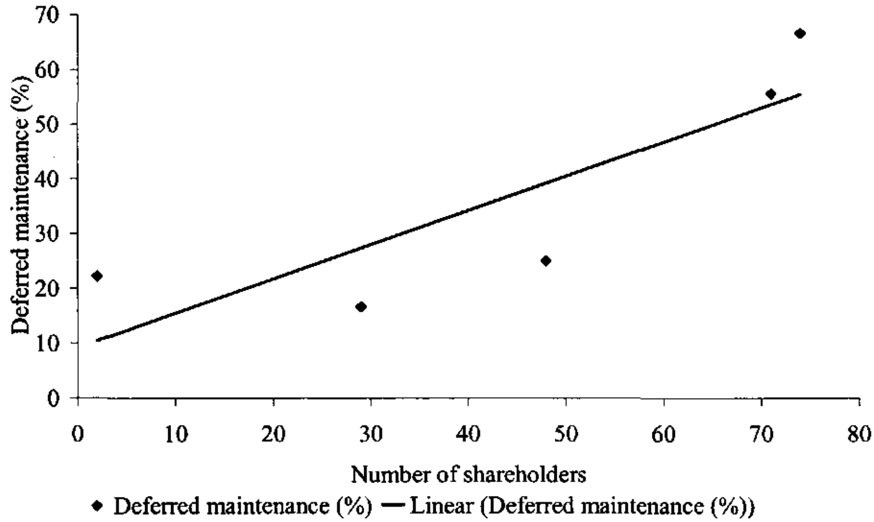

Figure 4.3: Number of shareholders and deferred maintenance in five (out of six) sample watercourses. FD 67-L was not considered for the analysis, as, after lining of the watercourse, farmers did not expect any need to desilt the watercourse

4.2.2 Why Desilt a Watercourse?

As a researcher we know that desilting of the watercourse is needed for better conveyance of irrigation water, to increase flow velocity by removing any hindrance - or technically speaking by decreasing the friction. Farmers, while they do not use technical terminology, still mentioned more or less the same reasons for watercourse desilting when asked -the improved availability of irrigation water in terms of less water loss.

Removal of weeds and silt from the watercourse results in increased velocity, smooth water flow, less water loss during conveyance (less conveyance losses) and increase in area irrigated per unit of time. Cleaning of watercourse bed and sides increases the velocity of the water by reducing friction, which saves water from overtopping and also reduces the risk of breach of *nakkas* or watercourse bunds. Hindrances at the tail of the watercourse tend to cause a breach in the *nakkas* at the head of the watercourse. Blockage of the rodent holes and bank strengthening also prevents the risk of a breach in a watercourse, and seepage through these holes, and thus saves water. It also reduces the risk of any legal conflicts with other shareholders of the watercourse. In case of a breach, the affected cultivator could go to the court against the farmer who had a water turn at the time of the damage caused[13]. Therefore to avoid such individual problems farmers collectively clean the watercourse.

The foremost impact of desilting is the increase in the area irrigated in a unit time, especially for the farmers at the tail of the watercourse. For the farmers having their land along the head of the watercourse the main reason to participate in the activity is to prevent a breach in the watercourse that happens when water is blocked.

[13] This however does not happen since apologies are made and help is extended in fixing the breach in the watercourse.

4.2.3 Indicators Used by Farmers in Organising the Desilting Activity

In some cases – as in FD 38-L – sedimentation in the watercourse causes a backwater effect and thus influences the discharge at the *mogha* by changing the flow condition from free flow to submerged flow. It is then necessary to clean the first 100 meters or so (depending on the slope of the watercourse) more often than the rest of the watercourse, in order to maintain free flow condition at the outlet. In the watercourse 67-L this situation existed before lining the watercourse. Here farmers had to clean the first 200 meters of the watercourse very frequently to maintain a free flow condition at the *mogha*.

The factors as mentioned by the farmers that are considered in deciding about the desilting of the watercourse are:

Obstruction in the flow of water

Growth of grass in the bed and the sides of the watercourse and sediment deposition obstructs water and reduces its velocity.

Overtopping

If the beds and the banks of a watercourse are not desilted water starts overtopping the banks and is lost.

Breach

A breach in the watercourse is an indication that the watercourse can not carry water properly anymore and that the watercourse has to be desilted and the banks of the watercourse have to be strengthened to prevent water loss.

Unit irrigated area during water turn

If the area irrigated during one water turn declines, it is time to clean the watercourse[14]. This indicator is a proxy for most of the indicators listed above.

Timing of the desilting activity

The main reason for organising the activity is the need of water; it needs to be saved at the time it is needed most. However, for convenience of undertaking the activity, other agrarian, physical and social factors are taken into consideration as well. The following are the practical considerations that farmers have in deciding about the timing of the desilting activity:

- It is more convenient to desilt a watercourse on the day water is used at the head of the main watercourse, since the whole watercourse is cleaned at the same time, therefore it should be empty. In case of desilting of a watercourse branch, it is done when water is flowing in the other branch.
- A watercourse could also be easily desilted when the parent canal is closed because of the rotation among the distributaries. Since the watercourse is empty and silt is already dried it is easier to remove it.
- A watercourse is often desilted just before the end of the canal closure since it is easier to desilt a dry watercourse. Besides a watercourse is used intensively immediately after the canal closure period.

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[14] Some farmers mentioned almost 100 % increase in area irrigated at the tail of the watercourse after the desilting of the watercourse.

- It is also convenient to desilt a watercourse when there are no crops in the field, for example after harvesting of wheat or cotton, since silt could be easily dumped in these empty fields.
- Desilting is postponed - or is not organised - at the time of weddings or death ceremonies since few farmers will be present.

4.3 CONVEYANCE LOSSES

The Engineers of the Colorado State University and several agencies in Pakistan conducted an intensive study of watercourse conveyance losses in 1973. The results of their study revealed that about 40% of water is lost in conveyance after entering the watercourse (Trout, 1979; Ashraf et. al, 1978; Clyma et. al., 1975). Conveyance losses of almost all the branches of all the selected watercourses were measured several times during the study period. Conveyance losses are influenced by, among other things the slope of the watercourse and the discharge at the *mogha*. Table 4.4 summarises the average conveyance losses in the branches of the selected watercourses and the slope. It is also one of the factors considered by farmers in deciding the desilting activity: however, they use different indicators to estimate the magnitude of the conveyance losses. Farmers use overtopping of the watercourse, rodents' holes and vegetation in the bed of the watercourse as main indicators to estimate the conveyance losses. One interesting observation is that the conveyance losses in the main branches of all the watercourses are very much in line with the deferred maintenance. Desilting is deferred most in the watercourse having least conveyance losses, MD 11-TC. The reason obviously is the better transport of irrigation water and hence no need to desilt it. The gap between the actual and required desilting is least in FD 84-L main watercourse, which has the highest conveyance losses.

The slope of the watercourse also has an influence on the conveyance losses since a steeper slope increases the velocity of water and therefore reduces the water loss. The design slope of the watercourses is 0.2 m to 0.25 m per 1000m for Punjab (Government of West Pakistan, 1961). The R^2 for the unlined watercourses including all the branches (in total 10) is 0.77. This indicates a relationship between the slope and the conveyance losses. Farmers have a very clear idea of the problems with the slope of watercourse. Figure 4.4 reproduces a study from the Hakra 6-R distributary along the Hakra Branch of the Eeastern Saidiqia canal by another IIMI researcher, that shows the slope of a watercourse and the areas that were considered problematic by the farmers. The match is amazingly in line; farmers knew exactly where the problem lay in term of slope even though they did not have any technical training in surveying. The spots identified by the farmers (boxes in the figure) as having problems with the slope are the same as those shown by the slope survey of the watercourse done by the trained field staff.

Table 4.3: Conveyance losses in the six sample watercourses

Watercourse, Branch	Conveyance losses (%)	Conveyance losses (%/1000 m)	Slope (m/1000m)
MD 1-R, main[1]	36	22	0.60
MD 1-R, right	51	33	0.58
MD 1-R, left[1]	48	39	0.35
MD 11-TC	28	15	0.86
FD 38-L	23	26	0.48
FD 67-L[2]	20	9[2]	0.70
FD 84-L, main	6.5[3]	11	0.54
FD 84-L, right	37	21	0.71
FD 84-L, left	45	32	0.23
FD 96-R	38	21	0.90
Average	33.7	23	0.60

[1] Partially lined watercourse

[2] Almost fully lined watercourse

[3] This is a very small reach, only 585 meters, therefore losses are very small. Moreover losses were measured soon after the desilting.

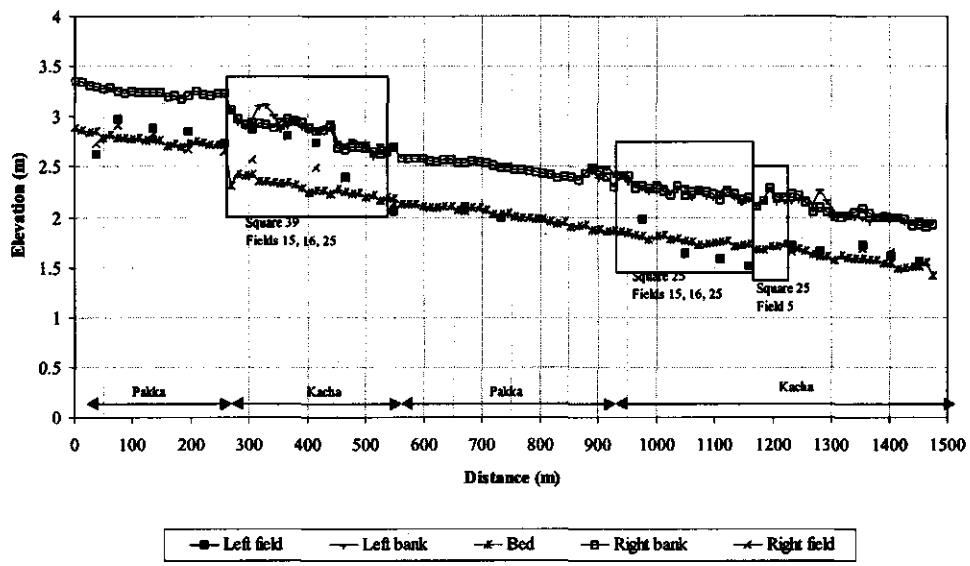

Figure 4.4: Problem areas in watercourse 101-R of the Hakra 6-R distributary, according to the farmers' and researchers' opinion

Source: De Klein and Wahaj, 1998

4.4 OTHER WATER MANAGEMENT ACTIVITIES

Apart from regular water management activities like watercourse maintenance, some other water management activities, like change in the location of the *mogha* and watercourse lining, are also undertaken by farmers collectively. These two activities are explained in the following paragraphs through examples from the study area.

4.4.1 Relocating Infrastructure

The channel of the watercourse FD 84-L has many bends in the first few hundred meters that considerably reduces the velocity of water entering the watercourse. Farmers have informally discussed this issue and came up with the solution to change the location of the *mogha*. If the *mogha* is shifted 130 meters downstream then the watercourse will become straight (see Figure 4.5). A few farmers including an ex *patwari* (of the ID) went to the ID to discuss the issue and were told by the officer concerned that it will cost them Rs. 50,000 (US$ 1250) to shift the *mogha* from its existing position to 130 meters downstream. These farmers informally discussed this issue with other shareholders. All but one agreed with the solution, although not all farmers were ready to pay a high amount of money for this change. One landowner Mr. X, having land along the first hundred meters of the watercourse, did not agree with this proposal since this change of location will not improve water supply to his farm. A shift in *mogha* location downstream will increase the conveyance time of water for this landowner. One of the farmers discussed this issue with Mr. X and promised to construct a good quality watercourse up to his land. Mr. X agreed to think about this issue. In the meantime other landowners decided to collect money, which according to some farmers is also not an easy task in this watercourse. However, money was not collected and no agreement was reached between Mr. X and rest of the farmers by the end of this research.

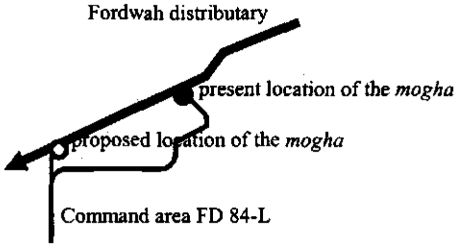

Figure 4.5: Present and proposed location of the mogha of the watercourse FD 84-L
Source: Terpstra 1998

4.4.2 Lining of the Main Watercourse

Watercourse desilting in an unlined watercourse is a very laborious task, but if not done causes loss of irrigation water which is a precious and scarce resource. Farmers prefer to get at least part of the watercourse lined to decrease the water loss and reduce hassle to desilt it. In a program initiated by the Punjab government called On Farm Water Management (OFWM) over 25000 watercourses have been renovated (www.ofwm.gop.pak/activities/htm, 2001) in the whole province[15]. Under this program farmers had to organise themselves in a

[15] A number of these improved watercourses were lined, mostly up to 10 % of the total length of a watercourse.

farmer organisation and had to provide 25 % of the total expenditure[16] of the lining and labour for construction. Since the benefit obtained from this activity is long term only owners were expected to pay for it, nevertheless the actual cultivators of the land (who could be an owner or a tenant) provided the labour. The OFWM programme provided technical help and materials such as bricks, sand and cement. Two out of the six selected watercourses are partly lined, and one is almost fully lined. MD 1-R main branch and MD 11-TC are lined up to 390 meters whereas FD 67-L is lined up to 2535 meters. This lining considerably reduced the number of desiltings in a year. Watercourse FD 67-L was desilted only once in three years after its lining. Frequency of desiltings of the lined main branches of the Mahmood watercourses is also less than the other watercourses.

Farmers CID 14, and CID 25 with some other farmers, initiated the lining of part of the watercourse in MD 11-TC. The head reach of the watercourse was lined up to 390 meters with the help of the Directorate of OFWM in 1988-89. Farmers provided labour and 25 % of the actual cost and OFWM provided technical support and material for construction. Landowners paid the money for the lining. The total contribution of a farmer is divided over a fixed period, in this case 3 years, which is paid with the *abiana*. Cultivators - including tenants - provided labour. A similar method was used to organise watercourse desilting as was used to organise the digging for the lined watercourse. All the cultivators were supposed to take part in it, so everyone had to come himself, send another family member, or hire a labourer to do his work. The lining has reduced the hassle to clean at least the first couple of hundred meters at the head of the watercourse, and thus saves a lot of water.

In the watercourse FD 67-L, farmer OID 41 is the biggest landowner (149 acres or 60.3 ha.). He has land at the tail of the watercourse therefore he was affected by the conveyance losses in the unlined watercourse. He took the initiative to get the watercourse lined and after discussing it with the fellow shareholders, he contacted the OFWM Directorate. They worked together and the watercourse was lined in 1995-96. However, the material used in the construction of the watercourse is not of very good quality, which sometimes results in seepage through the walls of the watercourse. Still according to the farmers the loss of water through conveyance is reduced considerably due to the higher velocity due to an increased slope. In the past it was difficult to irrigate fields at the tail of the watercourse but now it is no problem. This is also one of the reasons why one of the farmers, who worked in ID as a *Patwari*, wants to include some of his land that is presently in the command area of an adjacent watercourse, in the command area of the watercourse FD 67-L. Moreover, the frequency for desilting the watercourse has also been reduced significantly. Before lining the watercourse had to be cleaned once every two months but now once a year is enough. In addition the problem of change in the flow condition at the *mogha* is also solved. Earlier the sedimentation at the head of the watercourse caused a change in flow condition of the *mogha* from free flow to submerged flow, which decreased the discharge. Now because of the higher slope and much less sedimentation the condition always remains as free flow and the discharge is also not reduced.

[16] The percentage of the cost provided by the farmers was different in different projects. In the OFWM project (from 1976-77 to 1980-81) funded by the USAID, no cost was recovered by the farmers. Farmers had to pay 10 % of the material cost in two years of grace period in 10 instalments (1981- 1985) in the OFWM I, which was World Bank assisted project. In the OFWM –II Project (1986 to 1990), that was also funded by the World Bank, farmers had to contribute 25 % of the total cost in three years. The money was recovered in 6 instalments (2 instalments in one year) with the *abiana*.

Farmers in FD 84-L have talked about lining the watercourse. In a *Panchayat* meeting held in the first quarter of 1997 all the farmers agreed to line the watercourse. However, not all the farmers agreed on the payment and therefore the lining still had not been started by the end of the research.

4.4.3 Installation of *Pakka Nakkas*

A *Pakka Nakka*[17] is a concrete structure with circular holes that can be closed with concrete lids. Farmers prefer *pakka nakkas* over *katcha nakkas* because of several reasons. *Pakka nakkas* are easier to operate: it is much easier for a farmer to remove the concrete lid when he wants to irrigate as compared to remove wet mud with bushes in it. Similarly, it is easier to close the *pakka nakka* by putting the lid back than to fill the *katcha nakka*, that is a hole in the watercourse by mud. Generally there is less leakage through *pakka nakkas* as compared to the *katcha nakkas*, and usually they do not breach. A lined watercourse always has *pakka nakkas*, however they can also be installed in an unlined watercourse. In the selected watercourse *pakka nakkas* are installed in the watercourse FD 67-L and in the lined portion of the watercourses MD 1-R and MD 11-TC.

4.5 INSTITUTIONALISING THE COLLECTIVE ACTIVITIES: RULES, ROLES, AND RESPONSIBILITIES

Different forums are used for different kinds of activities within a watercourse command area, and different activities have different kinds of organisational requirements. For instance, watercourse desilting needs resource mobilisation in terms of labour, whereas water acquisition mainly needs resource mobilisation in terms of money. Different farmers are considered responsible for different kinds of actions undertaken. For instance in almost every watercourse someone is considered more vocal and assertive than the others and therefore very often takes the lead in negotiating interests of his group with the ID. Someone who is respected by the farmers is very often responsible for the resource mobilisation in terms of labour or money. Nevertheless the decision about performing these activities is taken collectively involving all the shareholders of the watercourse command area and only then a plan of action is chalked out.

In the selected watercourses collective action for watercourse maintenance and water acquisition activities was monitored in detail to get more insight in how farmers are organised to change the Water Delivery Environment within the watercourse command area. The rules, roles and responsibilities of different actors for these two activities are discussed in this section.

4.5.1 Desilting of the Watercourse

The rules and roles to desilt watercourses are more or less the same in all the selected watercourses. There is always someone responsible, either officially (by the people in the watercourse command area) or by always taking the initiative himself. The main watercourse is cleaned in the water turn of the head farmer or when there is no water in the distributary. Sometimes farmers have to close the *mogha*, which is illegal, to desilt the upper reach (first

[17] *Pakka nakkas* were developed and introduced by the On Farm Water Management Project Punjab in the 1970s by the researchers from Mona Reclamation Experimental Project (MREP), Water and Power Development Authority (WAPDA), and the Colorado State University (CSU).

few meters) of the watercourse. Different processes that are involved in organising this activity are outlined in the following paragraphs. De Klein and Wahaj (1998) explain these processes in more depth.

Initiative taking and responsibility

The person who is responsible to organise an activity may or may not initiate it. An initiator is the one who feels a need to organise the activity. However the activity is still organised by the person who is responsible. The person who is responsible for organising the watercourse cleaning very often has land at the tail of the watercourse command area. He often also takes the initiative for organising the activity, although there are other farmers as well who take initiative. Anyone who feels that desilting should be done can request the responsible person to organise the activity. Then the person responsible arranges the date and time to perform the activity and communicates it to other shareholders.

In the selected watercourses, however always the same farmers were found to take the initiative. At least two cultivators in every branch of all the selected watercourses are considered as initiative takers for watercourse desilting activity by the fellow shareholders, although officially only one person is responsible to organise it. These initiative takers are mostly from the tail reach of the branch but can also be from the head or middle reach. These farmers usually do not get any reward for organising the activity apart from better conveyance of the water in the watercourse to their farm. In some cases they do not clean their share of the section although their presence is necessary since they divide tasks among the shareholders as well. Table 4.4 presents the cultivators responsible for organising the activity, taking initiative and location of their farm along the watercourse. Some of these farmers, who are responsible for the watercourse maintenance, are also considered overall leaders of the watercourse. Farmers CID 1-R and CID 14 in MD 1-R main branch; farmer CID 49 in MD 11-TC; farmer CID 8 in FD 84-L main and right branch; and farmer CID 18 in FD 96-R are considered as leaders in their respective watercourses. In all the cases the person responsible to organise the activity is an owner-cum-cultivator, whereas in most of the cases an initiative taker is also an owner except in both FD 84-L right and FD 84-L left where a lessee also takes initiative to organise the activity.

While responsibility for organising desilting is delegated to one person in some watercourses, in others a farmer becomes the person responsible to organise the activity by always taking initiative and organising the activity. In most of the selected watercourses farmers have become responsible by just taking the initiative. In the watercourse MD 11-TC farmer CID 54 took over this responsibility from his father who was also responsible for organising desilting in this watercourse. In MD 11-TC and FD 84-L[18] the persons responsible for organising the activity also divide the work and do not have to clean the watercourse, whereas in the rest of the sample watercourses there is no reward for organising the activity.

Communication

The person responsible for organising the activity is responsible to communicate the time and the date of the planned activity. The loudspeaker of the Mosque is usually used to announce the time and the date. This is done one day before the activity has to be performed. The outlet (or *mogha*) number or the name of the *chak* is announced with the date and the time at which

[18] The farmer responsible for desilting activity in this watercourse is an owner who has given his land on share cropping to another farmer. Hence he would not have cleaned the watercourse even if he was not responsible for organising the activity. His tenant desilts the watercourse

the activity has to take place and the shareholders are requested to come. In some cases, a sanction (or fine) in case of absenteeism is also announced. In cases where some farmers live away from the village or watercourse command area, the *Chowkidar* (watchman) of the village is sent to inform them, or other farmers inform them personally. In a small watercourse, organiser personally informs other shareholders. In some cases all the methods are used to ensure everyone is informed.

Table 4.4: Status of the persons who take initiative or organises desilting activity in the watercourse branches of six selected watercourses; their tenancy status and location of their farms along the watercourse

Watercourse Branch	Cultivator/Owner Identification Code (CID/OID)[1]		Tenancy Status[2]	Location of farm
	Responsible/ Organiser	Initiator		
MD 1-R main		CID 1	OC/L	Head/Tail
	CID 49	CID 49	OC	Head
MD 1-R right		CID 22	OC	Middle
	CID 26[3]	CID 26	OC	Middle
MD 1-R left	CID 43[3]	CID 43	OC	Tail
	CID 9[3]	CID 9	OC	Tail
MD 11-TC	CID 54	CID 54	OC	Tail
		CID 14	OC	Head/Tail
FD 38-L	Not applicable[4]			
FD 67-L	Not applicable[5]			
FD 84- L Main	OID 49[5]	OID 49[6]	Owner	Tail (right branch)
		CID 53	OC/T	Head (right branch)
FD 84-L right	OID 49[6]	OID 49[6]	Owner	Tail
		CID 53	OC	Head
		CID 15	L/T	Middle
FD 84-L left		CID 14	L	Tail/Head
	CID 5	CID 5	OC	Middle
FD 96-R First half		CID 6	OC/L/T	Head/Middle
	CID 8	CID 8	OC	Head
FD 96-R Second half	CID 18	CID 18	OC	Tail

[1]CID is cultivator's identification code and OID if the owner's identification code (from this study).

[2]OC is Owner cum Cultivator, L is Lessee, and T is Sharecropper.

[3]They are not made in charge, however by taking initiative and organising the activity they have become responsible for organising the activity.

[4]This is a small watercourse with only two cultivators.

[5]This watercourse is not desilted since it has been lined.

[6]He is owner and sharecrops land with his tenant, therefore does not have a Cultivator's identification code. His owner identification code is given.

Resource mobilisation

Every shareholder is supposed to take part in the desilting activity. If the cultivator himself does not want to come, he may hire a labourer to do his part of work or he may send someone else, for instance his son, brother, or a servant. Tenants usually clean the watercourse for the landowners in case of share cropping.

The work is divided in such a way that the farmers from the tail of the watercourse have to spend more time and thus do more work as compared to the farmers at the head of the watercourse. Where the *nakkas* of some head end farmers are very close to the outlet they do not even participate in the activity, which is acceptable to the other shareholders. Since tail enders get most benefit from this cleaning, it is considered justified by all shareholders area that they also do most of the laborious work.

No funds are collected or maintained for emergency maintenance. Whenever maintenance requiring money is needed, it is collected. Every time funds have to be collected, for example for the lining of the watercourse or for installing *pakka nakkas*[19], it is collected according to the landholding size of each farmer. In cases where fines are recovered from absentees, the money is used to pay the labourer who did the work of the absentee. Farmers in some watercourses use this money to have tea and sweets afterwards. In case of a breach in a watercourse, a farmer who has his turn at that time is responsible to fix it. If he is not able to fix the problem other farmers, for instance the one whose crop is threatened by this breach and the one who has the next water turn, help in fixing it.

Distribution of work

All the farmers (or their substitutes) get together on the set date and time and desilt the main branch of the watercourse. In the case of a branch of a watercourse, farmers using that branch get together and clean it on the pre-set date and time. Usually one of the farmers, often the one who is responsible for organising the desilting activity, distributes the length of the watercourse over all the farmers present for desilting. The portion of the watercourse one cultivator has to clean depends on the amount of land he has in the watercourse command area.

Every farmer takes part in the desilting of the part or stretch of the watercourse that is used to convey water to his fields[20]. Therefore he starts from the outlet and continues until his last official *nakka*. The location of the stretch is divided according to the *warabandi* turns. The stretch of the watercourse from the head to the point (or *nakka*) where the first farmer takes his water turn is divided among all the farmers. Then the farmers taking water only from this *nakka* will drop out and the rest of the farmers will continue cleaning until the next *nakka*. This cycle is repeated until the last *nakka* of the watercourse is reached. Though the method of allocating work is the same, the units of measurements for deciding the stretch of the watercourse per person is different. For instance in some watercourses work division is 1 *karam*[21] per hour of water turn and in others farmers use 1 *kanah*[22] per square (approximately 325 meters) of land.

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[19] Such maintenance requirements did not emerge during the study period.

[20] Farmers use spades or shovels to remove the silt and the weeds.

[21] One *karam* is 5.5 feet = 1.67 meters

[22] *Kanah* is a stick to measure the length of the stretch and could be of any size. However the one mentioned by the farmers was 22 feet (6.7 meters)

In the selected watercourses all the shareholders are expected to desilt the watercourse at the same time (except in one branch of FD 84-L and the main watercourse of MD 1-R). In MD 1-R, work is distributed according to the *biradari* and then within the *biradari* cultivators redistribute the work according to area. Each *biradari* has to clean one third of the branch since three different *biradaris* have land irrigated by this branch. In the left branch of FD 84-L work is already allocated to the cultivators who are expected to do it at a convenient time. Nevertheless these farmers are supposed to desilt the entire watercourse within a week. This watercourse has a large number of cultivators and a mix of owners and tenants.

The principles for division of labour for desilting are more or less the same in all the watercourses. Table 4.5 summarises the rules for work allocation. The task is divided according to the land holding size and every farmer has to desilt up to his last *nakka* according to the *warabandi* schedule. These rules are easy to understand and acceptable to all the shareholders of the watercourse command areas. These rules are enforced since the start of the irrigation system and are developed by the farmers themselves since no rules to desilt the watercourse are provided by the Canal and Drainage Act 1873.

Table 4.5: Rules to allocate desilting work in six sample watercourses

Watercourse	Basis for labour input	Work-share principle	Mode of allocation of work	Are shareholders expected to work at same time
MD 1-R	*Biradari* and land holding size	1 *kanah*[1]/square	According to *warabandi* schedule	Yes
MD 11-TC	Land holding size	1*kanah*[1]/square	According to *warabandi* schedule	Yes
FD 38-L	Land holding size	Equally (since two cultivators)	Not applicable (only two farmers)	Yes
FD 67-L	Not applicable	Not applicable	Not applicable	Not applicable
FD 84-L	Land holding size, duration of canal water turn	1 *karam*[2]/hour of the canal water turn	Right branch: according to *warabandi* schedule Left branch: Fixed	Right branch: yes Left branch: no
FD 96-R	Land holding size, Duration of canal water turn	1 *kanah*[1]/hour of the canal water turn	According to *warabandi* schedule	Yes

[1]A *kanah* is a stick used to measure distance or length. In this case *kanah* is used to measure the length. This is just a reference stick to equally distribute stretch of the watercourse to be cleaned so it could be of any size.
[2]A *karam* is a local unit to roughly measure the distance. 1 *karam* is 5.5 feet (1.67 meters)

Desilting is a laborious work. On average it takes a farmer 90 minutes to clean only 67 meters of a watercourse, although time may range from 30 minutes to as long as 6 hours[23].

[23] The time to clean 67 meters depends on several factors. It takes a farmer more time to clean a section of the watercourse if there is high vegetation on the banks that has to be cleaned; a high sedimentation will also result in a longer time for cleaning; if banks of a watercourse need strengthening; it also depends on a farmer's health and therefore speed to clean a watercourse; if a farmer has to clean a long stretch of a watercourse, his speed will reduce with the increasing meters he has to clean.

Free rider control (sanctions)

All the shareholders are expected to show up or send a replacement on the day of desilting. If a person does not come without a genuine reason, (marriage, death, or illness is considered genuine reasons) he is considered an absentee and thus should be punished. Different rules are followed to deal with the absentees in different watercourses. The stretch of the watercourse that is supposed to be cleaned by the absentee is left for him to do later on if the work division is fixed. In some cases it is left even if the division of work is not fixed. This absentee is then expected to clean this part of the watercourse before water starts flowing again in that portion, since it is more useful to desilt the whole watercourse at the same time than spread the desilting over time. However, if fellow shareholders know that the absentee cannot do the work later for a genuine reason, other farmers do his share of work as well. When an absentee has no genuine reason to be absent and does do the work later on, a labourer is hired or a fellow shareholder cleans his portion of the watercourse. The absentee has to pay the labourer's wage for one day that goes to the shareholder who did the work.

In most of the selected watercourses no formal sanction is imposed on the absentees, even if announced. Nevertheless the farmers are rarely absent on the day desilting is organised. Different mechanisms to control 'free riding' are found in the selected watercourses. For not participating in the desilting activity a farmer can be fined, or in some cases other fellow farmers close the *mogha* during his *warabandi* turn. Yet another way to prevent lack of collective action for desilting is social pressure. Table 4.6 presents different measures adapted in the sample watercourse to ensure high participation of the farmers in desilting activities. The left branch of the watercourse FD 84-L however was observed to have difficulties in organising the activity collectively because of the high level of off-farm employment of most of the shareholders of the command area. This once created a problem in the desilting of the main watercourse since the main branch is cleaned by all the farmers together. When the farmers from the left branch did not show up on the planned day of desilting, farmers of the right branch also did not clean the main branch. Another time, the fine to be paid by any absentee was also announced in the Mosque with the announcement of date and time of the desilting activity. However the person responsible for this announcement said it was done more to control farmers who want to ride free, and will not be implemented. The result of this announcement was positive and almost all the shareholders appeared on the day the activity was to take place. In the right branch of the watercourse, MD 1-R, fellow shareholders block the *mogha* during the water turn of the farmer who does not participate in the desilting activity without any solid reason. This is also a good motivation for farmers to participate in the activity.

It is not easy to enforce the rules regarding payment of money because of the kinship relations, lack of authority and in some cases the financial position of the shareholders. Sometimes farmers are not able to pay a fine in terms of money because of lack of cash. It is difficult to punish a person from the same caste as well since they have to socialise with that person, besides he could also be a relative. Because of the clear leadership in desilting activities in one of the six selected watercourses, MD 11-TC, the rule of paying fine in cash is enforced. However it is not clear that higher participation of farmers is due to the fine enforcement or because of social obligation: farmers participate in a collective activity out of a sense of collective responsibility or for fear of paying the fine in cash. Another reason for higher participation of the shareholders could be the higher water need of MD 11-TC and lower rate of off-farm employment. In this watercourse most of the farmers are cultivating their own lands and are mainly relying on agriculture for their livelihood. They also grow high water demanding crops, like sugarcane and rice. Therefore, they may take more interest in the desilting activity to improve conveyance efficiency of their watercourse.

Table 4.6: Sanctions to control free riding in the six selected watercourses and their branches

Watercourse	Branch	Sanction
MD 1-R	Main	No[1]
MD 1-R	Right	Close mogha
MD 1-R	Left	No[1]
MD 11-TC	Main	Fine (labourer's wage)
FD 38-L	Main	No
FD 67-L	Main	Not applicable
FD 84-L	Main	No[1]
FD84-L	Left	No[1]
FD84-L	Right	No[1]
FD 96-R	Main	No[1]

[1] Leave the portion belonging to absentee who cleans it later on.

Sanctions in form of cash are not the only way to motivate people to take part in the desilting activity. Absentees also lose face if they are questioned in public by other shareholders for not being present on the day desilting took place. Sometimes the absentee is called in front of a group and asking him to explain why did he not show up. He is also warned not to be absent next time. In this way they lose face if they do not have a genuine reason for not being present. Moreover other shareholders can go to the house of the absentee and complain that he did not show up. This is called '*gilla shikwa*' and is embarrassing for a person. This fear for embarrassment is considered a motivation to participate in the collective action.

4.5.2 Canal Water Acquisition

Canal water acquisition is very often an illicit activity and no one in a watercourse command area is formally responsible to undertake that activity. If a farmer feels that the water supply is not enough for crop growth, he discusses it with other fellow farmers who are often the ones who arrange it with the ID. They discuss the course of action and then discuss the issue in the *Panchayat* with all the shareholders who have to pool money for the activity. If everyone agrees then a small group of farmers negotiates with the ID and when an agreement is reached, the money is collected and additional water is arranged - most often by enlarging the *mogha* dimensions. Thus for this activity though no formal platform is present to organise the activity, still farmers organised it in a systematic way. Some farmers are considered to be more effective in negotiation with the ID, hence they take the lead in performing the activity.

A *Panchayat* is held a number of times before the action is taken. A message is sent around to each shareholder about the time, date and place of the meeting. In some of the watercourses, a meeting is always held at one particular place, but in other watercourses it varies. However it never takes place at the *dera* of a lower caste farmer, or a ladles farmer[24]. For instance, in FD 67-L a *Panchayat* always takes place in the dera of farmer OID 41, who is the biggest land owner in the watercourse, and is considered a very helpful person by fellow shareholders. In

[24] Usually lower caste farmers are also ladles farmers, who acquire agricultural land by renting it in or by sharecropping it with a landowner.

the rest of the selected watercourses FD 11-TC[25], FD 96-R[26] and FD 84-L[27] meetings take place in different *deras*. In FD 67-L a big landowner always communicates the date and the time for the meeting to fellow shareholders. Where meetings do not take place at one fixed place the initiative taker discusses the issue with a few respectable persons in the watercourse and then send the message around for a meeting. Farmers who are informed and expected to join the meetings are mainly water users who have water rights - landowners and lessees. Sharecroppers on a tenancy contract are usually not expected to pay for this kind of acquisition activity since it has a more permanent impact. However, in some cases, for instance in FD 67-L, sharecroppers are also expected to share the cost to get the *mogha* enlarged. Among all the sample watercourses, this watercourse has highest amount of land under sharecropping. The amount to be paid for the *mogha* enlargement to the ID staff (as bribe) is fixed between the farmers and the ID staff. This kind of intervention usually last for about a year - and tenancy contracts are also for one year[28] - because most of the time the *mogha* is downsized again during the annual canal closure. Thus they are also invited to attend these meetings. Sometimes, this intervention could last for many years in which case often farmers have to pay for additional money to the ID officials[29]. Nevertheless the event of a fine from the ID for tampering with the *mogha* is dealt with, in all the watercourses, in the same manner and all the shareholders including tenants and sharecroppers have to pay the fine.

Table 4.7 notes the farmers considered as leaders of organising canal water acquisition or representing farmers' interests to the ID staff. Farmers in the watercourses along the Mahmood distributary usually do not take collective action for water acquisition. However in *kharif* 1997 MD 1-R farmers undertook a successful collective action in negotiating or organising increased *mogha* dimensions (for details see Box 4.1). The fact that there are only two cultivators in the watercourse FD 38-L also does not give much room for undertaking collective action to acquire canal irrigation water; they rather acquire additional water individually by illegal siphoning from the distributaries. In the remaining three watercourses landowners mainly organise the activity. Landowners in watercourses FD 67-L and FD 84-L, who lead in arranging additional canal water, have their land at the tail of the watercourse, and thus are affected most from low water supply. However, in the watercourse FD 96-R farmers from the head and the middle of the watercourse are more active in this collective action because they are considered leaders of the watercourse for organising collective action for all water management activities.

[25] Three places are often used for these meetings, *dera* of the *Numberdar* of the village, CID 48, *dera* of another senior farmer CID 14 and the Mosque of the village.

[26] Main places for meetings are *deras* of farmers CID 6, CID 8 and CID 18

[27] Meetings could be held at any place, however the *dera* of an ex *patwari* OID 49 is more common place for *Panchayats*

[28] However, in FD 67-L the sharecropping contracts continue beyond one year.

[29] Although, it did not happen in the FD 96-R until the end of the research. During the annual canal closure of 1997-98, when new Sub-Engineer was transferred to the Fordwah distributary, he prepared a check statement and on the basis of last check statements he wanted to remodel the outlets which deviated form their design dimensions. The Sub-Engineer also marked the outlet of FD 96-R (sample watercourse of the current study) for downsizing. According to farmers, the Sub-Engineer sent them a message through one of his *baildars* to pay money to him if they did not want their *mogha* to be downsized. Farmers agreed to pay the money, hence the mark was removed. When the Sub-Engineer was asked about the reason of this change, he said he marked that *mogha* by mistake. Farmers and Sub-Engineers disagreed on the amount to be paid, however before any decision could have been taken the Sub-Engineer was transferred again to another area. The *mogha* remained unchanged.

Table 4.7: Farmers active in organising collective action to acquire additional surface water

Watercourse	OID/CID	Tenure Status	Location of farm
MD 1-R	OID 50, CID 49	OC	Head
	OID 35, CID 1	OC/L	Head/Tail
MD 11-TC	OID 46, CID 48	OC	
	OID 14, CID 14	OC/L	Head/Tail
FD 38-L	NA	NA	NA
FD 67-L	OID 41	Owner	Tail
	OID 43	Owner	Tail
FD 84- L Main	OID 49	Owner	Tail (right branch)
FD 96-R	OID 14, CID 8	OC	Head
	OID 10, CID 6	OC/L/T	Head/ Middle

During the study period farmers from two of the selected watercourses, FD 67-L and FD 84-L discussed the possibility of enlarging their *moghas*. In the watercourse FD 67-L a few farmers realising the problem of water scarcity went to the watercourse leader farmer OID 41 to discuss the matter. They together discussed the situation and came up with the solution to get the *mogha* size enlarged through ID. A *Panchayat* was held to discuss the issue. Since all the shareholders would get benefit and thus had to pay money, everyone had to agree to take the action. All the farmers agreed about the problem and the way to solve the problem. However the timing of the action could not be decided. Moreover some of the farmers thought that the money they had to pay to get additional water was too much. Thus no proper action was taken before the end of the research.

Farmers of another watercourse FD 84-L also discussed to get their *mogha* enlarged but did not agree on the amount of money paid by each farmer therefore nothing happened by the end of the research period.

4.6 IMPROTANT COLLECTIVELY PERFORMED WATER MANAGEMENT ACTIVITIES

All the activities that farmers undertake are significant for farmers in term of hassle to organise them and the profit gained as a result of performing the activity. Farmers from all the watercourses were asked to list the collectively performed water management activities and prioritise them through group meetings in every watercourse. The most important activity identified by the farmer was watercourse desilting and then arranging more water at the *mogha*. It is amazing that the farmers of all the watercourses consider the desilting of the watercourse important since it is very laborious (see Table 4.8). Lining of the watercourse is also prioritised as an important activity since it considerably reduces the conveyance losses and the frequency to clean the watercourse – watercourse lining is considered equally important as desilting. Installation of *pakka nakkas* is also considered very important since it makes it easier to open and close *nakkas* and usually results in less leakage or seepage losses than *katcha nakkas*. Drainage was not mentioned as a water management activity in any of the watercourses, the reason being that it is more considered an individual activity rather than a collective action.

Acquisition of canal water is considered as the second most important water management activity. This includes higher and reliable discharge. However, farmers are aware that acquiring additional canal water supply that is usually through remodelling of the *mogha* is illicit.

Increasing watercourse command area was mentioned as an activity that needs a collective decision if not action by farmers of the watercourse command area of FD 67-L. Although a majority of the shareholders of the command area were against the undertaking of this activity.

Table 4.8: Importance of water management activities, in the six sample watercourses, as mentioned by the farmers

Water management activity	Watercourse					
	MD 1-R	MD 11-TC	FD 38-L	FD 67-L	FD 84-L	FD 96-R
Watercourse Desilting	1	1	1	1	1	1
Acquisition of surface water	2	2	2	2	2	2
Lining of the watercourse and installation of *pakka nakka*	1	1	1	1	1	1
Increase in additional Culturable Command area				X		
Repair the breach in the distributary		X				
Other collective activities (construction of roads, marriage etc)		X		X	X	

1: most important activity
2: second most important activity
X: mentioned in the meeting and considered equally important as 1.

In MD 11-TC land is sometimes flooded with water when there is a breach in the neighbouring Azim distributary. One of the banks of the distributary is not strong enough and needs strengthening once in a while to bear the pressure of water if the canal carries full supply. Farmers from Mahmood distributary including MD 11-TC take collective action to strengthen the bank of the distributary by putting more soil on the affected bank. Whenever Azim distributary receives full supply it breaches. However according to farmers "*it breaches whenever it receives water and remains dry for rest of the time*". When there is a danger of a breach in the distributary villagers patrol along its bank. In case of a breach they also have to repair the bank either all by themselves or with the help of the ID.

Other activities like construction of roads in the village or within the watercourse command area were also mentioned as important collective work. Although not an action or activity needed regulated actions. This activity was mentioned in three selected watercourses. In each watercourse farmers had to collect money to rent tractors or to buy some equipment and labour is provided by the farmers/villagers. In fact farmers from FD 84-L got a prize as a 'model village' after they constructed a sewerage system within the village[30]. Farmers also mentioned some social gatherings like marriage ceremonies and deaths as social events where farmers get together and take collective action.

[30] Farmers from two watercourses, FD 84-L and MD 11-TC.Farmers of the watercourse FD 84-L are living in two separate villages.

4.7 CONCLUSIONS

Collective action for water management was studied in six watercourses selected along two tail distributaries of the Fordwah Branch Canal. The main water management activities identified that are performed collectively in almost every watercourse are watercourse maintenance and canal water acquisition. These activities are repeated whenever they need to be performed. Desilting activity is performed more often in an unlined watercourse as compared to a lined watercourse. An unlined watercourse is desilted at least three times a year, as in the watercourse MD 11-TC and watercourse FD 84-L, and sometimes up to 7 times in one year, as in FD 38-L. Watercourse lining is also considered an important water management activity by the farmers in almost every watercourse. Given a choice, all farmers prefer to have fully lined watercourse with *pakka nakkas*. But since it is an expensive solution sometimes farmers get only part of the head reach lined, like in the case of MD 1-R and MD 11-TC. Farmers of the watercourses FD 84-L and FD 96-R also discussed the issue of watercourse lining, but it did not materialise by the end of the research period. Inclusion of more command area in the watercourse was the most recent water management activity that was being discussed in watercourse FD 67-L.

Canal water acquisition at the watercourse level is the other important activity farmers mentioned. It is done either by getting higher discharge in the distributary – so all in the distributary benefit - or by increasing discharge in the watercourse – by *mogha* tampering or *mogha* enlargement through remodelling. All of these actions are illicit and result in lower availability of water for other farmers. Higher discharge in one distributary means lower discharge in the other since the existing water supply within the system is redistributed. Enlargement of one *mogha* will result in the inequity within the distributary as this particular *mogha* will draw more than its designed share.

Generally it is easier to organise collective action in the watercourses along Mahmood distributary than along Fordwah distributary. That relatively higher number of owners are cultivating their land along the Mahmood distributary as compared to the watercourses along the Fordwah distributary may be the reason for successful collective action. The number of shareholders is very high in these watercourses however. Another reason could be that all the shareholders live in one locality making it communicate easier for farmers. These farmers also cultivate high water demanding crops; therefore better water management is needed to match supply with the demand.

Collective action for watercourse maintenance is organised smoothly in almost all the branches of the selected watercourses except in the left branch of FD 84-L where farmers do not undertake collective action easily because of their other off-farm activities. However, farmers of FD 84-L clean their watercourse at the specified frequency, but there have been difficulties in co-ordinating wok in the left branch.

Acquisition of additional water is organised very well in the watercourses along the Mahmood distributary and two of the selected watercourses, FD 67-L and FD 96-R, along the Fordwah distributary. These two watercourses have relatively fewer shareholders than the watercourse FD 84-L therefore it is easier to get consensus on any action and to act accordingly. Furthermore most of the farmers of these two watercourses are living in their respective watercourse command area. Farmers of FD 84-L are living in two different villages, that also makes it more difficult to communicate. However the majority of the shareholders live in one village with a very good history of co-operation. Though farmers of FD 84-L do agree on the need to undertake collective action they do not operationalise it.

In their efforts to acquire additional canal water, farmers interact with the Irrigation Department staff very regularly. These Agency-farmer interactions are sometimes confrontational, however as shown here they work in farmers' favour in the form of increased canal water delivery to their watercourse. Thus, the encounters of farmers and ID staff in their daily activities to manage water at different levels of the irrigation system influence the water supply of the watercourses.

A *Panchayat*, a word frequently used by farmers for their meeting, is still the main platform to discuss water related (and other) issues and take decisions in all the sample watercourses. However, most of the forms of organisation found in the sample watercourses were based on hydraulic units, although actions by *deras* was sometimes a sub-organisational level, and not on the village level. In four out of six of these watercourses farmers were living in their *deras* within the watercourse command area. In the two watercourses (FD 84-L and FD 11-TC) where farmers were living in villages, others forms of organisation - such as village level *Panchayat* - which were different than the watercourse level organisations also existed. Even in these two villages the *Panchayat*, held to discuss watercourse related issues, is attended by the shareholders of the watercourse command area and the *Numberdar*[31].

Table 4.9 presents the factors, as listed in the section 2.4, which can influence collective action and their presence or absence in the selected watercourses. The need for water and mutual benefit seems to be the major deciding factor for organising collective action in almost all selected watercourses.

From the table there are no universal factors that promote or limit collective action. However, some observations can be made on social factors that seem to facilitate or ease execution of collective action for water management in the selected watercourses:

- <u>Percentage of actual cultivators involved in off-farm employment</u>: If a high percentage cultivators are involved in off-farm employment they have less time for organising and taking part in water management activities. Besides intensive agriculture is not a priority for them.
- <u>Clear leadership</u>: Presence of one or two leaders in the watercourse helps in organising collective action. Though the decision is taken collectively, a leader who is well respected by other shareholders can organise the activity in a better way.

The factors that seem to inhibit collective action are:

- <u>Relatively equal distribution of power</u>: It is easier to organise collective action when people listen to each other. In one of the watercourse with less collective action, FD 84-L, a farmer said, '*nowadays no one listens to any one especially younger generation. No one accepts authority from others; everyone wants to be elder of the village. We lack unity therefore we can not organise collective action anymore*'
- <u>*Zid*</u>: Because of lack of interest by some shareholders others also do not undertake the activity and everyone suffers.

[31] Who may or may not cultivate land in that watercourse command area

In some sample watercourses work division for the execution of some water management tasks, like watercourses desilting, is based on the *biradari*. However, the *biradari* does not seem to play a decisive role in most of the water management activities. For organising the water acquisition activities, what is more important is the involvement of landowners and lessees (because they get temporary rights of the land they rent).

Table 4.9: Presence or absence of factors effecting collective action in the selected watercourses

Factors effecting collective action	Watercourse				
	MD 1-R	MD 11-TC	FD 67-L	FD 84-L	FD 96-R
Number of cultivators	71	74	57	48	29
Number of pure tenants[1]	7	18	25	24	12
% cultivators with land holding size between 2.5 to 10 ha.	13	27	42	35	25
% cultivators with land holding size less than 2.5 ha.	84	72	51	65	75
% cultivators with land holding size greater than 10 ha.	3	1	7	0	1
% cultivators involved in off farm employment	1	9	14	46	41
Panchayat takes the decision about collective action	Yes	Yes	Yes	Yes	Yes
Farm location of influential farmer(s)	Head Tail	Head Tail	Tail	Tail	Head Middle
Clear Leadership		Yes	Yes		Yes
Relatively equal distribution of power	Yes			Yes	
Shareholders of single *biradari*	No	No	No	No	No
Social gain or loss	Yes	Yes	Yes	Yes	Yes
Zid				Yes	
Enforcement of sanctions	Yes	Yes	No	No	No
Effective conflict resolution	Yes	Yes	Yes	Yes	Yes
History of co-operation	Yes	Yes	Yes	Yes	Yes
Crops- Higher crop water requirement	Yes	Yes	No	No	No

[1] pure tenants are the tenants (lessees or sharecroppers) who do not own any land in the watercourse command area

To conclude, Uphoff 's (1990) theory about the scope of collective action in relation to water scarcity situations, and Wade (1977, 1988 and 1990) argument of emergence of collective action as a result of water scarcity holds true in the selected watercourses[32]. Farmers from the selected Mahmood watercourses took collective action for canal water acquisition when their canal water supply was reduced. Similarly they desilted their watercourse more often at the peak crop water requirement. Whereas, farmers from two of the sample watercourses along the Fordwah distributary took no collective action to acquire additional canal water even after

[32] However, Wade's hypothesis about water scarcity in canal system that reliability decreases and farmers hoarding behaviour increases with the distance of farmers' location from the source, is very simplistic. It is not fully true for the study cite. At the higher level, both the distributaries offtake at the same point from the Branch Canal, but water supply to the Mahmood distributary is much better than the water supply of the Fordwah distributary. Similarly, along the Fordwah distributary the remodelled *moghas* were found all along the distributary and not only in the tail reach of the distributary.

discussing it. The perceived need of their crops was still better met, in *kharif* 1997, than the perceived irrigation requirement of Mahmood watercourses[33]. However farmers from FD 96-R did take collective action for desilting the watercourse, which they thought will improve water delivery to the tail end farmers. This also proves the argument of De Klein and Wahaj (1998) that farmers take collective action when they need irrigation water and benefit mutually. However, there are some other factors, like off-farm employment transaction costs to organise collective action or lack of mutual benefit that sometimes inhibit collective action, as in watercourse FD 84-L. Nevertheless farmers discussed it. In this case – change of *mogha* location - the benefit of collective action are perceived less than the efforts to organise the action by some farmers. This proves Ostrom's (1993) point that collective action happens if the benefits outweigh the efforts involved in organising it.

[33]In *kharif* FD 84-L and FD 96-R have better RWS as compared to the other sample watercourses of the Fordwah distributary and one sample watercourse of the Mahmood distributary. This is mainly because their crop water requirement is also less. Only MD 1-R had RWS higher than these two watercourses.

5 INDIVIDUAL STRATEGIES TO INCREASE CONTROL OVER IRRIGATION WATER AT THE FARM-GATE

Lack of accountability of the Irrigation Department to the farmers and the fact that the canal water delivered to the farmers at the farm-gate is highly variable and inadequate, coerces farmers to adapt certain strategies to get additional canal irrigation water, or to dispose of excess water. Generally farmers are not concerned about the causes of this fluctuating water deliveries that could be technical and may be related to the geographical location of their irrigated agricultural land. Hence the farm-gate is the focus of this chapter. This chapter first looks at the individual action and then actions with a wider benefit. It describes the range of activities undertaken and estimates the benefits from them, showing resourcefulness and financial sense of actions chosen.

5.1 INDIVIDUAL ACTION AND WATER CONTROL

Water control could be defined differently at different levels of the irrigation system. At the more individual level of decision making and managing water, that is farm level, water control refers to the flexibility to use water in the right quantity and at the right time, i.e. when required by the crops. It is also needed to perform other on-farm water management activities, for example fertiliser application. Therefore for farmers, water control is the capacity to adapt irrigation supply to their production requirements (Freeman and Lowdermilk, 1991). Hence in supply driven large irrigation systems, water control at the farm level refers to two sets of activities, those performed to acquire additional water for irrigation and those to use available irrigation water more efficiently. Together they both result in better room to manoeuvre and flexibility in the use of irrigation water for farmers at individual level.

The following factors are found to explain individual actions for better water control.

- Results bring individual benefit, without significant benefit for the whole group of farmers,
- Lack of collective action (even if needed but not initiated) would lead to individual struggle to acquire better control over irrigation water,
- More tenants in a watercourse command area would result in more individual actions for water management,
- Farmers with either very small or very large operational land holdings will prefer to make individual arrangements,
- Involvement of many farmers in off farm employment would result in more individual actions, and
- No clear leadership would result in more individual action.

The first two points listed above are mainly the reasons why farmers take individual actions and the rest are the characteristics of the watercourses having possibilities of more individual actions. Most of the factors that are assumed to explain individual action for water management are the result of the lack of collective action. On the one hand these individual actions depend on the need to acquire better individual control over irrigation water. On the other hand, it would depend on opportunities to attain better individual control over irrigation water.

In case of a highly fluctuating water supply, a majority of the farmers would borrow part of or full water turn from another farmer and would also give this water turn back. Strosser (1997) found that the water turn duration (based on the land holding size) does not affect canal water transactions that are more dependent on the physical characteristics of the farm. The main determinant is canal water supply at the head of the watercourses and eventually at the farm-gate. Similarly almost every farmer would like to and will try his best to have access to groundwater though it depends highly on the capital investment and some other physical conditions. Meinzen-Dick (1996) reports that tubewell owners with big landholding size are less involved in selling of groundwater since they need to use it on their own land. On the contrary Strosser (1997) found that the main sellers of groundwater are large commercial farmers.

Big landowners tend to show their physical power, and are likely to intervene with the system physically at the distributary level and watercourse level, for example, blocking the whole distributary and siphon off water from the distributary. Nevertheless being a big landowner is relative in terms of owning land within a watercourse command area. Operational landholding size increased through tenancy contracts would also influence water acquisition through illicit practices of physical intervention. Tenants who could get larger land holding size to cultivate in a watercourse command area are likely to be involved in practices like siphoning of the water from the distributary. Cultivators who are getting less time per unit of land than their right are also likely to indulge in water acquisition by intervening with the system at lower level (for example at watercourse level). Farmers with landholding sizes in the middle range would try to influence water allocation and hence would be involved in institutional interventions. These activities are mostly illicit.

Since only individual actions are studied here, social relations and kinship would not matter in most of the activities. But when considering water transactions (canal water as well as groundwater) as individual activity the social relations would come in as they influence the dealings of the farmers in terms of access to additional irrigation water as canal and groundwater transactions (see Malik and Strosser, 1994, Meinzen-Dick, 1996; Strosser, 1997).

In this study the activities undertaken to fulfil perceived individual needs in terms of irrigation water are:

- Canal water and groundwater management strategies that include conjunctive water use, and water exchanges.
- Institutional modifications related to water allocation strategies.
- Physical interventions related to: (i) cleaning of farm channels, (ii) refusal to accept surplus water, and (iii) siphoning of canal water
- crop choice

5.2 CONJUNCTIVE USE OF CANAL AND GROUNDWATER

With the increased cropping intensities, canal water deliveries are not enough to fulfil irrigation water needs, therefore groundwater has to be exploited to fill the gap between canal water deliveries and irrigation water needs. In past the Government of Pakistan encouraged installation of tubewells in this area - there was even a subsidy on installing tubewells. However, at present the procedure to get that subsidy is so long and difficult that farmers are not interested in acquiring this subsidy anymore, moreover some of the farmers are not even aware that such a subsidy exists.

If the canal water supply to the area is high, usually the tubewell density is low. When farmers own land in adjacent watercourses they do not have to install separate tubewells in these watercourses. They can install one tubewell and use it's water to irrigate lands in both the tertiary units provided that the water could be conveyed to the other watercourse command area. Tubewell density, number of tubewells and the number of landowners for the selected watercourses are presented in table 5.1. Tubewell density per owner and per cultivator is calculated in two ways: (i) using the number of tubewells within the watercourse command area, and (ii) the total number of tubewells (in and out command), owned by the farmers of selected watercourses.

Table 5.1: Tubewell density according to area and number of owners in six selected watercourses

Watercourse	Number of Land owners – Cultivators	Number of Tubewells[1]	TW density per owner – cultivator		TW density per 100ha. (only TWs in command area)
			TWs in command area	Including TWs out of command area	
MD-1R	77 – 71	10+2	0.1 – 0.1	0.2 – 0.2	7.1
MD-11 TC	78 – 74	5+1	0.1 – 0.1	0.1 – 0.1	3.0
FD-38 L	03 – 2	2	0.7 – 1.0	0.7 – 1.0	4.7
FD-67 L	44 – 57	17+2	0.4 – 0.3	0.4 – 0.3	10.9
FD-84 L	86 – 48	24+7	0.3 – 0.5	0.4 – 0.6	22.5
FD-96 R	48 – 29	10+6	0.2 – 0.3	0.3 – 0.4	14.5

[1] Number of tubewells is the actual number of tubewells present in the watercourse command area + number of tubewells owned by the farmers of sample watercourses in other watercourses. The water pumped from these out of command tubewells is also used in the selected watercourses.

Since canal water supply to the watercourses along Mahmood distributary is very good tubewell density is low. Similarly, because the watercourse FD 84-L has poor canal water supply and a large number of landowners, tubewell density (number of tubewells per 100 ha) in this watercourse is also highest. Each individual landowner wants to be flexible in irrigating his crops, thus likes to install his own tubewell. TW density in the Fordwah watercourses is higher than the Mahmood watercourses except FD 38-L. FD 38-L has only three landowners and two cultivators[1]. Such a high intensity of tubewell indicates a high pumpage of groundwater and unreliability of canal water. Overall 83 % of total water users in

[1] Two of the landowners belong to one family; they are father and son. Their land is cultivated is rented in by only one farmer.

the watercourses studied were using groundwater in addition to the canal water. Because of comparatively better canal water supply, a lower percentage of farmers (70 %) along Mahmood distributary are using groundwater as compared to 96 % of the farmers along Fordwah distributary. Farmers not using groundwater were mostly small farmers with land holdings of less than 4 acres (1.76 ha). These farmers mostly grow one crop per season: fodder, wheat, cotton, and sugarcane are the main crops they cultivate. Groundwater use was observed more in *kharif* 1997 than in *rabi* 197-98 because of disturbed canal water supply[2]. In *kharif* 1997 groundwater provided 47 % of the total irrigation water available for irrigation at the farm-gate. Whereas in *rabi* 1997-98 groundwater supplied 22 % of water for irrigation at the farm-gate.

Farmers prefer to irrigate crops with canal water, firstly because it is of better quality as compared to groundwater, and secondly because pumped water is far more expensive than the canal deliveries. Nevertheless, when they decide to use groundwater they prefer to blend it with canal water mainly because of the small stream size of the pumped water and to reduce the negative effects of marginal quality groundwater. However, a farmer can use groundwater out of his *warabandi* turn as well if the tubewell is within his farm since he only uses farm channels for the conveyance of groundwater. In case he needs to use (a portion) of the main watercourse to transport the pumped groundwater, he cannot use it as long as there is canal water flowing in the watercourse[3].

Some farmers also give alternate irrigations with canal and pumped groundwater to reduce the impact of marginal quality groundwater on land and crops[4] (Kuper, 1997). Farmers have their own indicators to judge the quality of tubewell water. Hoeberichts (1996) researched the indicators used by the farmers to evaluate groundwater quality. The tubewell water is of bad quality if: i) it tastes salty; ii) if one feels satiated just after drinking this water; iii) if it foams easily while washing clothes; iv) if after infiltration, there is sign of salinity on the soil surface; and v) if irrigation with the tubewell water causes the soil to harden. The quality of the tubewell water in the selected watercourses along the Mahmood distributary is good, farmers also acknowledge it. In the selected watercourses along the Fordwah distributary the groundwater quality is not as good as in Mahmood and varies a lot even within a watercourse command area. Almost all the tubewell owners were consulted about the quality of tubewell water. Ten tubewells, from the watercourses FD 67-L, FD 84-L and FD 96-R, were selected for the chemical analysis of their water. Two factors influenced this selection, firstly the intensive pumpage from those tubewells, and secondly that their owners complained about the quality of the water. The analysis showed that water from 5 out of 10 tubewells was found unfit for irrigation[5]. While it is very rare that other farmers buy water from these tubewells

[2] One of the link canals, which bring water for Fordwah Irrigation system, was damaged in *kharif* 1997. See chapter 3 for details.

[3] During *kharif* 1997, groundwater was intensively used by the farmers of FD 67-L because of unusual high canal water scarcity. Farmers were also using the main watercourse for tubewell water conveyance. Once, during this period of water scarcity, a very thin layer of the canal water started flowing in the watercourse, which upset these farmers. As the canal water was not enough to fulfil irrigation water need and they could also not use groundwater since they could no longer use main watercourse to transport the pumped water form the source to the point it was needed for irrigation.

[4] Hussain *et al.* (1990) found that alternate irrigation with canal and groundwater is more effective in keeping the ECe and SAR levels of the soil as compared to mixing of canal and tubewell water (in Kuper 1997).

[5] Water samples from tubewells considered to have bad water were tested by Soil Fertility Punjab, Bahawalpur office. The criteria used to estimate the quality is the one used by WAPDA that could be found in WAPDA

the owners are still using this water since it still gives more flexibility in terms of timing of irrigation.

The presence of tubewells also influences the choice of crops for the farmers in a water scarce system. Farmers with access to groundwater could grow more water sensitive crops since they are more flexible in terms of amount and timing of the irrigation water as compared to the farmers having no access to groundwater. Moreover, farmers having more than one piece of land in one watercourse would prefer to cultivate a water sensitive crop in the parcel that is closer to the outlet and/or the tubewell. For example in the watercourse MD 1-R one farmer has a land at the tail of the watercourse and has also rented in some land at the head, he cultivates rice at the head and sugarcane at the tail of the watercourse, which is very logical. He is the last and the first in *warabandi* cycle: he thus has a longer water turn, as he also gets all the remaining water when the watercourse is drained. This gives him much flexibility in using his water turn. Farmers also prioritise crops to irrigate with only canal water. For example, farmers growing rice, like in the MD 1-R and MD 11-TC prefer to irrigate rice with canal water, sugarcane is at second priority. Farmers mainly growing sugarcane and cotton, as in MD 11-TC, prefer to irrigate rice with canal water. Cotton could be irrigated with the groundwater, as it requires less irrigation depth in one irrigation event.

Tubewell ownership gives better control and more flexibility to use irrigation water for better crop yield, and hence increases the productivity of irrigation water. Freeman *et al.* (1978) found that the productivity of irrigation water was higher for tubewell owners as compared to the purchasers of groundwater and non-users of groundwater, since they have the highest degree of control over irrigation water[6]. In the research area most of the farmers who are purchasing pumped groundwater in *kharif* 1997 have landholding sizes between 5 acres (2.02 ha.) and 12.5 acres (5.06 ha.), whereas in *rabi* 1997-98 majority of farmers who are buying tubewell water have landholding size of less than 5 acres (2.02 ha). Large farmers, with landholding size bigger than 12.5 acres (5.06 ha) are least interested in buying tubewell water, also because they own their own tubewells. The net value of production[7] of selected farmers, both tubewell owners[8] and farmers who rely on purchased groundwater, is calculated for *kharif* 1997. Information from 35 farmers (14 tubewell owners and 21 purchasers of tubewell water) of all the selected watercourses was collected about their total expenditure (except *abiana*) and income from the produce during the whole season. These 35 farmers were randomly selected from all the watercourses for collecting information regarding the input use. The income[9] from the produce of these farmers was calculated using the yield data and the actual prices for the crops marketed by these farmers. As expected, the average net value of production of the tubewell owners is significantly higher than the average net value of

publication of 1975: Appraisal of Initial Chemical Quality of Groundwater in Kot Adu Unit of SCARP III, 1972-74. SCARP Monitoring Organisation (SMO) Publication Number 78.

[6] In Freeman's (1978) study crop yields of wheat and cotton were respectively 1.3 and 1.8 times higher for farms with tubewells as compared to the farms with no tubewells. These results were based on the data from 40 watercourses in Pakistan.

[7] Net value of production is the gross value of production – input. Input here does not include *abaina* because of several practical reasons: 1) information about *abiana* (water rent) paid was not available, as farmers were not willing to give that information. 2) Very often farmers manage to pay much less *abiana* than they should pay by bribing patwari who assess the *abiana*

[8] Tubewell owners here refer to the farmers who have direct access to the tubewell water. It may include the owner of the tubewell himself or his sharecropper tenant who can operate the tubewell whenever he needs to irrigate his crops.

[9] This does not include the earnings of tubewell owners by selling water from their tubewells.

production of the purchasers of pumped groundwater. On average tubewell owners earned about 13000 Rs (325 US$) more than the farmers who were purchasing groundwater since the owners are much more flexible in pumping the water whereas purchasers depend on the willingness of the tubewell owners to sell water.

To compare canal water and conjunctive water, 8 farmers were taken from 3 watercourses-MD 1-R, MD 11-TC and FD 67-L. Farmers with similar cropping patterns in the two water use patterns were selected. Table 5.2 presents information about the farmers studied for this comparison of conjunctive water use. Most of the farmers who rely only on canal water for irrigation belong to the Mahmood Distributary as it used to get very good canal water supply before *kharif* 1997. Hence it was only possible to select farmers from only one Fordwah watercourse.

Table 5.2: Selected tubewell owners and non-users of groundwater, their tenancy status, cropping pattern and yields in *kharif* 1997 and *rabi* 1997-98

	Farmer	Tenancy Status[1]	Cropped area *kharif* 1997 hectares	Cropped area *rabi* 1997-98 hectares	Crops cultivated *kharif* 1997[2] (yield in tons/ha)	Crops cultivated *rabi* 1997-98[3] (yield in tons/ha)
Tubewell owner	MD 1-R 09	OC	2.83	3.23	Rice (4.6) Sugarcane (47) Fodder	Wheat (2.0) Sugarcane Fodder
	MD 11-TC 17	OC	2.78	2.78	Cotton (2.07) Sugarcane (48) Fodder	Wheat (3.53) Sugarcane Fodder
	FD 67-L 03	OC	2.88	3.03	Cotton (1.53) Rice (2. 59) Fodder	Wheat (2.29) Fodder
	FD 67-L 08	T	2.71	3.26	Cotton (1.19) Vegetable Fodder	Wheat (2.2) Vegetable Fodder
Non user of pumped water	MD 1-R 40	OC	0.81	0.81	Rice (2.46) Fodder	Wheat (2.95)
	MD 11-TC 02	OC	1.01	1.21	Sugarcane(26)[4] Fodder	Wheat (1.48) Sugarcane Fodder
	MD 11-TC 66	OC	2.18	1.52	Sugarcane (23) Fodder	Wheat (2.2) Sugarcane
	MD 67-L 28	T	0.81	0.81	Cotton (destroyed)	Wheat (2.07)

[1] OC is owner cultivator and T is sharecropper

[2] Figures in the brackets are yield in tons per hectare. For some crops and farmers this information was not available.

[3]The yield of sugarcane is unknown as it is a ratooned crop and was not harvested by the end of this research.

[4]Sugarcane grown in 20 % of his area was of very poor quality and therefore used as fodder.

Figure 5.1 presents the irrigation water requirement, calculated with the help of FAO software CROPWAT 4 for Windows, and mm of water (canal and groundwater) available to the farmers at the farm-gate[10] of tubewell owners and tubewell non-users. Therefore it was decided to choose farmers with different cropping patterns.

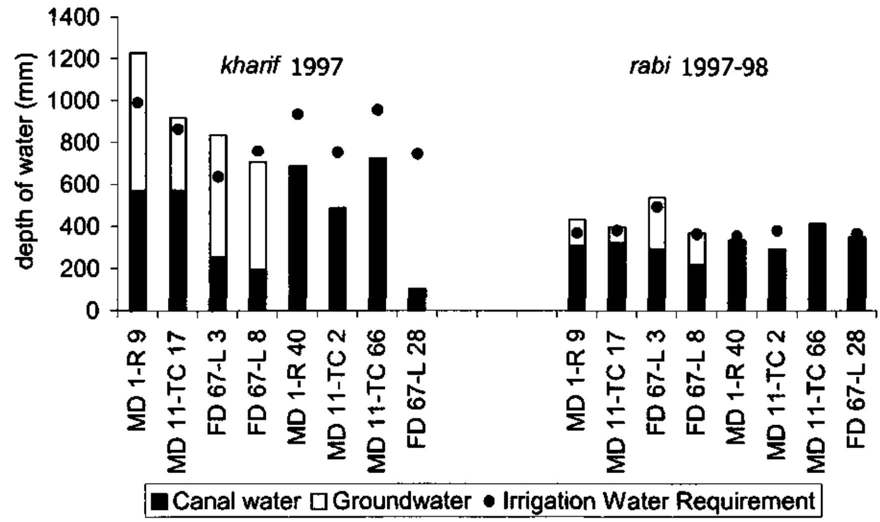

Figure 5.1: Irrigation water requirement and conjunctive water use by selected farmers in *kharif* 1997 and *rabi* 1997-98

There are two very striking things: one is that the irrigation water requirement of the farmers of one watercourse with two patterns of water use does not differ much specifically in *rabi* 1997-98; secondly non-users of tubewell water in Mahmood managed to get the same or greater canal water supply than the tubewell users in *kharif* 1997. With relatively higher availability of canal water they managed to prevent significant yield reduction. These are the farmers who are also more involved in the exchange of canal water turns. Another strategy they adapted was to concentrate on part of the crop that is growing better and use the rest as fodder, as was done by the farmer CID 11-TC 02 in case of sugarcane. He cultivated sugarcane on 0.5 hectares, when the crop cultivated in 0.1 hectare was almost damaged; he decided to use it as fodder for his cattle and irrigate the rest of the crop with the available canal water. Only one farmer, i.e. FD 67-L 28, has very little canal water supply. He grew cotton but when it was ruined through disrupted water deliveries, he gave away his water turn to other farmers in the watercourse command area. The tubewell owners could easily meet the gap between demand and supply and therefore benefited in terms of better yield[11]. The sugarcane yield of tubewell owners is about 94 % higher than the sugarcane yield of non-users of groundwater. The difference in the rice yield of the tubewell owners is not as big as for sugarcane. The difference is about 46 percent. However, only one non-user of tubewell

[10]Amount of water available at the farm-gate was calculated in the spreadsheet by volume balance method. Application efficiency is not considered in these calculations.

[11] It seems that the tubewell owners are over-irrigating their crops, which is not true. Part of this water is needed for application and distribution losses. In these calculations application efficiency is not deducted from the water available at the farm-gate. Therefore, actual water available for the crops is less than what is presented in the graph.

water for the analysis is growing rice. In *kharif* 1997, tubewell owners have more diversified cropping patterns as compared to the non-users of tubewell water, as they count on additional irrigation water at the time they plan which crops to grow. It seems that cotton is not widely grown by the farmers who do not use tubewell water - only 18 % of non-users of groundwater cultivated cotton. In the *rabi* 1997-98 cropping pattern, yield of the main crop(s), and the gap between water demand and supply is more or less consistent for all the farmers. In fact almost all the farmers are able to provide irrigation water to match evaporatranspiration demand of the crops cultivated. Although the use of pumped water was much less in *rabi* 1997-98, all tubewells owners did use groundwater for irrigation: they use it mainly during the canal closure.

5.3 WATER TRANSACTIONS

Water trading was studied separately for canal water and groundwater, as the trade of irrigation water from these two different sources is dealt with separately by the farmers. Canal water is mostly exchanged and not sold or bought. However, groundwater, since it is more expensive than the canal water, is formally sold or bought. Social relations matter in both canal and groundwater transactions, although actual exchanges are also limited by physical constraints. For example, groundwater cannot be transported upstream from a tubewell.

5.3.1 Canal Water

According to the Canal and Drainage Act 1873 (Nasir, 1993) water trading, that is defined as any kind of exchange of water turns or selling and buying of water turns, is forbidden, since the water turn is allocated to the land and not to the farmers. However, exchange of water turn is very commonly practised to cope with the uncertainty of canal water supply. A canal water turn is not sold unless it is really difficult to make use of it. Farmers who have more than one water turn in one watercourse command also swap turns for one parcel of land with the water turn for another parcel of land to consolidate time.

Two kinds of arrangements exist for canal water transactions: one is a more *ad hoc* arrangement and the other is more planned. In an *ad hoc* arrangement, if a farmer realises during or before his *warabandi* turn that he is not able to irrigate the desired number of bunded units which need irrigation, he borrows all or part of the water turn from another farmer. This borrowed water is given back in terms of time used and not in terms of quantity, nevertheless it is made sure that the difference in quantity is not very big[12]. More permanent arrangements are planned at the start of a crop season. Farmers having very small water turns (very often less than half hour), which is not enough to irrigate one bunded unit during one *warabandi* turn, give their water turn to another relatively bigger farmer for two to three weeks. They would then get a longer turn every third or fourth week depending on the deal. This deal is mostly made among the neighbouring farmers (Strosser 1997 found the same). Though this arrangement is considered beneficial for both the farmers, the quantity of water could not be compensated, so it is possible that the smaller farmer misses his longer water turn because of no supply and vice versa. That may be one of the reasons that this arrangement is not found in the watercourses studied, nevertheless 12 % of cultivators had a water turn of less than a half-hour. Most of these farmers are owner-cultivators having

[12] Farmers though they do not measure quantity, do have their own criteria to judge the quantity of water, for example if the watercourse is flowing at full capacity or is half full (Hoeberichts, 1996).

agricultural land of 1.0 acre or less, and exchange water turns very often with the neighbouring farmers who in many cases are relatives[13]. Such a small agricultural land holding and hence short water turn has implications on the cropping pattern as well, farmers can only grow one or at maximum two crops since the produce would not be significant if they cultivate more crops under small area.

Swapping of canal water turns was practised more in *kharif* 1997 in the watercourses along the Mahmood distributary whereas along the Fordwah distributary it was done more regularly in the *rabi* 1997-98. The reason is that *kharif* 1997 was a water scarce season for the farmers in the privileged Mahmood distributary that also has lower tubewell density per hectare. Therefore these farmers had to exchange canal water turns more often than usual. Whereas farmers of the Fordwah distributary have tubewells that could be used whenever additional water is needed. The high intensity of water exchanges in *rabi* is possible as when a farmer does not need water it could be used by another shareholder in the watercourse command area. The longer water turns are more often borrowed at the start of the season, when water is needed for pre-irrigation. A farmer can borrow a water turn from more than one farmer, and thus can have more than 4 hours of irrigation time in one *warabandi* turn. Since the water demand is low at the start of the season, also because of the different sowing dates of the same crops, farmers can give away full water turns.

Most often farmers exchange canal water turns for between 30 and 60 minutes. On average 28 % of time farmers borrowed water for 30 minutes or less during the year 1997-98, it occurs more often in the watercourses along the Mahmood distributary (33 % of time) as compared to the watercourses along the Fordwah distributary (22 % of time). Sometimes one farmer borrows a canal water turn from more than one farmer to be able to give pre-irrigation or irrigate a large area. These exchanges happen almost all year round, but it is easier to borrow longer canal water turns when not every farmer in the watercourse needs to irrigate. *Warabandi* in this case becomes flexible. Sometimes, the discharge at the mogha is so low that it does not reach the point where a farmer has his land, in which case another farmer upstream can use this water without returning this water turn.

Another kind of arrangement is the rotation among a group of farmers sharing one official *nakka* in the *warabandi*. Usually, each square in a watercourse command area has one official *nakka*: farmers having land in the square share this *nakka*. Officially, only one farmer within a square gives time to the watercourse to fill and only one farmer gets all the water from drainage. To distribute the filling and draining time equitably among all the farmers from one square, they rotate their *warabandi* turns. Each week, a different farmer irrigates first, hence each week a different farmer has the drawback of the advance phase, by filling the watercourse, and benefits from the drainage phase. These changes are made at the start of the season, and remain while a farmer does not object.

In some cases farmers even sell their full *warabandi* turn for the whole season. Two brothers in the watercourse FD 96-R, who also own land in another adjacent watercourse, sharecrop[14]

[13] Note that they exchange canal water turn on ad hoc basis, rather than more permanent or structural basis, because they are more aware of the quantity of canal water they will receive in this case.

[14] In fact they cultivated this land only in the first season studied that is *rabi* 1996-97, for the remaining two seasons they left this part of land as fallow. In *Rabi* 1996-97 they cultivated wheat, and the yield per acre from their field was 1.7 tons per hectare, that is 69 % of the average yield per acre in this watercourse for this season.

with the same tenant on the basis of 50-50. They sold out their irrigation water turn(s) of this watercourse for the full season(s) because of the following reasons:

- The elevation of their fields located at the tail of the watercourse command area is very high and the slope of the watercourse in the tail reach is very little. Therefore it is very difficult to irrigate these fields;
- These farmers buy sewer water for irrigation from the local council of the town and use it for irrigation - this arrangement is cheaper than the levelling of fields;
- They own a tubewell (out of command) that could be operated to pump groundwater whenever needed;
- These farmers also have side businesses hence have less time to take care of agriculture, therefore have a lack of interest in levelling the fields.

At the tail of watercourse FD 84-L four cultivators have sold out their irrigation turn mostly to other relatives in the command area because they rarely get water. The reason for this unavailability of canal water is the lack of maintenance of the main watercourse and low discharge at the *mogha*. Furthermore these farmers also have off-farm employment hence do not have enough time to mobilise resources and maintain the watercourse. They have direct access to groundwater and mainly cultivate fodder and cotton. In this case the benefit of collective action is not substantial according to the farmers hence individual action is taken. One of the cultivators is using canal water from another outlet.

5.3.2 Groundwater

In Pakistan groundwater is an open access resource, anyone can exploit it by drilling a tubewell in his/her land. Tubewell water supply gives better control over security of irrigation water supply in terms of quantity and timing, however not all the farmers have enough capital to install private tubewells. Another alternative to get access to groundwater at times it is needed is to purchase it from the tubewell owners. In the study area water users started to trade groundwater during the eighties. In this study about 39 % of groundwater users in the selected watercourses have direct access[15] to the groundwater (58 % in Fordwah and 19 % in Mahmood distributaries). However 61 % are purchasing pumped water (42 % in Fordwah and 81 % in Mahmood). Sometimes, the tubewell owners also have to buy pumped groundwater if i) the tubewell is temporarily out of order; or ii) irrigation water requirement is so high that it can not be fulfilled by operating only his own tubewell; or iii) the quality of his tubewell water is hazardous for crops and soil.

Access to groundwater for non-tubewell owners primarily depends on the need of the owner to use it. A tubewell owner will be willing to sell water if he himself does not need water from his tubewell. Three kinds of arrangement for groundwater trading are found in the study area depending on many factors. The first is to pay money to buy water, which is mostly by flat rate per hour to the tubewell owner. The amount to be paid depends on several factors that will be discussed later. A second way is to bring ones' own fuel and use the tubewell: this arrangement is based on social relations of the involved farmers. A third way is to use ones' own tractor to pump the water. One can argue that the second and third kind of trading is not trading since there is no money involved and the owner of the tubewell does not get any material thing in return. However, the buyer has to invest money in buying diesel. Also the

[15] This includes tubewell owners, lessees who have rented in land with an installed tubewell, or tenants who could operate an installed tubewell anytime and then share the cost with the owners.

owner of the tubewell does get some respect if he allows others to take some material benefits from his tubewell. The reason for listing the last two kinds of arrangements is to show all the possibilities of access to groundwater for non-tubewell owners. Meinzen-Dick (1996) carried out a study on water markets in Pakistan and also found a share of crop as a mode of payment for groundwater purchase, though this was only found in North West Frontier Province (NWFP) and not in Punjab.

In the first kind of arrangement, the price of pumped water[16] varies and is dependent on the discharge, type of tubewell, quality of groundwater, price of the diesel used etc. The price of pumped groundwater sold in the selected watercourses ranged from 30 Rs (US $ 0.75) per hour to 120 Rs. (US $ 3) per hour. The discharges of the tubewells used for water trading were in the range of 7 l/s to 50 l/s. The second and third kinds of arrangements are mainly dependent on the social relations of the farmers involved. These arrangements usually exist among brothers and other relatives. If the relations are good and the owner is not using the tubewell then the farmer in need can pump water.

To summarise there is no strict procedures for buying or selling of groundwater. Many physical and social factors influence farmers' preferences for selling or buying from a particular tubewell. A buyer would prefer to purchase:

- Groundwater from a tubewell that is close to the land to be irrigated to avoid conveyance losses,
- Good quality groundwater. There is always a trade off between the quality and the price though. Sometimes farmers decide to use cheap water of marginal quality to save some money, and
- Groundwater from the seller with whom he has good relations. In case of a dispute, a seller may turn down the request of buyer.

5.4 INSTITUTIONAL INTERVENTIONS: WATER ALLOCATION STRATEGIES

Warabandi is the only written proof of the canal water right in a *warabandi* system since water is allocated to land and not to the farmers in form of time per acre. This method of time-sharing was adopted to make water allocation equitable, and the procedure to distribute water transparent. Sometimes farmers try to get some individual benefits out of this transparent system of water allocation.

Figure 5.2 a presents the percentage difference of the water allocated to the individual landowners with the official water allocation in minutes per acre according to the official or *pakka warabandi*[17]. Though water allocation to the individual landowners in the selected watercourses is reasonably equitable, and generally water users do not complain about the *warabandi*, there are still some institutional interventions that are interesting to study. Water allocation for about 85 % of the landowners is within 10 % of the official water allocation in minutes per acre. Most of the landowners are receiving slightly higher number of minutes per

[16] Tahir (1997) found that in Chishtian sub-division the main factors that influence price of groundwater are the type of tubewell, quality of tubewell water and tubewell density within a watercourse. Cropping patterns, as a major demand factor, also influence price of groundwater.

[17] These farmers may not be the actual cultivators of the land, some of them may not even be alive anymore. Since they are official owners of the land, they have official right to use this canal water.

acre than the allocation (Appendix VII presents the way water is allocated by a *patwari*). While, the reasons for some of these discrepancies in water allocation are not really known they are well accepted by other farmers in a watercourse command area[18]. In most of the cases when a farmer's allocation is greater than the official allocation in minutes per acre, it is because a *patwari* gave away left over minutes to these farmers.

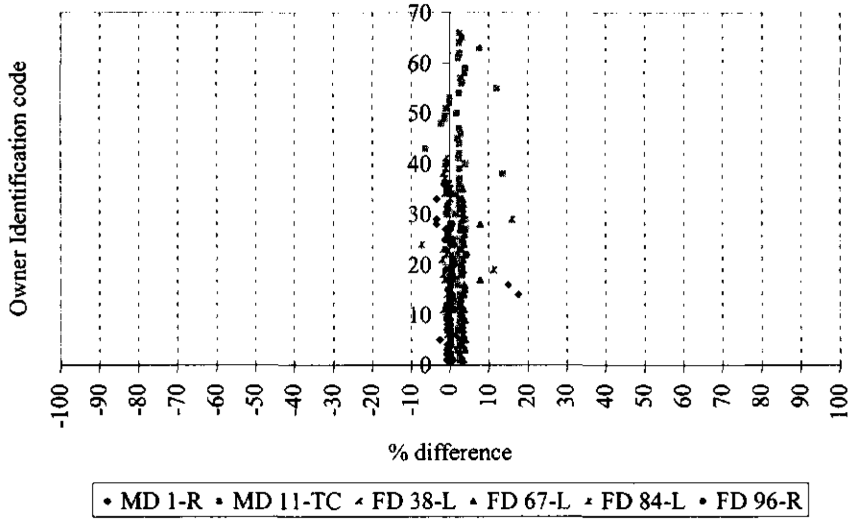

Figure 5.2a: Variation in official time allocation to individual landowners in six selected watercourses. Variation is presented as the percentage difference of individual official allocation (minutes per hour) with the average official allocation (in minutes per hour) of the respective watercourse

The agreed upon *warabandi*, which is the real water distribution schedule used by the farmers also shows more or less same pattern. Figure 5.2 b presents the variation in the percentage difference of the canal water turn time (in minutes per acre) allocated for cultivators with the official allocation (in minutes per acre). The time allocated for cultivators is within 10 % range of officially allocated time in minutes per acre[19]. More extreme deviations - that is higher than 10 % of the officially allocated time for an acre - in the official *warabandi* have disappeared in the agreed upon *warabandi*, largely because the extra time that was allocated to one land owner is distributed among more farmers either through tenancy or inheritance.

Large variations in the water allocation of agreed upon *warabandi* are due to the trade of the canal water turn and use of water allocated for the Government property. While former has already been discussed in the section 5.3, the latter will be discussed later in this section.

[18] The *patwaris* who made these *warabandis* are no longer in the area therefor it was difficult to really find out the reason of these few discrepancies. Even farmers can not explain it.

[19] These small deviations within 10 % are even minimised because most of the farmers are practising rotation within the square (see section 5.3.1 for rotation).

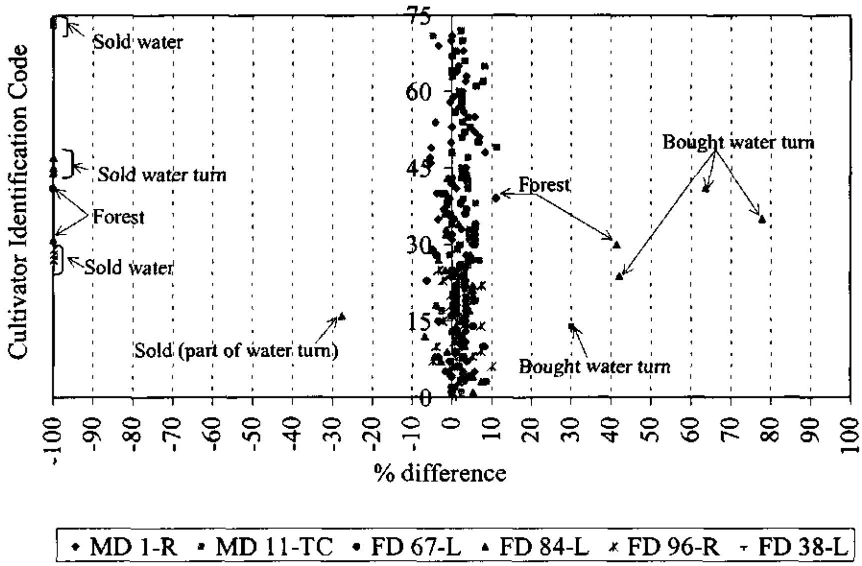

Figure 5.2b: Variation in time allocation to individual cultivators in the six selected watercourses. Variation is presented as the percentage difference of individual allocation (minutes per hour) with the average official allocation (in minutes per hour) of the respective watercourse

The main water allocation strategies found in the study area are: (i) combining different irrigation water turns, and (ii) use of canal water allocated for orchards and Government property for irrigating crops.

5.4.1 Combining Different Irrigation Water Turns

A farmer can have more than one irrigation water turn in one watercourse, depending on the location of the parcel(s) of land he cultivates. He can use this water turn to irrigate any of the parcels and any crop. However if a farmer wants to swap one water turn with the other he has to take care of the schedule of the rest of the *warabandi*. Officially he is supposed to give water to the farmer having the next water turn in the schedule at a fixed *nakka*. In practice if he wants to disturb the *warabandi* schedule he has to communicate with other farmers, and try to change the order of turns in a way that he could use this water on the parcel of land for which this water turn is not granted. Sometimes, farmers try to get a combined official water turn for parcels of land that are close but not adjacent. In some cases it is even difficult to get what a farmer perceives his legitimate official right. He has to make physical financial efforts in order to get his right. Box 5.1 explains the effort of individual farmers to get a combined water turn and to safeguard water rights in terms of time allocation. However, in both cases the intermediary that was used was money. These kinds of efforts are mainly made by Owner Cultivators since they are the legal right holders of canal water. Besides Tenants or Lessees do not have to deal with the official water allocation, and discuss these things with the landowner when they finalise the tenancy contract.

Box 5.1: Individual efforts to make localised minor changes in official *warabandi*

Trying to get a combined water turn for different parcels of land
In the watercourse MD 1-R, *warabandi* was changed on 13-05-97. CID 09 and CID 10 both belong to one *biradari* and are relatives and both had more than one water turn (CID 09 had two water turns and CID 10 had three water turns) in the watercourse command area. They wanted to combine two water turns into one in order to be able to have more control over this water and use this water more efficiently. Therefore they requested the *patwari*, who is responsible for the *warabandi*, and the SDO to make adjustments in the *pakka warabandi* several times but nothing happened. Recently they again asked the *patwari* who suggested that if these farmers paid something in cash then the changes could be made. However officially *patwari* is not supposed to get any money from farmers to make any change in *warabandi* at farmers' request. Changes were incorporated after the payments were made. Now CID 9 has one water turn instead of two and CID 10 has 2 water turns instead of one, which is more practical in terms of management and efficient use of water.

Trying to get perceived right of water turn time
CID 58 in the watercourse MD 1-R owns two parcels of land and therefore has two water turns. The time allocated to him for both the water turns is less than the official allocation of 29 minutes per acre (29 minutes per acre). He was getting 28 minutes per acre for one parcel and 24.8 minutes per acre for the other parcel of land (Appendix VII explains how the *patwari* allocates water). Therefore in total he was losing 5.20 minutes. He started making efforts to get his right but it was difficult in the beginning. Then he tried to use money as intermediary and it worked. He had to pay Rs 1500 (approximately US $ 33) to get his 5 minutes back. It was also not easy for the *patwari* to do it since he had to extract these five minutes from water turn of others farmers as every minute in the week is allocated. Now CID 58 is getting 28 minutes per acre on one parcel of land and 30 minutes per acre on the other parcel of land, which on average is 29 minutes per acre.

Some farmers (including CID 49, 57 and 27) have objected to this change since their water turn time is reduced. However, no one took any action to stop this change perhaps because they knew that they were wrong, they had taken this water illicitly. Besides they have to pay some money again to the *Patwari* to get this water back.

5.4.2 Use of Canal water Allocated for Orchards for Irrigating Crops

Some farmers also use canal water allocated for orchards[20] for irrigating crops. If a farmer plants orchards he gets a double water allocation for that plot. However, they first have to plant the trees and get it inspected by the Irrigation Department officials in order to get water allocated for the orchards. In many cases the orchards disappear after few years but the water allocated remains and hence some farmers get extra water for their crops. When the trees are still small farmers grow other crops, like wheat and fodder, in the fields.

Moreover, sometimes farmers use part of the irrigated land for non-agricultural purposes - for instance for the construction of a (farm) house - but the water allocation for this part of land remains and is used for another piece(s) of agricultural land. However in some cases, like in the watercourse FD 96-R, other farmers complain about this situation to the Irrigation Department. As a result this water is subtracted from the water turn of the owner and

[20] Recently in 1999, the Government of Punjab has announced that no further special allocation will be made for orchards because of the water scarcity and illegal use of canal water. The question now is whether they take back already allocated extra time for Orchards?

distributed among all the shareholders of the command area. This actions is seen more in the watercourses along the Fordwah distributary since farmers along the Mahmood distributary already get enough water hence they do not need to put efforts into such activities.

Three farmers - CID 18 and CID 19 in the watercourse FD 96-R, and CID 26 in the watercourse FD 67-L – have allocations for Orchards as though they are cultivating crops in those fields. They are all owner cultivators and only one has direct access to groundwater. The other two buy groundwater if needed - which is not very often because of the longer canal water turn with the 'Orchard allocation'. Had these water users not had this extra time allocation they would have had to buy groundwater every time they needed this water. A rough estimate tells us that farmer CID 26 would have spent RS 4000 (US$ 87) and farmers CID 18 and 19 would have spent RS 3000 (US$ 75) each time in order to get the same volume of groundwater. Whereas now each one of them has to give approximately RS 330 (approximately US$ 8) per year as "*abiana*" (water fee) for orchards. Farmer CID 26 mainly cultivates sugarcane, wheat and cotton; farmer CID 19 cultivates cotton, wheat and fodder but farmer CID 18 cultivates only fodder. The reason for this is that CID 18 and 19, who are brothers, both have dairy farms and therefore they cultivate fodder, which could also be sold in the nearby market if in surplus.

5.4.3 Allocation for the Government Property

Sometimes a *pakka warabandi* schedule also includes time allocation for a Government property, e.g. a school, a forest, a guesthouse etc within a watercourse command area. However in reality these Government properties hardly get any canal water as it is used by farmer(s) within a watercourse command area. In most cases users of these water turns have to pay something in kind or cash for this additional water to the person responsible to take care of this Government property.

In two of the selected watercourses, FD 67-L and FD 84-L, 60 minutes and 69 minutes respectively are allocated for a forest and a school. A Lessee, CID 39[21], is using the canal water allocated for forest in FD 67-L and owner cum cultivator CID 30, is using water allocated for forest in the watercourse FD 84-L during the study period. In the case of FD 84-L the farmer gives fodder in return to the irrigation staff responsible for this water whereas in case of FD 67-L the farmer gives cash. Both the water users have direct access to groundwater (one through ownership and the other through the tubewell owned by the landowner) and are full time cultivators, growing sugarcane, wheat and cotton.

5.5 PHYSICAL INTERVENTION: ACQUIRING MORE AND REFUSING SURPLUS CANAL IRRIGATION WATER

Farmers intervene physically with the system in both situations when they need more water for irrigation, and also when canal water supply is present but not needed for irrigation. The former is mostly done during the period of peak crop water requirement, and the latter during the rainy season or at the end of the crop season.

[21] He stopped giving us data at the beginning of *kharif* season because of some problems with another project of IWMI in the area. We tried our best to convince him but did not succeed. However, he remained nice and hospitable with us throughout the research period but refused to give data to us since we were representing IWMI.

5.5.1 Water Acquisition

Individual farmers who do not want to spend their resources in relatively long-term solutions for water scarcity – such as *mogha* enlargement or tubewell installation - sometimes decide to physically intervene with the system. The preferred point of intervention varies depending on location of the *mogha* or more precisely farm location along the distributary.

Water acquisition at the distributary level

Farmers who have power and access to resources to acquire additional canal water intervene at the distributary level. Some efforts are easier to make if a farmer is living along a smaller distributary or at least close to the head of the distributary. For example it would be difficult for farmers living at the tail of a long distributary to go to the head of the distributary to arrange additional water. Whereas a farmer living at the tail of a smaller distributary could walk up to the Gauge Reader (Irrigation Department staff member responsible for the operation of the gates of the distributary) and request to increase the discharge in the distributary.

Water users along the Fordwah distributary mostly acquire water at the watercourse level while in Mahmood distributary individual efforts to acquire additional water are more geared towards the distributary. Such an individual action would benefit all since this water would be distributed to all the ungated outlets. Still it takes much less effort compared to siphoning. The Gauge Reader has also rented in some agricultural land in one of the head watercourses of the distributary hence a social pressure is there on him to grant the request from the fellow farmers. The Gauge Reader is considered as a friend by the farmers and is not paid in cash for the services he provides to the farmers in terms of additional water. According to farmers they give him fodder as a token of friendship that he could use for his cattle. This way of appreciation is not seen as a bribe. In return he usually keeps the gate of the Mahmood distributary fully open. Supply patterns in the past show that the flow is more stable for the Mahmood distributary compared with two other two tail distributaries (Habib and Kuper, 1998).

Blocking the whole distributary is another way of getting additional water for irrigation in Punjab's feudal system. Big landowners block the whole distributary and take as much water as they want for their crops. After these big landowners are satisfied only then small farmers downstream could get irrigation water. On one the hand the big landowners do this to get additional water for irrigation. On the other hand it is the matter of their honour or "*izzat*", though this *izzat* they gain is out of fear and is what Merrey (1979) calls false *izzat*. A farmer may also do it to prove that he is not weak, or out of stubbornness. Sometimes the same farmer who is indulged in this act of water stealing by blocking the whole distributary could have a completely different image in another distributary command area. Box 5.2 gives an example of such a person.

Box 5.2: Blocking the distributary for honour

Farmer X is a landowner in one of the watercourse along Mahmood distributary and has also leased in land in the watercourse MD 11 TR that is adjacent to the command area of watercourse MD 11 TC. He visits the watercourse MD 11 TC very often since he is a relative of the *Numberdar* (person responsible for collecting *abiana*) of the village and is considered a very helpful and kind person by the farmers of MD 11-TC and MD 11-TR. He gives loans to the farmers in need of money and helps them in negotiating for more water with the Irrigation Department staff since he is an influential person. When asked what he gets out of it, he said that he gets respect and trust of the farmers in this watercourse. If he needs help in terms of labour he could easily get it; farmers in this watercourse command area help him with labour in case his servants are not available. This interdependency is not seen by the other farmers like this, they however feel obliged by the fact that they get help from Mr. X when they need it most, therefore they should help him when he needs them.

However the same farmer X now and then blocks the whole distributary to fulfil the perceived irrigation water requirement of his crop. The justification he gives of this act is that along the bigger distributary where he owns land he has to show his strength to fellow big landowners along the distributary. Therefore he uses force to take what he considers his share of water. According to him if he does not do it there he loses his pride and other big landowners will consider him a weak person and he would most probably be deprived of his share of canal water.

Water acquisition at the watercourse level

Unpredictable supplies of canal irrigation water make farmers take some actions to ensure that they are able to irrigate the bunded units needing irrigation in one irrigation turn. Use of tubewell water and/or exchange of canal water turns are two options to ensure crop water requirements. However some farmers opt to take temporary control over irrigation infrastructure and decide to intervene physically with the system.

Siphoning

Farmers having their water turn in the night can take advantage of the dark and dare to steal the water by putting a pipe in the distributary, hence increasing the total amount of water in the watercourse. The diameter of the pipe depends on the farmers' choice and could be influenced by various factors. If a farmer needs more water he will use a bigger diameter. The ease with which a pipe could be installed, and removed depends on the available labour for that particular water turn, and also influences choice of pipe diameter. Pipes with diameters of 4 inches (about 10 cm) and 6 inches (about 15 cm) are more commonly used. According to the Canal and Drainage Act of 1873 the punishment for water theft is a fine of up to Rs. 200 and imprisonment for up to three years. The Irrigation Department can fine the farmer and report the matter to the police, and the Police can arrest the farmer who stole the canal water. Very often a farmer manages to escape punishment by paying some money to the police or with the help of some influential person, even if the Irrigation Department files a case at the police station. These cases are hardly registered at the police station[22]. Moreover, the fine that a farmer has to pay in case he is charged of water theft is much less than the profit he would

[22] During *kharif* 1998, 4000 water theft cases were reported in the whole Punjab, 1400 cases were registered while only 150 arrests were made (DAWN-the international edition, 4 June 1999).

likely gain by this extra irrigation water[23]. According to some of the staff of Irrigation Department since police hardly takes any action against the farmers stealing water, they have also lost interest to report incidents and do not bother about water theft anymore (personal communication with the Sub-Engineer Irrigation Department, 1998).

In the study area the watercourses that have more collective action and better water supply conditions have less water theft through siphoning. However, logically it seems reasonable that a higher number of cultivators and small operational land holding size in a watercourse command area would be more likely promote localised individual actions for water acquisition that mainly includes siphoning. A small operational land holding size means a small water allocation in terms of minutes per acre, which sometimes is not enough even to irrigate one bunded unit. Also a short duration of water turn could stimulate the theft of water from the distributary since farmers would like to irrigate one full plot during a water turn. However, this supposition seems untrue for the study area, since siphoning was only found in two out of six selected watercourses. One of these two watercourses, FD 38-L, has only two cultivators, with big land holding sizes and long water turns. Whereas the other watercourse, FD 84-L, has many farmers, with small land holding size but reasonably long water turns and comparatively poor water supply. Perhaps, a long water turn is needed to install an illegal pipe in the distributary.

The overall increase in irrigation water attained from different sources plays a vital role in the crop production strategies and water management practices at the farm level. For instance if a farmer has an opportunity to get good quality water from a cheap source even if it is illegal to do it, he would use it in preference to water that is expensive but legally allowed. The longer breaks in the canal water supply also lead to illicit water acquisition practices by the farmers. Table 5.3 gives an overview of the canal water supply and different water management actions at farm level undertaken by individual farmers in one of the watercourses FD 38-L, along the Fordwah distributary. Research could not define the amount of water acquired through siphoning from the distributary[24]. The supplementary water helped them to achieve a sugarcane (the main cash crop in the watercourse command area) yield 36 % above average (39 % for farmer 1 and 34 % for farmer 2). This water siphoned from the right of other watercourses downstream disturbs the water distribution of the distributary and deprived other farmers of their rights. Long breaks in the water supply during the *kharif* 1997 created a kind of mistrust and farmers started to get involved with illicit practices to fulfil the loss of water in earlier weeks[25]. Later in the season whenever they received an irrigation turn they continued to acquire additional water in the same manner and hardly operated their tubewells, perhaps because there is almost no check on these kind of practices from the Irrigation Department or any other law enforcement agency. Because there were only 2 shareholders in

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[23] Recently in 1999, the Government of Punjab has increased this punishment which now is a fine up to Rs 5000 and imprisonment up to three years, or both. It would be interesting to see if the Government is able to enforce these punishments in the political system of Punjab.

[24] Permission to measure the discharge through siphoning was not granted by the farmers, although they were open about being involved in this activity. The frequency of occurrence of siphoning was recorded during the study period. In some cases the diameter of the pipe used to take water from the distributary is known but other information is also needed in order to be able to estimate the amount of water acquired through siphoning.

[25] In the first monitoring season *rabi* 1996-97 siphoning was not reported during the monitoring of water distribution. One of the involved farmers in this watercourse is an owner-cultivator and the other is a lessee. The lessee was changed after *rabi* 1996-97 (in April 1997), the former lessee said that he did not steal water. However it could not be verified as the reason he did not siphon might also be low crop water requirement in *rabi*.

the watercourse practices have no effect on any other farmer within a watercourse command area hence local farmers were bothered to take any action against the thieves.

Table 5.3: Water management actions of individual farmers from the watercourse FD 38-L over time

			MM OF CANAL WATER		ACTIONS TAKEN BY THE FARMERS	
			Farmer 1	Farmer 2	Farmer 1	Farmer 2
Kharif 1997	April 1997	Wk1	5.4	5.4		
		Wk2	0.0	0.0	TUBEWELL	
	May 1997	Wk3	0.0	0.0		
		Wk4	7.0	7.0	TUBEWELL	
		Wk5	0.0	0.0		TUBEWELL
		Wk6	14.3	14.3		TUBEWELL
	June 1997	Wk7	0.0	0.0		
		Wk8	0.0	0.0	TUBEWELL	TUBEWELL
		Wk9	0.0	0.0	TUBEWELL	TUBEWELL
		Wk10	0.0	0.0	TUBEWELL	TUBEWELL
	July 1997	Wk11	0.0	0.0	TUBEWELL	TUBEWELL
		Wk12	0.0	0.0		
		Wk13	0.0	0.0	TUBEWELL	
		Wk14	0.0	0.0		
		Wk15	24.2	24.2	**SIPHONING**	**SIPHONING**
	August 1997	Wk16	0.0	0.0		
		Wk17	0.0	0.0		TUBEWELL
		Wk18	25.6	25.6	TUBEWELL	TUBEWELL
		Wk19	27.0	27.0	**SIPHONING**	
	September 1997	Wk20	23.7	23.7	**SIPHONING**	**SIPHONING**
		Wk21	22.7	22.7	**SIPHONING**	**SIPHONING**
		Wk22	26.0	26.0	**SIPHONING**	**SIPHONING**
		Wk23	7.7	7.7		**SIPHONING**
	October 1997	Wk24	15.2	15.2		
		Wk25	26.1	26.1		
		Wk26	22.4	22.4		
Rabi 1997-98		Wk1	21.3	0.0		
		Wk2	0.0	0.0		
	November 1997	Wk3	0.0	0.0		
		Wk4	20.2	29.6	**SIPHONING**	**SIPHONING**
		Wk5	22.3	22.6		OUTLET CLOSED
		Wk6	24.7	25.9		
	December 1997	Wk7	23.0	23.9		
		Wk8	23.9	1.9		
		Wk9	14.4	20.5		
		Wk10	15.7	6.4		
	January 1998	Wk11	14.5	0.0		
		Wk12	0.0	0.0		
		Wk13	0.0	0.0		
		Wk14	0.0	0.0		
		Wk15	0.0	0.0		
	February 1998	Wk16	0.0	15.6		
		Wk17	17.6	18.4	OUTLET CLOSED	
		Wk18	29.9	27.2		OUTLET CLOSED
	March 1998	Wk19	0.0	12.5	OUTLET CLOSED	
		Wk20	16.2	22.9		
		Wk21	15.5	22.8		
		Wk22	21.0	21.7		OUTLET CLOSED
		Wk23	28.3	25.4		
	April 1998	Wk24	28.7	32.6		
		Wk25	25.2	32.6		
		Wk26	0.0	0.0		

Siphoning was mostly done in *kharif* season, which was also irregular in terms of canal water supply because of the damaged link canals. Siphoning is usually done in response to the uneven and inadequate canal water supply. There are no clear pattern why farmers are undertaking siphoning since:

- The number of farmers involved in this activity is limited, only 8 % of the total population in the selected watercourses,
- There is no exception to the tenancy status since Owner Cultivator, Lessee and Share-cropper all are involved, and
- Tubewell ownership also does not seem to have any influence since 75 % of the farmers involved are tubewell owners.

In addition to siphoning, some farmers try to increase the working head by putting some grass or bush downstream side of the *mogha* to get higher discharge into the watercourse when water in the distributary is less than the normal. Though this activity is not very common it happened a few times during the study period specially during the month of July 1997 when the irrigation requirement for rice is very high in watercourse MD 1-R, along Mahmood distributary. A farmer usually takes this action during his water turn - however he does not always take out the bushes afterwards. Usually every farmer goes to the head of the watercourse just before the start of his water turn to check the water level in the distributary or otherwise ask about it from the farmer irrigating his field before him. In both the cases he would know if someone has tried to increase the working head and if the water level in the distributary increases he would remove the bushes. It may be possible that not all the farmers have intentions of intervening with the system like this but they take advantage of the prior action of a fellow farmer. Unfortunately the researcher does not have information about who was involved in this activity since almost everyone benefits from it and farmers were not always willing to tell about these things, though it was observed and noted every time it happened.

Using multiple water sources

Figure 5.3 shows irrigation water requirements and irrigation water used from different sources by MD 11-TC CID 14: a buyer of canal water. The ratio of his water use is 68 % supplied (including his borrowed and given water), 11 % bought[26] (canal water) and 21 % groundwater. The over-irrigation shown in October is in fact the pre-irrigation for wheat. Sometimes when farmers acquire additional canal water that is much cheaper as compared to pumped water, they also over irrigate their crops. It also happens that when farmers do not get water during one water turn they try to compensate later by irrigating for longer than is required. Beside some water is required for application and distribution losses. That is also the case with this farmer, as application efficiency is not considered in the estimation of water available for irrigation at the farm-gate. Farmer CID 14 managed to reduce the gap between demand and supply, by buying canal water turns from other farmers and operating his tubewell. However, the total amount of irrigation water needed during the whole year is much higher than the amount used (1372 mm required and 934 mm used). Operating a tubewell more often could have filled this gap between the canal water supply and demand. However,

[26] CID 14 bought canal water turn of a farmer, CID 74) who had land at the tail of the watercourse. Some fields of CID 74 are elevated because of which he could not irrigate. He also did not want to invest in land levelling, therefore he sold out his water turn. Another farmer sold out his *nikal* time (time to drain water from a watercourse after it is blocked form upstream) of one hour to CID 14 because of the same reason.

perhaps operating tubewell for cotton may not have been recovered from cotton yield. He used pumped water from his tubewell to irrigate crops grown on his land which was in another adjacent watercourse. By doing so he managed to prevent any crop failure in *kharif* 1997, and gave priority to irrigate rice and then sugarcane. Hence, the yield[27] of his rice crop is 2.73 tons/ha that is nearly the same as the average yield in the watercourse command area, which is 2.72 tons/ha. Sugarcane and cotton yields are 18.5 tons/ha and 0.217 ton/ha. These are much less than the watercourse average yield of both the crops, which are 34 tons/ha and 0.94 tons/ha for sugarcane and cotton.

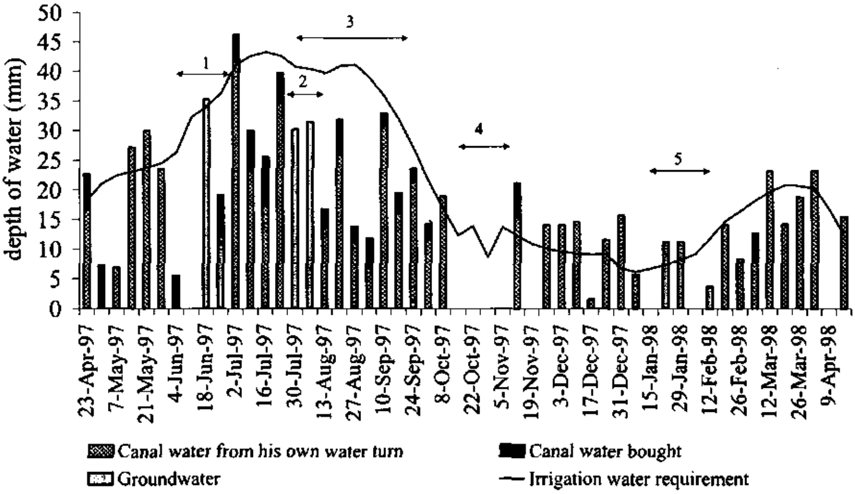

Figure 5.3: Irrigation water requirement and use of irrigation water obtained from different sources by farmer CID 14 of the watercourse MD 11-TC. He cultivates 8.96 hectares of land out of which he owns 1.92 hectares, rents in 5.97 hectares and sharecrops 1.06 hectares. He also owns a tubewell. 1: problems in canal water supply because of damaged link canal. 2: distributary closed because of rotation. 3: *mogha* adjusted and discharge of the distributary reduced. 4: canal water drained in *budh* because of early harvesting of cotton, crop water requirement is still calculated by the CROPWAT. 5: Annual canal closure

The financial rewards of water acquisition

The previous paragraphs in this section have outlined farmers' individual efforts to acquire additional water for irrigation. Although with available data it is not possible to show actual financial rewards of individual action for water acquisition, an effort is made here to get an idea of the magnitude of benefit in terms of money. An estimate has been made to find out how much money a farmer would have had to pay if he used the same amount of groundwater. Table 5.4 gives an overview of the individual actions related to water acquisition and gain and loss as an outcome of their activities. For siphoning and installation data were not available to estimate the actual cost spent and benefit achieved for one year.

[27] This yield is of the crop from the command area of the sample watercourse.

The special allocation for orchards, and use of canal water allocated for Government property, is the cheapest source of supplementary canal water for irrigation, Although this is only possible in command areas where there are allocations for Government property. The orchards could create some disagreement between the shareholders since this water could be distributed equally within the watercourse command area. The next cheapest option is exchange and trade of canal water- although it also depends on some agrarian factors and physical conditions of the fields of seller.

Table 5.4: Rewards of farmers' individual actions to acquire additional irrigation water (April 1997-April 1998)

Actions taken to acquire additional water	Farmer (OLHS)[1] in hectare)	Amount of water gained in one year (m^3)	Time required to operate Tubewells for equivalent water (hrs)	RS/$ spent on this activity Loss	Equivalent RS/US$ for acquiring groundwater	Difference RS/US$ Gain
Canal water buying	MD 11-TC 14 (8.96)	5748	60	1000/25	4000/100	3000/75
Special Allocation for Orchards	FD 96-L 19 (1.06)	3248		230/6[2]	3400/85	3170/79
Allocation of Government property	FD 84-L 30 (1.74)	2838	57	In kind (fodder)	2000/50	
Siphoning[3]						
Groundwater purchase		1000[4]			813/20[5]	
Perceived right of water[6]						
Capital cost (Tubewell Installation)				18000/450[7]		

[1] Operational Land Holding Size
[2] This is the *abiana* (water rent that he had to pay for)
[3] Estimation of water obtained through siphoning was impossible since farmers did not allow to measure that water
[4] It is not the volume of water gained by a person but to make calculations practical and comparison easier 1000 m^3 is taken as reference
[5] Average price of 1000 m^3 of groundwater purchased. Average for Mahmood and Fordwah watercourses is Rs723/US$18 and Rs872/US$22 respectively
[6] Estimation of total volume of water gained by getting additional 5 minutes was not possible because of fluctuating canal water delivery and inconsistent length of water turns
[7] This is the total cost of tubewell installation for year 1996-97.

Groundwater acquisition, though the most common source of additional water for irrigation is the most expensive individual activity The main reason for its popularity is far better water control in terms of timing and quantity in comparison with the canal water since its availability is purely supply oriented. Moreover, it is more easily accessible to more farmers as compared to the water attained through institutional or physical intervention that is very often illicit and hence could create some problems.

5.5.2 Refusal to Surplus Canal Water

Closing of the *mogha* is illegal and may cause a breach in the distributary. However, in the absence of drainage infrastructure sometimes farmers have to close their *mogha* to make sure that undesirable irrigation water does not destroy their crops. This happens mostly during the monsoon rains or during the harvesting periods when farmers do not irrigate their crops. Farmers at the extreme tail of the distributary cannot close the *mogha* since water cannot flow further downstream. These farmers are left with three choices: (i) irrigate their crops that would cause over irrigation and may damage the crops, (ii) dump all the water in a water-logged area fields (if there is one), and (iii) complain to the concerned Irrigation Department staff and request for either reducing the inflow or shutting down the distributary. Option (iii) is not practical for tail farmers of longer distributaries, since the time lag between the shutting down of the distributary and its of effect at the tail[28] is too long[29]. When farmers would need water again it will take a long time to reach the tail. Besides, during this time lag (when distributary is opened again and the water reaches the tail) some farmers would miss their water turn and will again have to wait for seven days for their turn to irrigate. Option (ii) is also not practical for the distributaries without a water-logged area within or adjacent to the tail watercourses. This only leaves with the option (i) for those farmers having no water-logged area for water disposal. Farmers choose an option that is appropriate to their situation.

The tail of the Fordwah distributary was dry for more than half of the time during the study period[30]. Recently in Fordwah distributary one farmer in the tail reach of the distributary has tried to store unwanted water in a small reservoir and used it with the groundwater later though it was done in a small watercourse with only one land owner. It is difficult to say that if this would work in the watercourses with more shareholders since later the distribution of this water may cause conflicts among the shareholders.

Farmers from the tail of smaller distributaries have the great advantage of smaller time lag and quick access (in terms of shorter distance) to the Gauge Reader or higher level Irrigation Department officials. Whenever it rains any farmer can go to the Gauge Reader and requests him to close the distributary, it is also easier for the Gauge Reader to divert the relatively less discharge of the smaller distributary to the bigger distributary. In Mahmood distributary it is easier to do so since the Gauge Reader is considered as the farmer and a friend rather than a representative of Irrigation Department. The Gauge Reader himself also feels closer to the farmers since he almost lives among them and knows their problems and worries.

[28] In some of the distributaries the time lag is as long as three days

[29] Distributaries at the tail end of the system cannot be just closed like this as they can cause a breach in the main canal hence the Irrigation Department staff of the Sub-Division has to communicate with the staff upstream and request them to release less water. Officially Irrigation staff are supposed to prevent any breach in the main or branch canal even if it is at the cost of breach in the distributary(ies) since it is more difficult to repair the main branch as compared to the distributaries. Besides a breach in the main or branch canal would cause more damage than a breach in a distributary.

[30] In fact tail of Fordwah was dry for about 70 % of the time in first two seasons of the study period, *rabi* 1996-97 and *kharif* 1997. This situation considerably improved in the last season when the tail was dry for only 30 % of the time. Hence the overall dry days were 55 % of the time during the whole study period.

Sometimes farmers also drain all this water in a water-logged area or field[31], which enhances an existing water-logged situation. Farmers in one of the selected watercourse MD 11 TC have access to a water-logged area that is the old river bed locally called "*budh*" of river Sutlej. Hence if a farmer decides not to irrigate his field and he knows that other farmer(s) may need to irrigate he just leaves the water to flow in the watercourse that leads to *budh*. Figure 5.4 shows different options used by farmers in the selected watercourses along Mahmood distributary to deal with surplus canal irrigation water during the study period and the rainfall[32]. Most of the actions taken to manage surplus water were in November, December March and April either after the rain or sowing and harvesting of wheat. Note that because of different sowing dates of wheat, the sowing and harvesting periods of wheat could be 30 to 45 days apart. Also, not all the farmers keep the outlet closed or drain the water in *budh*. However, even if only a few farmers within the watercourse command area refused to accept unwanted canal water supply, it is shown in the graph. Sometimes, at the time of sowing or harvesting of a crop it also happens that farmers do not need their full irrigation turn. They use the water that is needed and then close the *mogha* or drain the rest of the water in *budh*. The next farmer in the *warabandi* may open the *mogha* if he needs to irrigate his fields. It happened only once for a few days that farmers requested the Gauge Reader to shut down the distributary. It happened after a very heavy rain shower of more than 50 mm.

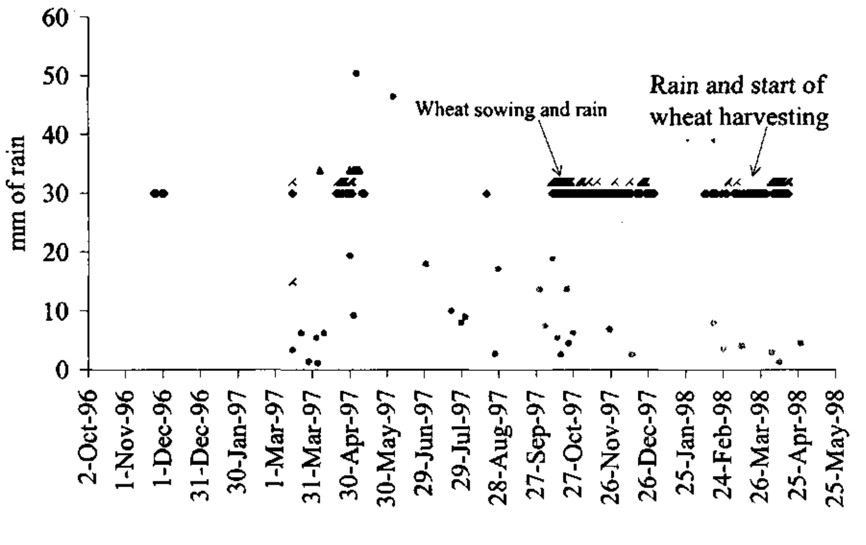

Figure 5.4: Actions taken by the farmers along the Mahmood watercourses to deal with surplus canal water supply. The outlet was closed for only MD 1-R and water was drained into *Budh* for only MD 11-TC

[31] In one of the watercourse along 6-R distributary of Eastern Sadiqia canal irrigation system farmers use this option and dump all the surplus water in the water-logged field (de Klein and Wahaj 1998).

[32] Most of the time when a *mogha* is closed or water is drained in the *budh*, it is for more than a day and happened when most farmers do not need to irrigate their crops. Nevertheless sometimes only one farmer does not need water therefore he closes the *mogha* but the next one opens it again. The graph includes the records of every time a farmer closed a *mogha* or drained water in the *budh*.

5.6 CROPPING PATTERN

The availability of total irrigation water and its control by an individual farmer influences the cropping pattern of his farm in terms of which crops to grow. If a farmer is confident of good canal water delivery in terms of quantity and timing he will cultivate more water sensitive crop(s). Access to groundwater also influences the choice of crops. In the sample watercourses almost all the farmers have access to groundwater therefore it is not the major deciding factor of different crop choices of farmers but still tubewell owners have more flexibility and control over the groundwater. Therefore they have more options of which crop(s) to grow.

The choice of crops also depends upon other factors like risk, capital investment, and availability of labour, storage facilities, transportation facilities, access to markets, and above all family need. Some crops like sugarcane need more inputs (including water) as compared to fodder, wheat or cotton but have less risk of failure from pest attack. Sugarcane is difficult to store, and its price goes down with delay but if harvested and sold at the right time it gives a good profit. In the study area, some farmers sell their standing crops of sugarcane to the sugar mills, and then it is the responsibility of the sugar mill to get the crop harvested. This saves a farmer the hassle of finding a good buyer for the crop and also to transport the harvest to the sugar mill. Others harvest the crop first and then transport it to sugar mill to sell. MD 1-R, MD 11-TC and FD 38-L have a high percentage of sugarcane since they are very close to the sugarcane mill. Cotton on the other hand does not need a lot of water, and cannot be grown in places with a high groundwater table. It is profitable but prone to pest attack and risk of crop failure is much higher as compared to sugarcane. In the selected watercourses the percentage of the difference between maximum and minimum yields is bigger for cotton than for sugarcane. Cotton can also be stored and sold later in the year whereas sugarcane loses its sugar content if stored for longer periods.

Wheat is grown basically for home consumption, does not need much water and can be stored. That is the reason for its higher cropping intensity in *rabi* as compared to *kharif*: fallow land is much less in *rabi* than in *kharif*. Rice simply needs lots of water, therefore is grown only in the watercourses with high canal water availability (like MD 1-R). Fodder grown in the study area has a higher water requirement than wheat, but can do well even with limited water supply[33]. Farmers also irrigate fodder (berseem, millet, and maize) in case of surplus canal water supply, as up to a certain level of over-irrigation, fodder is not damaged. It has more than one cutting and has to be transported fresh to the market. The watercourse FD 96-R has the highest percentage of fodder since it is quite close to the market, besides there are dairy farms very close by this watercourse that give a good incentive to farmers to grow fodder. Vegetables are labour intensive, can not be stored for long and are highly profitable. Vegetables are not among the first three main crops in any watercourse, however they contribute significantly to high gross value of production of the watercourse FD 96-R in *rabi* 1997-98.

When a farmer has more than one plot along the watercourse he prefers to cultivate more water demanding crop(s) in the plot closer to the head of the watercourse. Sometimes a farmer gives part of his farm on lease if it is difficult to irrigate that plot, due to a bad slope of the watercourse or another physical reason. Similarly, priority crops are cultivated on good

[33] Berseem is the main forage crop cultivated in the area. Other main fodder crops are millet and maize.

quality soil. Other crops, like oil seeds, are cultivated in the saline/sodic soils (Kuper, 1997). Farmers prefer to grow sugarcane in a better quality soil as compared to cotton. Cotton is more salt resistant than sugarcane (Doorenbos and Kassam, 1979). Very often farmer(s) tend to cultivate fodder towards the tail of the watercourse. In the watercourse MD 11-TC, a farmer, CID 14, cultivates 21.6 acres (8.8 hectares) of land, of which he owns 4.75 acres (1.92 hectares). All the land he cultivates is spread over the whole command area of the watercourse from head to tail (see figure 5.5) therefore he has many water turns. The map reveals that he cultivates rice at the tail of the command area and other crops in the rest of the land he cultivates, which does not seem logical of first since the water availability is lowest in the tail section. Nevertheless he bought water turns from the other two cultivators who follow him in the *warabandi* schedule, and therefore he could easily use all the water for rice. By doing so he on the one hand has acquired more water and on the other hand increased his control over that water and ultimately increased the water productivity.

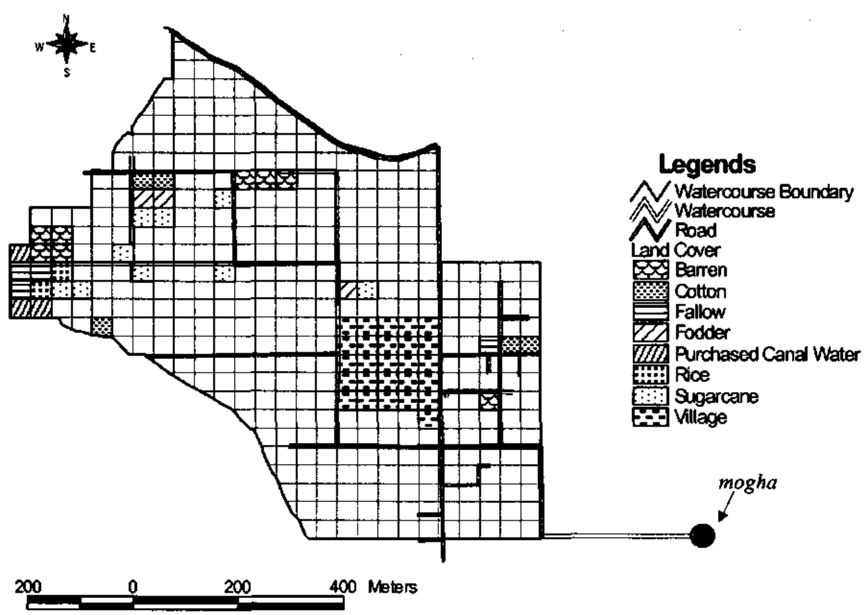

Figure 5.5: Cropping pattern of the farmer CID 14 in the watercourse MD 11-TC

5.7 MAINTENANCE OF FARMER'S CHANNELS

The maintenance of the main watercourse has been discussed in Section 3.1 The criteria of maintenance of farmers' channels is the same except the fact that the farm channels are to be taken care of by the individual farmers. These channels are not permanent: a farmer can make a new channel whenever he thinks it is needed – although it is not very often that a farmer makes a new channel. A farmer constructs a new channel when a) he changes the layout of his farm completely; b) the rodent holes are irreparable; c) the slope of the channel and the banks have deteriorated and need complete overhauling. It is easier to take a decision about the maintenance of these channels as compared to the main or branch watercourse, since the matter does not have to be discussed with other shareholders.

The frequency of desilting of farmers channels is much more than the frequency of desilting of the main or branch watercourses, since individual channels are much smaller and have much less slope as compared to the main or branch watercourse therefore more silt is deposited and obstructs the flow. Besides these channels are used for much less time than the main or branch watercourse. Farmers also clean these channels or part of the channel as routine activity. For instance, if a farmer during his water turn sees an obstruction in the water flow, he removes the obstruction right away without even realising that he is cleaning the channel. The frequency of channels desilting increases if farmers have to use only groundwater[34] since groundwater is much more expensive and the discharge is also lower as compared to the canal water. It was not possible to measure conveyance losses in the farmers' channels since the length of the channels is not enough for an inflow outflow test. According to a rough estimate 25 % of total water losses occur in farmers' channels (Barral, 1994).

Sometimes a farmer individually maintains part of the main watercourse that runs through his farm and for this he does not has to inform anyone or discuss it with anyone. Usually a farmer intervenes with the main watercourse when the leakage from that part of the watercourse is significant especially during the period of peak water requirement. A farmer reconstructs the part of the main unlined (*katcha)* watercourse[35] when water is not flowing in that part of the watercourse to ensure smooth and safe conveyance of canal water. This clearly shows the way an individual farmer actualises his actions for his own benefit which also benefit the other farmers as well. Box 5.3 shows the entrepreurship of an individual farmer in a sample watercourse: his knowledge about the system, and actualisation of his actions to manage his farm and crops individually.

[34] During canal closure or when canal water is not available for more than two weeks only groundwater is used for irrigation.

[35] A farmer cannot intervene in this way with the *pakka* (lined) watercourse.

Box 5.3: Entrepreneurship of an individual farmer

Farmer OID 49 is an ex *patwari* of the Irrigation Department (ID), who served ID for 32 years between 1948 to 1980. He is considered an influential person in the village and in the watercourse, he is a member of *Panchayat* and some other village level social work organisations. Within the watercourse command area he is responsible for organising watercourse desilting, and representing farmers interests to the ID. He together with another farmer also resolves any conflict related to watercourse maintenance.

OID 49 is a farmer as well and owns 7 acres (2.83 ha) of land at the tail of the right branch of the sample watercourse FD 84-L. He sharecrops this land with a tenant CID 26, who is sharecropping land with some other farmers in the same watercourse, on the basis of 50 % share in input and produce. He realises that this system was designed for much less cropping intensity than the existing cropping intensity of the system. It is because of the increased cropping intensity and unpredictable and inadequate canal water supply that he, in 1986, installed a tubewell. Pumped tubewell water could also be sold if not needed to irrigate his fields.

He, unlike many landowners who when sharecropping their land leave most of the task for their tenants to perform, is involved in day to day management of his land and crops. He is usually present in the fields, when his tubewell has to be operated and during his *warabandi* turn, however it is his tenant who practically irrigates the crops. But he is often involved in decision making regarding the water distribution like borrowing or lending a part or full water turn. He also makes sure that the farm and field channels are cleaned especially when pumped water alone has to be used for the irrigation, since it is more expensive to pump groundwater than the *abiana* of the canal water. According to him, the frequency of farm channel cleaning increases from once in three weeks to almost once in a week if a channel is used to convey only pumped tubewell water. According to OID 49 they have a saying that '***it is better to clean your own watercourse than to borrow an irrigation water turn.***'

5.8 CONCLUSIONS

Individual actions taken to acquire better water control were studied in six selected watercourses with varying water delivery situations at the head of the watercourse. In the study area farmers take many actions to manage irrigation water, however most widely and intensively practised individual water management activities are conjunctive water use and exchange of canal water turns. Table 5.5 gives an overview of all the events took place during the study period and the percentage of cultivators involved in these events. Most of the farmers are undertaking almost similar kind of actions to manage their water effectively, for instance exchanging canal water turns, desilting of farm channels and conjunctive use of irrigation water. These are the actions which do not require much capital investment, and most of them are necessary. Farmers cannot afford to miss these actions. While combining of different water turns is one way to increase water control, it only happened in one of the selected watercourses. It does not mean that farmers in other watercourses do not have more than one water turn, it is just that the hassle involved in this action is so high that farmers prefer to have separate water turns. Moreover, very often these different water turns belong to different owners, hence it is not possible for the tenant (both sharecropper and lessee) to have it merged and get a single water turn.

Most of the canal water acquisition activities are also undertaken by a limited number of farmers since they depend on the opportunity - for example in the case of use of water allocated for the Government property - and on willingness of other farmers to let it happen - for example canal water trade and getting special allocations.

Groundwater use is the main source of additional irrigation water. Though farmers would still like to attain additional canal water, that is always dependent on the Irrigation Department services that are not considered satisfactory by farmers. For example even after buying a canal irrigation turn the farmer CID 14 had to operate his tubewell in order to match his irrigation water requirement.

Tubewell installation, though the most expensive activity to undertake, provides more room for manoeuvre to farmers and also some income by selling its water to other farmers. It has also been shown that the net crop income of purchasers of groundwater is less as compared to tubewell owners. However, while every farmer would prefer to install an independent tubewell most of the farmers still opt to buy pumped water instead because if the capital investment required by installing a tubewell.

Mostly owner-cultivators or lessees are involved in the activities related to the canal water acquisition since they are the ones who have a right to water - owner by inheritance and lessee by renting in land. Tenants are only involved when they hold more than one tenancy status within a watercourse command area, for instance they also own land. Canal water was bought by the cultivators having more than 20 acres (8 ha.) of land regardless of their tenancy status, though none of the cultivators involved was only a tenant. It also depends on the willingness of other farmers to sell all or part of the water turn. Farmers only sell canal water when it is almost impossible for them to use it. The assumption made at the start of the chapter that cultivators with landholding size in the middle range would be mostly indulging in institutional interventions holds true for the study, since most farmers involved have between 2.25 and 5 acres.

The hypothesis regarding the involvement of big landowners in physical interventions with the system is true at the distributary level. At the watercourse level, cultivators that were found to be active in physical intervention included people of different tenancy status. Big landowners, lessees and small landowners were all found to be acquiring canal irrigation water through siphoning from the distributary. All the farmers who were siphoning had long water turns (greater than an hour) at night. The risk involved of being caught and fined may discourage cultivators to undertake this activity. Moreover it also requires a higher labour input.

Usually it is assumed that water distribution in large-scale irrigation systems is effective through collective action and that most individual actions for water management are a result of lack of collective action. However there are still some individual actions that would be undertaken by farmers regardless of existence of collective action within the watercourse command area. In chapter 3 we have seen that the watercourse FD 84-L has problems in organising collective action. Table 5.5 shows the number of individual activities to acquire supplementary water for irrigation is also highest in the watercourse FD 84-L (5 activities). However, the difference is not much compared to the other watercourses. Therefore it could not be said that individual actions to acquire more water are undertaken only because of lack of collective action.

Table 5.5: Percentage of farmers undertaking individual actions for increased water control in six selected watercourses

Better Water Control	Actions	% farmers undertaking these activities in the studied Watercourses					
		MD 1-R	MD 11-TC	FD 38-L	FD 67-L	FD 84-L	FD 96-R
Water acquisition	Canal water buying		3			4	7
	Groundwater trade	42	58	50	52	77	58
	Getting special allocations of canal water				2		2
	Use of water allocated for Government properties				2	2	
	Getting right of water back	1					
	Siphoning from distributary			100		8	
	Tubewell installation	18[1]	11[1]	100	33	56[1]	52[1]
Usability/ Effective use of water	Exchange of canal water turns	76	50	0	56	70	72
	Conjunctive water use	69	70	100	98	98	88
	Combining different water turns	2					
	Desilting of farmers' channels	100	100	100	100	100	100
	Rejection to (or disposal of) excess water	100	100	100			

[1] Tubewells were also installed during the study period

The most important factor influencing the number of different kind of individual actions for water management is the canal water supply at the head of the watercourse. Figure 5.6 shows the number of individual activities and delivery performance ratio in the selected watercourses. The number of total individual activities for water acquisition increases with the decrease in the DPR. This relationship between the DPR and the number of individual activities undertaken within a watercourse is stronger (R^2 of 0.7) if only Fordwah watercourses are considered, which is logical since overall water supply to Mahmood distributary is much better than the supply to Fordwah distributary.

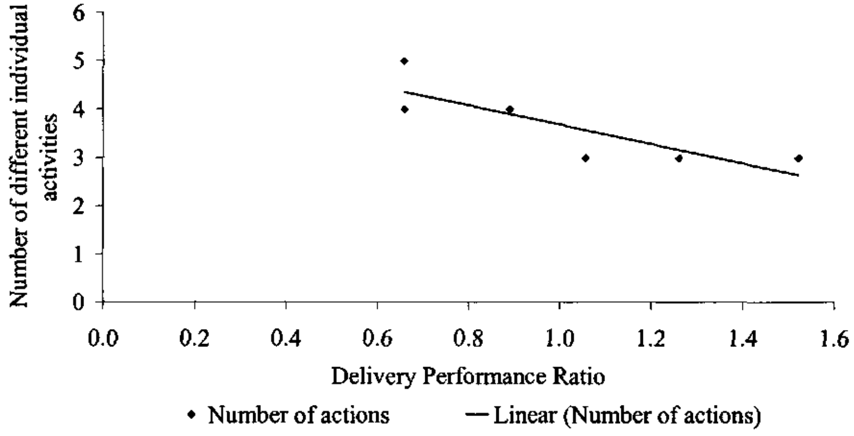

Figure 5.6: Relationship between the Delivery Performance Ratio and number of water acquisition activities performed individually in the selected watercourses

This relationship was also tested for other watercourse factors including: numbers of tenants, average operational land holding size, number of owners, number of actual cultivators and number of farmers with off-farm employment. When all the watercourses were considered the relationship was best for off-farm employment ($R^2 = 0.81$) followed by the number of tenants ($R^2 = 0.58$). Which means, that if a large number of farmers within a watercourse command area have off-farm employment, farmers will take up more, and diverse ways of individually acquiring additional water for irrigation, because collective action is difficult and they need to organise their on-farm and off-farm chores as suits them. These different types of action may and may not be legal. No relation was found for other watercourse factors. However, when these factors were tested for Fordwah watercourses only the results were very good. The correlation between the number of owners and number of different types of individual water acquisition activities is strongest with R^2 of 0.99. The number of farmers having off-farm employment is also strongly related to the number of individual actions for acquiring irrigation water with $R^2 = 0.90$

To conclude, in a highly unreliable and fluctuating canal water delivery, water acquisition is the most important individually undertaken activity. The Delivery Performance Ratio or discharge at the head of the *mogha,* and off-farm employment are the most important factors influencing diversity of individual strategies to acquire more irrigation water. Farmers take a range of effective and financially astute actions for water management to get water supply that meets crop needs.

6 OUTCOMES OF ACTIONS FOR WATER MANAGEMENT TO IMPROVE WATER DELIVERY

The previous chapters have described the actions of farmers and their organisation. They have also shown the financial incentives and rewards to farmers taking part in these activities. This chapter demonstrates the outcomes of these activities in terms of water availability at the farm-gate and their effects on key crops. The activities selected for analysis are the ones that (a) have been shown to be most important in case collective action; (b) in case of the individual actions, the activities practised by the majority of the farmers are considered for analysis. These activities are:

- Desilting of watercourse
- Water acquisition
- Conjunctive water use
- Exchange of canal water turn
- Refusal to accept surplus water

6.1 DESILTING OF WATERCOURSE

Farmers desilt the watercourse for smooth flow of water that results in an increased amount of water in one *warabandi* turn. Increased velocity will increase a discharge during the same time period in a section thus increasing the total amount of water available at a certain point particularly at the tail of the watercourse. Consequently time to irrigate a unit land decreases and more area can be irrigated in same period of time with the same discharge. In some cases the time to irrigate a unit land, at the tail of a watercourse, becomes half after the desilting of the watercourse. The difference in the availability of water between head and tail end sections of the watercourses is on average about 34 % (see section 4.3 for details). Desilting reduces this gap and thus improves equity of water distribution within a watercourse command area.

The research found that farmers, in general, desilt a watercourse four to five times in one year at the time of perceived higher water demand. The first desilting of the year usually takes place either at the end of the canal closure period or right after the canal closure[1]. Second and third desiltings are usually done before the sowing and during the growth period of the crops like rice and cotton between May and August[2]. A watercourse is desilted for the fourth time before the sowing of wheat. This activity is also undertaken when the flow condition of the *mogha* changes from free flow to submerged flow because of the backwater effect caused by the sedimentation in the upper reach of the watercourse[3]. In the following paragraphs an

[1] Canals are closed for one month in a year to carry out routine maintenance. The canal closure period is different for different canals between November and February. This is done at the time of lowest water demand. For the study area canals are closed for four to six weeks in January and February.

[2] Like in MD 1-R and MD 11-TC the second desilting of the year was done in May just before rice planting and cotton sowing and the third in June when irrigation water requirement is at its peak. In the watercourse FD 84-L it was done in July and August whereas in FD 96-R these were organized in May and August.

[3] As in case of FD 38-L, but in this case the whole watercourse is not always cleaned. Only the first few hundred meters effecting the flow condition of the *mogha* are cleaned.

effort is made to demonstrate the impact of the desilting activity by establishing the water losses before and after the desilting has taken place.

The water loss rate - that is the amount of water lost over a certain length of watercourse (for example l/s/1000m) - changes with the discharge, it increases with the higher discharge. For this analysis two different loss rates - before and after desilting - were developed. To give an example, figure 6.1 presents loss rate at different discharges at the *mogha* for the watercourse FD 96-R, with and without desilting. Note that up to a certain length of the watercourse the loss rate does not differ much even if the watercourse is desilted. The water loss rate equations with and without desilting for the sample watercourses were developed based on the conveyance loses tests conducted before and after the desilting activities undertaken by the farmers[4]. Watercourse FD 67-L was not considered in the analysis as it was only desilted once and not enough data was available to develop a water loss rate after desilting. FD 84-L also presented a challenge. Here, as the loss rate was developed after the desilting it was mainly done for the farmers along the right branch of the watercourse where the desilting is done frequently and collectively. Along the left branch farmers desilt the watercourse but not collectively. Hence the effect of desilting is not the same in the two branches. Since not enough data was available to develop a loss rate after desilting for the left branch, the same loss rate was used for the farmers along both the branches.

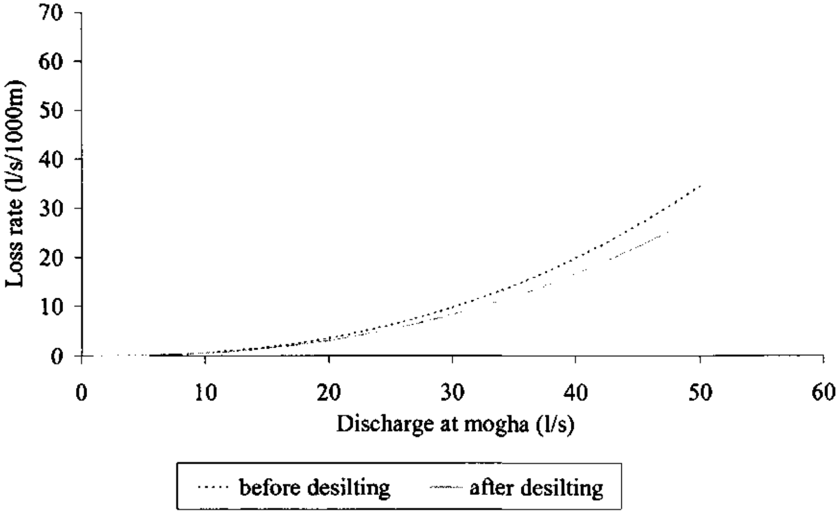

Figure 6.1: Loss rate with and without desilting of the watercourse FD 96-R

The discharge and thus the volume at the *nakka* along the watercourses was estimated using these loss rates for two scenarios, 1) when desilting was done and 2) if desilting would not have been done. A three weeks period before and after desilting was considered to minimise the effect of fluctuating canal water supply. The volumes of these three weeks were averaged to obtain one value for before and one for after desilting event. The percentage difference between these two conditions is presented in figure 6.2 a and b. This difference in percentage

[4] To develop loss rates, several conveyance loss tests before and after the desilting were conducted in each sample watercourse.

of volume available increases with the power function as the distance from the *mogha* increases, in all the selected watercourses. However the pattern is the same - the impact of desilting is higher in the watercourses along the Fordwah Distributary as compared to the watercourses along the Mahmood Distributary. As expected the effect of the desilting activity is more visible at the tail of a watercourse where the difference in the amount of water available with and without desilting is highest. However, the difference in the amount of water available before and after desilting in the first half of all the watercourses (about 1000 meters) is less than 5 %. The farmers in the first half of the watercourse still take part in the activity because of a) social obligation; b) their work load is much less than the work load of the farmers from the second half as they only have to help in cleaning the watercourse up to their own nakka; and c) they may also have a parcel of land at the tail of the section and so they are also interested in cleaning the first half. Since FD 84-L has longer breaks between the two desiltings – four desiltings during the study period as compared to six desiltings in FD 96-R (see table 4.1) - the difference between the head and the tail end farmers is bigger in this watercourse. In the watercourses along Mahmood distributary, the situation is more or less similar in both the watercourses – water saving is approximately same for same length of watercourse.

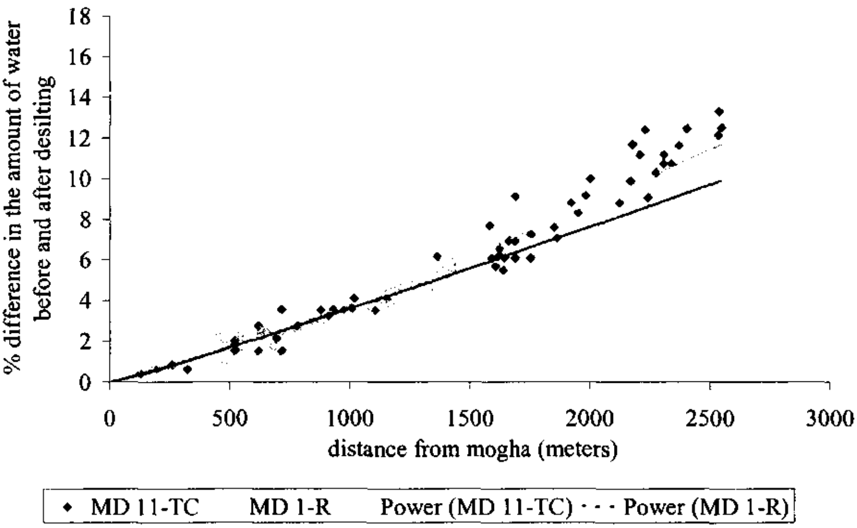

Figure 6.2a Percent difference in the water availability along the Mahmood distributary sample watercourses with and without desilting. These watercourses are lined up to about 400 meters from the *mogha*

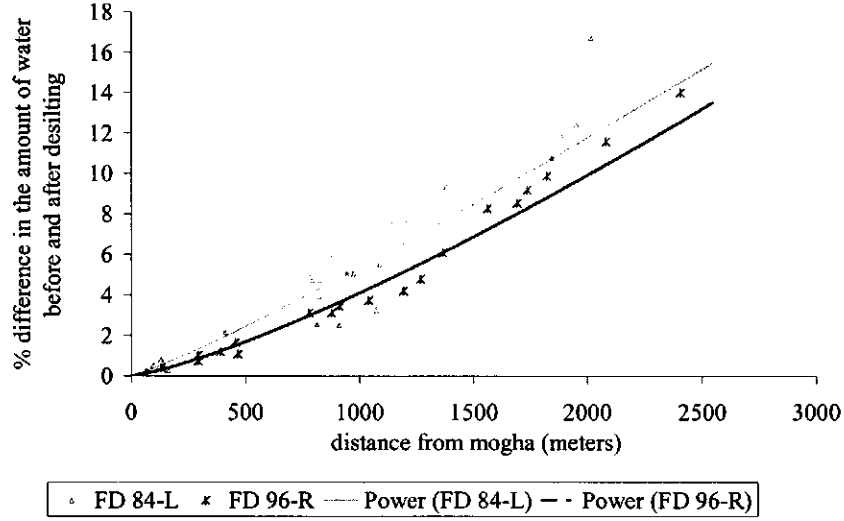

Figure 6.2b Percent difference in the water availability along the Fordwah distributary sample watercourses with and without desilting

In the sample watercourses the highest increase in volume of canal water available at the farm-gate, as a result of desilting is about 17 % at the tail of the watercourse FD 84-L (right branch) and the lowest is 0 % at the head of the watercourse MD 11-TC. This increased availability of canal water in FD 84-L accrues to the farmer who is responsible of desilting of the watercourse. Also in the watercourse MD 11-TC, the farmer responsible for the desilting is among those who benefit most from the desilting of the watercourse. Which explains the reasons of active involvement of these farmers in organising the activity. At the end of the season, desilting may not result in an increase of significant volume of water but it saves water from losses when it is needed most, and therefore is an important activity to be undertaken. The average amount of water saved in four sample watercourses is only 5.1 % but the fact is that it does make a significant difference in the tail section of the watercourse and encourages tail end farmers to organise and undertake this activity. Conveyance losses decrease significantly after the desilting, and results in the higher discharge at the field inlet at a given point of time, which consequently improves the application efficiency at the field level. The application efficiency of a basin[5] increases with the increasing field inlet flow (Walker, 1989). Kalwij (1997a) has also found the same results during her study on the field irrigation performance in the Chishtian subdivision (the same area where this research was also conducted). Moreover, if farmers do not desilt the watercourse at all then the water available without desilting will be much lower and it could also be possible that the watercourse loses its capacity to carry water.

In some cases farmers at the tail section of the watercourse stop using the canal water and sell out their canal water turn because they think that the time and labour investment in the desilting is more than the benefit they gain out of this activity. They do it because (a) the elevation of their fields is higher that makes irrigation difficult (b) because of sedimentation problems they hardly receive any water. In these situations they decide to either install a

[5] Basin irrigation is commonly practiced in the study area.

tubewell or make some other arrangements, like getting canal water if possible from another adjacent watercourse. However they officially remain the shareholders in the watercourse. Examples of such cases were found in the sample watercourses. In FD 84-L tail of the left branch two farmers have stopped using the water from this watercourse. Instead they are buying a water turn from the adjacent watercourse. They could also buy tubewell water from that watercourse. In the watercourse FD 96-R the slope is very low, the two farmers who have their land along this portion of the watercourse have access to tubewell water, and are also buying sewerage water for irrigation. Therefore they have decided to sell out their water turn. Similarly one farmer at the tail of the watercourse FD 11-TC can not irrigate his land because of the high elevation of his field. He has also sold out his water turn for that particular parcel of land to another farmer upstream and is using tubewell water. In the watercourses where tail end farmers cannot rely on water from other adjacent watercourse desilting becomes inevitable in order to be able to use canal water. Therefore, the farmers consider it an important activity, however it is also very labour intensive to desilt the watercourse. Given the choice farmers would opt for a lined watercourse.

6.2 WATER ACQUISITION

The canal water delivery to the farms is much lower than the demand of the existing cropping pattern at the farm level. To reduce this gap between the demand and supply farmers try and acquire additional water either by individually exploiting the groundwater resources or by collectively arranging additional canal water. The acquisition of additional canal water is relatively cheaper than pumping groundwater but since it benefits all the farmers within a watercourse command area it requires collective efforts. A collective decision has to be taken whether the activity should be undertaken or not and a course of action has to be formulated. Because all the farmers have to pay for the intervention it is important that all the farmers give their consent even if they do not take part in the actual activity. Section 4.1 discussed the efforts made by farmers to acquire more canal water through collective action. The most common way of acquiring water at the watercourse is to get the *mogha* enlarged. This benefits all the farmers within a watercourse command area.

The difference in the water available at the *nakka* (farm-gate) before and after the *mogha* enlargement is calculated using the actual duration of the water turn of farmers along the watercourse, and the two discharges (i.e., the actual discharge and the discharge that would have been delivered in case of no intervention). The discharge at a *nakka* is calculated by subtracting the conveyance losses for that length of the watercourse from the discharge (with and without intervention) at the *mogha*. The conveyance loss rate was developed earlier based on several conveyance loss tests in the field. The discharge was converted into volume by multiplying it with the time used for the irrigation. This volume was then added for the whole year for every farmer in the watercourse command area and the percentage difference between the two quantities of water was calculated.

Figure 6.3 shows the impact of *mogha* enlargement on the percentage difference in water availability to the farmers along the watercourse FD 96-R, in the year, mid-April 1997 to mid-April 1998. As a result of increase in *mogha* dimensions, the average increase of the discharge at the *mogha* of the watercourse FD 96-R was about 20 % for the year 1997-98. One would expect that this increase of discharge is the same for the whole watercourse and the expected performance would look like the straight dotted line in the figure 6.3. However, in reality the situation is different. The difference in the percentage of water available for irrigation at the *nakka* decreases linearly as the distance of the *nakka* increases from the *mogha,* as conveyance loss is a function of discharge at the *mogha* and distance from the *mogha* (Ali *et al.*, 1978).

The farmers at the tail of the watercourse are mainly the small farmers with less than 5 acres of land and are mainly growing fodder. Whereas, the farmers with higher water delivery near the head of the watercourse have more diverse cropping patterns. They are cultivating cotton, vegetables, fodder and also sugar cane and some oil seed crops. The average increase in the amount of water delivered to all the farmers along the watercourse is 13.8 % with highest 20 % increase at the head of the watercourse and lowest 6.3 % increase at the tail of the watercourse. The farmers CID 6 and CID 8, who took the initiative in getting the *mogha* remodelled are among the farmers who benefited most from this intervention. Water delivery to their farms was increased by about 18 % and 20% respectively. About 85 % of farmers get more than 10 % increase in the canal water supply at the farm-gate. This overall increase of water delivery to the watercourse has helped in improving the adequacy of water at the farm level. The Relative Water Supply would have been 19 % less in the year 1997-98 had this *mogha* not been increased, of which 24 % increase was in *kharif* 1997[6] and about 11 % in *rabi* 1997-98. Unfortunately information about the cropping pattern and yield before the remodelling of the *mogha* is not available for comparison. The tail-enders who managed to receive 6% higher water supply might have missed some of their water turns in case of no enlargement of *mogha*.

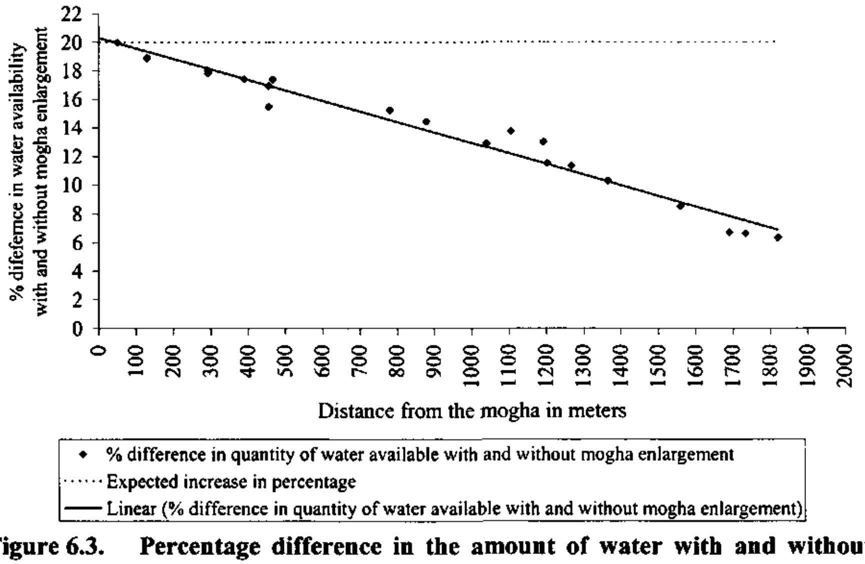

Figure 6.3. Percentage difference in the amount of water with and without *mogha* enlargement along the watercourse FD 96-R

[6] This increase would have been more if the canal water supply was not disturbed because of the damaged weir upstream of the Fordwah canal.

6.3 CONJUNCTIVE WATER USE

Conjunctive water use is the main water acquisition strategy of individual farmers in the study area. Out of total irrigation water used, 34 percent in *kharif* 1997 and 13 percent in *rabi* 1997-98 came from groundwater. Groundwater is pumped more in *kharif* than in *rabi* because of the higher water demand. In *Rabi* tubewell water is used mostly during the canal closure, in the watercourses along the Mahmood distributary. In the rest of the season groundwater pumpage is very limited. However, in the Fordwah distributary farmers do take access to tubewell water into account at the start of the season when they plan which crops to grow. Therefore a higher tubewell use is observed in both the seasons.

Farmers try to use water efficiently from all the sources – canal, ground, and rainfall. Although they can not control rainfall, in case of heavy rain they will stop irrigating from canal water. Not all the water that infiltrates the soil is lost, as it can be re-used by pumping. However, it becomes more expensive to use as compared to the canal water. One way to see the impact of farmers' conjunctive water management practices is to look at the depleted fraction. The depleted fraction of water is that part which is not available for further use (Molden, 1997)[7]. Water depleted at the farm level is calculated by deducting all the losses from the gross inflow at the *mogha*, plus the groundwater pumped. In this study Gross Inflow, Depleted Water and Depleted Fraction of the Gross Inflow is calculated in the following way:

Gross Inflow = Discharge at the *mogha* + total rainfall in the watercourse command

Depleted Water[8] = (Discharge at the *mogha* - conveyance losses[9]) + effective rainfall[10] + pumped water[11]

$$\text{Depleted Fraction of Gross Inflow} = \frac{\text{Depleted Water}}{\text{Gross Inflow}}$$

Figure 6.4 presents the ratio between the water depleted for irrigation and gross inflow for all the selected watercourses. That this ratio is higher than 1 indicates that removal of groundwater is higher than the addition to the groundwater storage. In the selected watercourses the depleted fraction is higher than 1, in *kharif* 1997 and for full year, for the watercourses FD 67-L and FD 84-L. These two watercourses had the worst canal water supply situation during the *kharif* 1997 season (see figure 3.4 for DPR that is a canal water supply indicator). The watercourse MD 11-TC has the lowest depleted fraction of the gross inflow because of less groundwater pumpage and drainage of surplus canal water supply. This

[7] Molden (1997) provided a conceptual framework for water accounting. In which he defined water depletion as use or removal of water from a water basin such that renders it unavailable for further use. There are four processes through which water can be depleted: (i) evaporation: water is evaporated form the surface or transpired by plants; (ii) flows to sinks from where it can not be reused; (iii) it is polluted to an extent that it is unfit for certain uses; and (iv) it is incorporated into a product like incorporation of irrigation water into plant tissues.

[8] This water is not further available for any other use. Part of this water may recharge the groundwater reservoirs through infiltration from the fields, however this has not been included in the analysis at the farm level. In fact in Molden's water accounting diagram (Molden 1997; p:5) removal from and addition to the storage is shown to be taken place before the water is available for depletion

[9] In case of the watercourse MD 11-TC, water that was drained in the *budh* (water logged area) has also been subtracted.

[10] Effective rainfall was obtained by the software Cropwat 4.

[11] In the original Molden's formula to calculate depleted fraction change in groundwater storage was estimated based on groundwater level instead of groundwater pumpage. In this study groundwater use is used since groundwater level data was not available for one full year.

factor of farmers' refusal to surplus canal water supply does not influence the depleted fraction, in other watercourses as the *mogha* is closed hence it is not included in the gross inflow. The canal water that was illicitly siphoned from the distributary by the farmers of the watercourse FD 38-L is also not included here, as the actual amount of that water siphoned could not be estimated. In general, farmers from selected Fordwah watercourses are making better use of their gross inflow as compared to the farmers from the, better supplied, selected watercourses of the Mahmood distributary. However, even after getting the *mogha* enlarged, farmers of the watercourse FD 96-R are using about 90 % of their gross inflow. Firstly because they are pumping significant amounts of groundwater and secondly by keeping the conveyance losses low by frequently desilting of the watercourse. This depleted fraction also suggests that the groundwater level is significantly rising for the watercourses along the Mahmood distributary and falling for the watercourses along the Fordwah distributary[12].

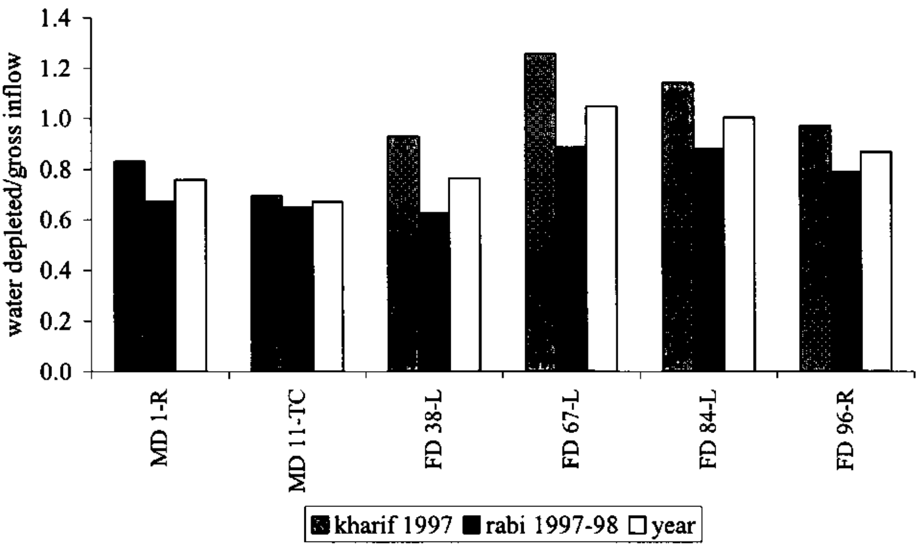

Figure 6.4: Depleted fraction of gross inflow in the six selected watercourses

The depleted fraction does demonstrate the impact of conjunctive water use in terms of water availability at the farm level and also in terms of groundwater levels. It also includes the effect of other activities, like desilting and drainage. Therefore, to study the influence of conjunctive water management of canal and groundwater one has to study the share of both sources of waters in achieving irrigation water supply. The shares of canal and groundwater in fulfilling irrigation water need at the farm level are calculated for *kharif* 1997 and *rabi* 1998. 225 farmers from all the selected watercourses are considered for this analysis. Relative Irrigation Supply, that's is the ratio of irrigation water supply to irrigation water demand (Perry, 1996), is calculated for both the sources of water The rainfall is deducted from the crop water requirement to obtain irrigation water requirement[13].

[12] This statement is based mainly on the basis of farmers' interviews. However, to prove this point a long- term data of groundwater table depth is required, which was not available to the researcher.

[13] Effective rainfall and crop water requirement for individual crops are estimated with the help of CROPWAT 4 program. Later Relative Irrigation supply at the farm level is calculated in the spreadsheet.

Figure 6.5 (a, b, and c) presents contribution of canal water and groundwater in the Relative Irrigation Supply (RIS) at farm level in *kharif* 1997. The share of canal and groundwater in the RIS is plotted against the total Relative Irrigation Supply of each farm. For instance if the irrigation water requirement (IWR) of a farm is 360 mm and the water used from canal and tubewell is 347 and 114 mm respectively. The RIS of such a farm will be 1.28, and the contribution of the canal and groundwater will be 0.96 (347mm /360 mm) and 0.32 (114 mm/ 360 mm). The sum of these RIS of canal and groundwater (0.96 + 0.32) is equal to the total RIS (1.28). One would expect that farmers would try to achieve RIS of 1.0 (or 1.25 in this case as field efficiencies are not included). The canal water is more or less a given range depending on water available in the distributary and conditions in the watercourse. Whereas tubewell operation is flexible therefore the expected outcome of the conjunctive water management would be decreasing canal water and increasing groundwater share as the RIS increases at farm level. In reality up to a certain extent, the contribution of water from both the sources is increasing with the increasing Relative Irrigation Supply because of differential reliability of water and crop choices. However for *kharif* 1997, in Fordwah all high RIS depend on high groundwater contribution whereas in Mahmood it is the other way around. The situation in *rabi* 1997-98 for all farmers in the selected watercourses and in *kharif* 1997 for farmers in the selected watercourses, along Mahmood distributary is more or less same. Canal water makes a major contribution in RIS. Farmers with extra canal water allocations (like Orchards allocation or allocation for Government property) were able to achieve better RWS (higher than 0.6) with only canal water supply, they used groundwater mainly in June 1997 when canal water was disrupted because of damage link canal.

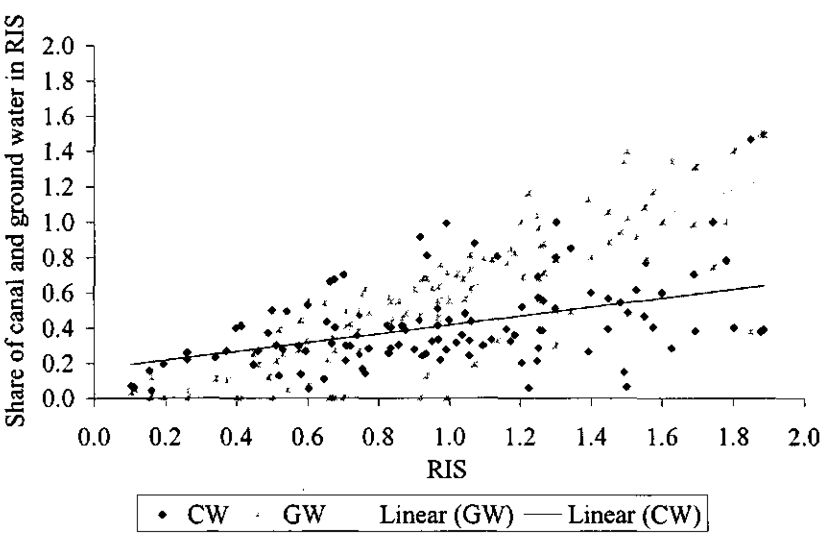

Figure 6.5a: Contribution of canal water and groundwater in Relative Irrigation Supply at farm level in *kharif* 1997, farmers along the Fordwah distributary

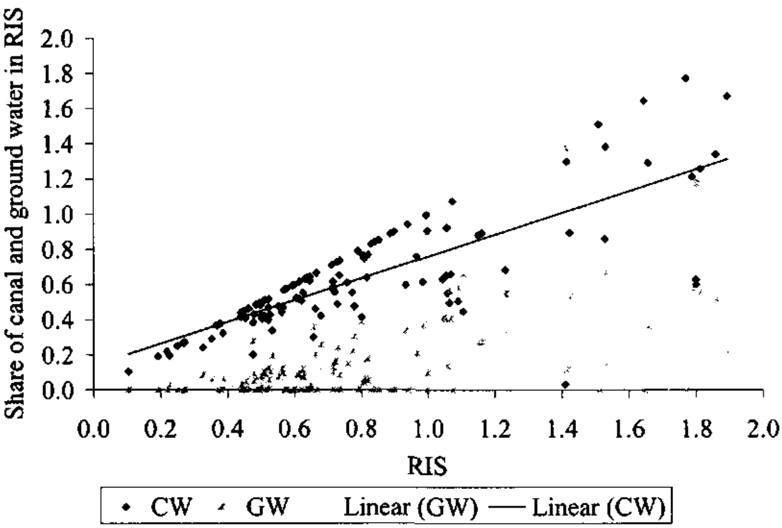

Figure 6.5b: Contribution of canal water and groundwater in Relative Irrigation Supply at farm level in *kharif* 1997, farmers along the Mahmood distributary

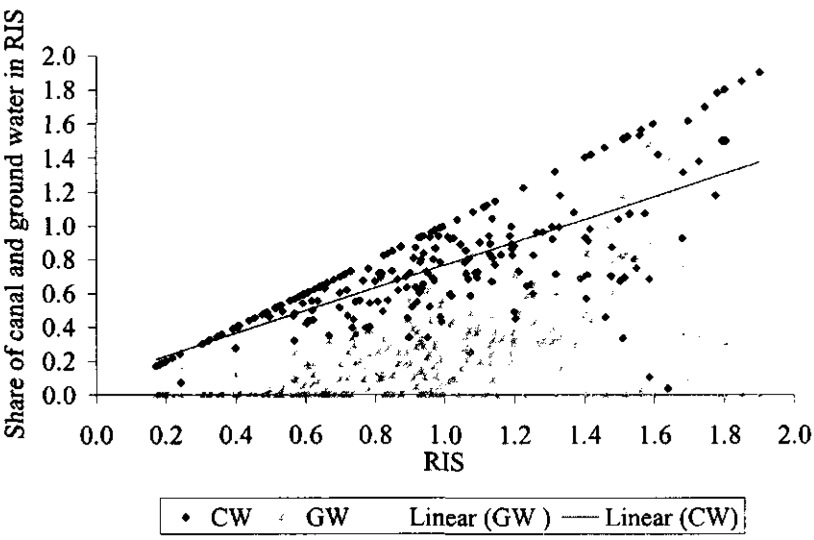

Figure 6.5c: Contribution of canal water and groundwater in Relative Irrigation Supply at farm level in *rabi* 1997-98, all the farmers

The farmers along the Mahmood distributary with RIS greater than 1.25 are mostly growing rice that is grown under continuous submersion - for which an RIS of more than 1.25 is required for the better growth of the crop. Along the Fordwah distributaries most of the farmers who seem to over-irrigate and have RIS greater than 1.25 are tubewell owners who grow mainly cotton and fodder. During *kharif* 1997 when canal water supply was scarce these farmers used tubewell water for irrigation. Most of the groundwater was used in the months of June and July 1997 in Fordwah watercourses - 40 % of the total groundwater use in *kharif* 1997- and in June 1997 in Mahmood watercourses – 75 % of total groundwater use in *kharif* 1997. But when canal water supply was normalised they started receiving water that was not needed for irrigation anymore. In the absence of proper drains they dumped this water over the fodder that is a crop more tolerant of water-logging. Therefore at the end of the season it seems as if they are over-irrigating their crops.

The farmers growing 50 % or more cotton or wheat or sugarcane or rice are the main users of groundwater. Farmers use groundwater for vegetables as well but the main crops in the study area for which groundwater is used are cotton and wheat. The contribution of groundwater in RIS is usually least for farmers have fodder over 50 % or more cropped area and highest for farmers growing wheat or cotton on 50 % or more cropped area. Therefore the main crops, wheat and cotton, of the area are further evaluated.

6.3.1 Cotton

Cotton, one of the main crops in the study area, is quite sensitive to water stress and requires frequent irrigation during the whole growing period. Adequate water supply is required for all the growth stages except early in the growing period. It needs adequate water prior to and during the bud formation, continued water supply during flower opening and yield formation A little water stress at the start is good for root and crop development (Doorenbos and Kassam, 1979). Farmers in the study area do keep track of the growth stages and try to provide adequate water at the time of flowering to prevent yield reduction. They give 5 to 7 irrigations to the cotton, between 5 and 6 to *Desi* cotton and between 6 and 7 to American cotton (Agricultural extension data 2000). *Desi* cotton and American cotton are the local names of the varieties mainly grown in the area. Cotton is a salinity tolerant crop, its yield starts reducing if salinity exceeds 7.7 mmhos/cm (Doorenbos and Kassam, 1979)[14].

A large percentage of farmers (85 %) in the selected watercourses practice conjunctive water use for cotton cultivation. In fact all the farmers in the selected watercourses along the Fordwah distributaries and the watercourse MD 1-R along the Mahmood distributary relied on tubewell water in addition to the canal water. In the watercourse MD 11-TC, the majority of farmers (63%) irrigated cotton with only canal water. One does not expect such a high intensity of conjunctive water management in the watercourses along the Mahmood distributary, as it is a privileged distributary in terms of canal water delivery. This relatively high use of pumped water is due to the water scarcity induced by a damaged structure upstream. Although the overall groundwater use along the Mahmood distributary still remains lower than the Fordwah distributary, Mahmood farmers give priority to their rice and sugar cane crops. They tend to irrigate these crops with the canal water first and irrigate cotton with the tubewell water. Because the depth of water applied to rice and cotton during one irrigation event is higher as compared to the water depth applied to cotton in one irrigation event.

[14] Soil from different fields of the watercourses FD 67-L, FD 84-L and FD 96-R was laboratory tested. ECe value of all the fields was found less than 1.5 mmhos/cm

Table 6.1 presents the percentage of farmers using only canal water and farmers using both canal and tubewell water, the average depth applied by these farmers, average relative water supply and average yield per unit area. Farmers practising conjunctive water are applying higher depth of water to the cotton; managing to achieve higher Relative Water Supply (close to 1) and therefore getting higher yield. Since they are usually more flexible in applying irrigation, they managed to irrigate the crop in time and that improves RWS and also the yield. Whereas the cotton yield of the farmers using only canal water for irrigation have suffered.

Table 6.1: Water depth applied to cotton, in *kharif* 1997, and it's yield for farmers using canal water (CW) and practising conjunctive (Conj.) water use in the study area

	% farmers using		Average depth applied (mm)		Average RWS		Average Yield (tons/ha)	
	CW	Conj. Water	CW	Conj. water	CW	Conj. water	CW	Conj. water
All farmers	15	85	265	492	0.90	1.04	0.77	0.95
MD	63	37	265	310	0.90	0.97		0.83
FD		100		514		1.05	0.77	0.96
MD1-R[1]								
MD 11-TC	63	37	265	310	0.90	0.97	0.77	0.83
FD 67-L	0	100	0	537		1.25		1.11
FD 84-L	0	100	0	460		0.94		0.88
FD 96-R	0	100	0	605		0.92		0.86

[1] Because of insufficient data available, this watercourse was not used in the analysis. Cotton was only 3 % of the total cultivated area in the watercourse.

6.3.2 Wheat

Wheat is the other main crop of the study area. The crop stages that are more sensitive to the irrigation and have a maximum effect on yield reduction are establishment or early vegetative growth and flowering stage. Irrigation or rainfall at the early stage is required for a good yield of wheat (Doorenbos and Kassam, 1979). Realising this fact, farmers in the study area try to provide the first irrigation to the wheat after 3 to 4 weeks of sowing. They also try to take care that sufficient water is supplied at the flowering stage. Total irrigation turns provided to wheat in the study area are between 5 to 6 (Kalwij, 1997b; Agricultural extension data 2000). However, data form this study suggests that farmers irrigate wheat from 4 to 6 times with average of 5 irrigations. Wheat is moderately tolerant to soil salinity however the ECe levels should not exceed 4 mmhos/cm in the upper soil layer during germination (Doorenbos and Kassam, 1979)[15]. That may be the reason for farmers to give a heavy pre-irrigation to wheat. Some of the farmers use the last irrigation they provide to cotton as a pre-irrigation for wheat.

About 70 % of farmers in the selected watercourses are using both canal and groundwater for irrigating wheat. This high percentage is due to the 4 to 6 weeks canal closure in January/ February, that is the time when many farmers have to give the first irrigation to wheat. In the watercourses with better canal water supply the average yield of wheat is better for farmers who used only canal water as compared with farmers that practised conjunctive water use. However in the watercourses with comparatively less canal water supply the situation is reversed (see Table 6.2). Very often the farmers who are using only canal water apply the first irrigation before the canal closure. By applying sufficient irrigation at the early stages of the

[15] See footnote 14.

crop and at the flowering stage they could still get better yield than the farmers practising conjunctive water use. Farmers usually mix tubewell water with the canal water for irrigation to increase the discharge and thus to decrease application losses. This mixing also reduces ill effects of the marginal quality groundwater. When groundwater alone is used for the first irrigation during the canal closure the soil is only moistened that may result in the yield reduction.

The farmers who are only applying canal water can still get a better yield if they provide irrigation at the proper time even if they apply less total water than those than used by farmers practising conjunctive water. In fact when all the farmers are considered, there is hardly any difference in the wheat yield of the farmers practising conjunctive water use and farmers using only canal water for irrigation suggesting farmers apply canal water carefully. Surprisingly, for the watercourse FD 96-R the wheat yield of only canal water users is also higher. This may be explained by the fact that there are only 3 farmers who are not using groundwater for irrigation and all of these farmers got good yield by applying a good amount of water at the most crucial crop stages. Therefore, the average yield of these farmers became higher than the average yield of conjunctive water users in the area who are in majority. The canal water users sow the wheat such that they could apply water before the canal closure. The reason is that farmers from watercourses with a better canal water supply plan their crops based on only canal water supply and hence delay use of groundwater as much as possible. Besides there are comparatively fewer tubewells in the area in the watercourses with better canal water supply. The average depth of irrigation water applied by the farmers practising conjunctive water use is still higher than the average depth of water applied to wheat by farmers relying only on canal water.

Table 6.2: Water depth applied to wheat, in *rabi* 1997-98, and it's yield for farmers using canal water (CW) and farmers practising conjunctive water (Conj. Water) use in the study area

	% farmers using		Average depth applied (mm)		Average RWS		Average Yield (tons/ha)	
	CW	Conj. Water	CW	Conj. water	CW	Conj. Water	CW	Conj. water
All farmers	27	73	247	293	1.06	1.62	2.3	2.2
MD	49	51	252	291	1.58	1.80	2.4	2.2
FD	8	92	218	293	0.67	0.83	1.8	2.3
MD1-R	26	74	153	262	1.10	1.26	2.7	2.3
MD 11-TC	63	37	276	325	1.90	1.94	2.2	1.9
FD 67-L	11	89	209	324	0.72	0.87	1.3	2.0
FD 84-L	3	97	91	273	0.29	0.77	1.5	2.4
FD 96-R	12	88	300	276	0.76	0.86	3.0	2.5

6.4 EXCHANGE OF CANAL WATER TURN

Swapping and exchange of canal water turn is commonly practised in the study area even though farmers are not allowed to do so according to the Canal and Drainage Act 1873 (Nasir, 1993). Farmers who have more than one water turn in the watercourse command exchange water turns for one parcel of land with the water turns for another parcel of land. Two kinds of arrangements exist for canal water turn exchange among different farmers. One is on an ad-hoc basis while the other one is planned.

In the planned arrangements, the decisions are made at the start of the cropping season. A farmer having very short water turns (very often less than half hour) that is not enough to irrigate one *bunded* unit during one water turn gives his water turn to another relatively bigger farmer for two to three weeks and gets a longer turn every third or fourth week depending on the deal. This deal is mostly made among neighbouring farmers. Though this arrangement is considered beneficial to both the farmers the quantity of water is not always compensated for. It is possible that the smaller farmer misses his longer water turn because of no supply and vice versa. That may be one of the reasons that this arrangement is not very common in the selected watercourses (12 % of cultivators have water turns less than half-hour).

In the ad-hoc arrangement a decision to exchange a full or a part of the water turn is taken just before or during the water turn. If a farmer realises that he is not able to irrigate the desired number of *bunded*[16] units, he borrows a part of or the full water turn from another farmer. This borrowed water is given back in terms of time used and not in terms of quantity. Nevertheless it is made sure that the difference in quantities is not very big[17]. Almost 100 % of the farmers are practising it in the study area. Canal water turns are more frequently exchanged, in the watercourses along the Fordwah distributary, than in the Mahmood distributary because of better water supply in to the Mahmood distributary.

Like desilting, fluctuations in the canal water delivery make the effect of canal water exchange on the amount of water available at the farm level difficult to show. An effort is made here to present the difference in the mm of water if farmers do not take part in canal water turn exchanges. Figure 6.6 compares water availability at the farm-gate for all the farmers in the watercourse FD 84-L for *kharif* 1997. FD 84-L has the highest occurrence of exchange of full or part water turns in one year. Some of the farmers would have had higher water availability per irrigation if they had not exchanged their water turns. However, this water might not have come at the right time. Farmers do try to give the same quantity of water back, although they can not measure it precisely. Therefore at the end of the season, the amount of water given away by a farmer may be more than the amount of water borrowed.

The farmers who have significantly higher or lower canal water supply through canal water exchanges are marked with their farmers identities (CIDs) in the figure. Farmer CID 4 is cultivating his own land and also sharecropping land with another owner in the area of whom farmer CID 49 is a brother. In *kharif* 1997, CID 49 only cultivated fodder, and gave away many of his water turns without taking it back from the tenant of his brother who was cultivating a cotton crop that needs more water[18]. Farmers CID 19, 20 and 22 are relatives, CID 20 and 22 are brothers and CID 19 is their nephew. Farmer CID 20 and 21 borrowed many water turns from their nephew without returning them. Farmer CID 20 cultivated cotton and did not use groundwater at all whereas farmer CID 21 cultivated fodder and sugarcane and he also used groundwater. Their nephew cultivated cotton, fodder and vegetables, and has direct access to tubewell water. Farmers CID 11 and CID 53 gave away more water than they received through canal water turn exchanges. They only cultivated fodder, and both used groundwater for irrigation. CID 11 has direct access to tubewell water. The rest of the differences are mainly because of the fluctuation in the canal water supply.

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[16] One *bunded* unit is usually equal to 0.25 acres.

[17] Farmers though do not measure quantity, they have their own criteria to judge the quantity of water, for example if the watercourse is flowing at full capacity or is half full (Hoeberichts, 1996).

[18] However, they both purchased tubewell water. CID 4 used much higher amount of groundwater as compared to the farmer CID 49.

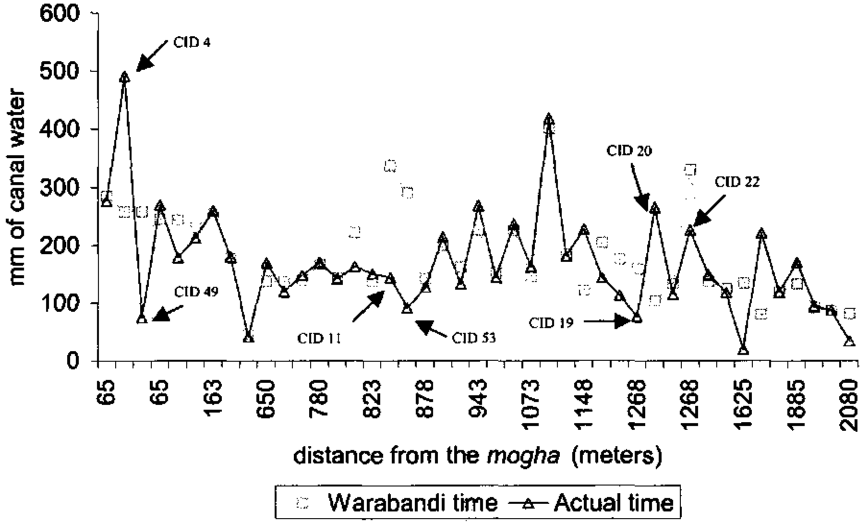

Figure 6.6 Depth of water available for irrigation at the *nakka* (farm-gate) in *kharif* 1997 with actual practices and in case farmers had not exchanged any canal water turn in the watercourse FD 84 -L

6.5 REFUSAL TO ACCEPT SURPLUS WATER

Canal water supply changes over time and so does crop and irrigation water requirement. There are times when supply is higher than the demand. None of the six selected watercourses have possibilities to drain the surplus water except MD 11-TC, where the watercourse itself leads to a water-logged area that is the old riverbed of the Sutlej River. Farmers in the five watercourses close the outlet to deal with the unwanted canal water supply while the farmers of the watercourse MD 11-TC let the water flow to the *Budh* if they don't need to irrigate their crops. Since MD 11-TC is at the extreme tail of the distributary, farmers along this watercourse cannot close the *mogha*, which may cause a breach in the distributary and damage a larger area. The frequency of refusing the surplus water is higher in the watercourses along the Mahmood distributary as compared to the selected watercourses along the Fordwah distributary. The *moghas* of the selected watercourses along the Fordwah distributary were closed only in *rabi*, and then well for less than 15 days. FD 38-L and FD 84-L were closed for 12 days; FD 96-R for 14 days; and FD 67-L was closed only for one day. The *mogha* of MD 1-R was closed for 21 days in *kharif* 1997 and for 103 days in the *rabi* 1997-98. It mainly happened in October 1997 after the heavy rains. Canal water was drained to the *Budh* for 3 days in *kharif* 1997 and 58 days in *rabi* 1997-98 by the farmers of the watercourse MD 11-TC. Note that the number of days the outlet was closed or water was drained to the *budh* does not mean that this water was refused by all the farmers or was not used for all the 24 hours. It means that the canal water was refused for at least part of the day. Canal water was surplus for most of the farmers in the months of October, November 1997 and April 1997 and 1998 at the end of the seasons.

Relative water supply (RWS) is one way of showing the impact of the farmers' water management activity of refusing surplus water. As the RWS of the watercourse exceeds a certain limit the farmers start closing the outlet or start draining the water in the *budh* in their *warabandi* turn. Figure 6.7 presents weekly RWS of the watercourse MD 11-TC during 1997-98 and the weeks when water was refused by the farmers by draining it to the *budh*. The supply in the RWS is calculated by using all the water entering the watercourse minus conveyance losses plus the effective rainfall and groundwater. The water drained to the *budh* is not deducted from the supply and therefore is included in the RWS. Crop water requirements and effective rainfall is estimated with the help of CROPWAT 4 software. A RWS of 1.5 appears as a threshold value for farmers to drain water[19]. Almost all the farmers did not use canal water during the two weeks of October, two weeks in November and two weeks in December. These are the weeks with the highest RWS. The amount of total water drained to the *budh* was 10 % of the total canal inflow in *kharif*, 30 % of the total canal inflow in *rabi* and 20 % of the total canal inflow in the whole year. This canal surplus water could have been supplied to another distributary however it became available at the time when most of the farmers do not need water, therefore it was of little use to divert it to the other distributary.

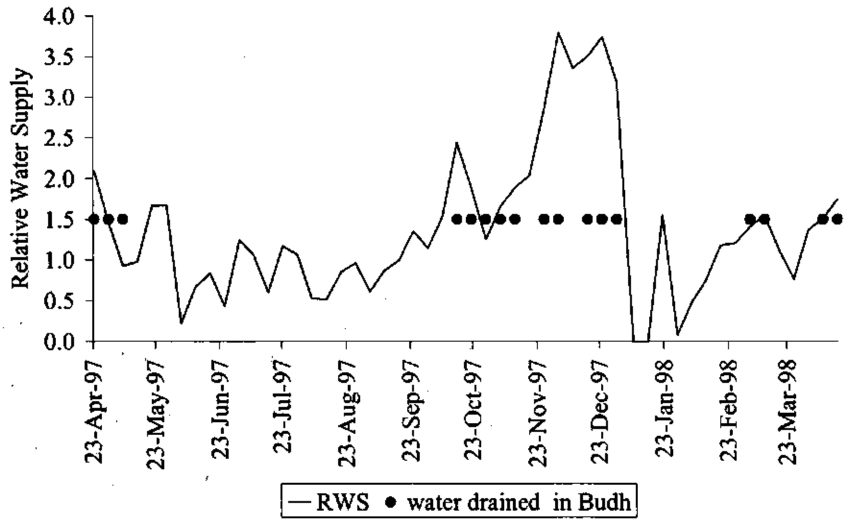

Figure 6.7: Relative Water Supply and farmers reaction to the surplus canal water supply in the watercourse MD 11-TC

6.6 INDIVIDUAL GAINS: COMPOUNDING THE EFFECT OF ACTIONS FOR WATER MANAGEMENT

The previous sections in this chapter have shown the impact of different water management activities on the water availability at the farm level in general. They have also demonstrated that the impacts of these water management activities are not the same for all the farmers within a watercourse command area. Some farmers benefited more than others. It is interesting to see the difference in availability of canal water, in terms of water depth, to all

[19] However, in some other watercourses RWS of about 2 is also observed. This is mainly because i) farmers have no other option but to spread as surplus water ii) farmers want to flush their soils for leaching.

the farmers within a watercourse command area and to study how well are these farmers managing the gap between demand and supply. To do so, this study first looks at the variation in the total canal water depth available to the farmers at the farm-gate over two seasons (*kharif* 1997 and *rabi* 1997-98) in all the selected watercourses. According to the design and the recommended operational rules of the irrigation system, the depth of canal water should be the same for all the farmers, especially farmers from one watercourse. However in reality it is not so because of different physical, institutional and agrarian conditions. The physical condition of the system has been changed over time because of lack of maintenance. The main system is not always operated according to the rules. Besides the location of the farm also influences the amount of water available at the farm-gate for irrigation. This canal water availability is also influenced by the farmers' actions resulting from changing agrarian conditions of their farms. Farmers with high water demanding crops tend to borrow water turns for longer time as compared to farmers who are cultivating low water demanding crops. Trade (selling and buying) of canal water will also be reflected in the variation of depth across the watercourse. Figure 6.8 presents the coefficient of variation of the depth of canal water (in mm) among the farms within all the selected watercourses. This variation in depth not only reflects the fluctuations in the canal delivery to the watercourse but also the impact of all the water management activities undertaken above the farm level. The impact of conveyance losses, canal water turn exchanges, and farming strategies (mainly crops grown, which influences the demand for irrigation water) is compounded in this variation in the water depth available to the farmers for irrigation.

The variation in the depth of canal water for farms in the selected Mahmood watercourses was higher in *rabi* 1997-98 than in *kharif* 1998. In the selected Fordwah watercourses, along the Fordwah farm level canal water depth also varies more in *rabi* 1997-98 than in *kharif 1997*. Nevertheless this seasonal difference is higher in the Mahmood watercourses than in Fordwah watercourses. The reason was higher canal water requirements, because of which a stricter *warabandi* schedule was followed and desilting was more frequent, to give lower conveyance losses. Most of the farmers in watercourses MD 1-R and MD 11-TC are growing high water demanding crops, rice and sugarcane, therefore in *kharif* 1997 when canal water was extremely scarce farmers tended to stick to their *warabandi* schedule[20]. Whereas in *rabi* 1997-98 during the time of harvesting of one crop and sowing of another crop warabandi became more flexible: farmers who needed water could use the *warabandi* turns of farmers who did not need water in those weeks. Because of high irrigation water demand farmers of the Mahmood watercourses desilted their watercourses more often in *kharif* than in *rabi*[21].

The coefficient of variation of the canal water depth in the watercourse FD 38-L is zero, which is unusual and surprising. This may be the result of several factors: i) Since this watercourse has only two cultivators, their water turn is unusually long, about 3.5 days (84 hours) per farmer in a week. It is possible that the fluctuations in canal water delivery when averaged were equalled out for both the farmers. ii) The watercourse is quite short, that is 1300 meters, and is desilted quite frequently therefore conveyance losses do not make much difference on the amount of volume available at the farm-gate of the two farmers. Besides,

[20] However, in the Fordwah watercourses more canal water exchanges were observed in *kharif* as compared to *rabi*. The water given away is more or less compensated as it is received back another time.

[21] Although, in the Fordwah watercourses the frequency of watercourse desilting is also higher in *kharif* than in *rabi* the range was relatively than the Mahmood watercourses.

both the farmers have the same *nakka*, one on the right side of the watercourse and the other on the left side of the watercourse.

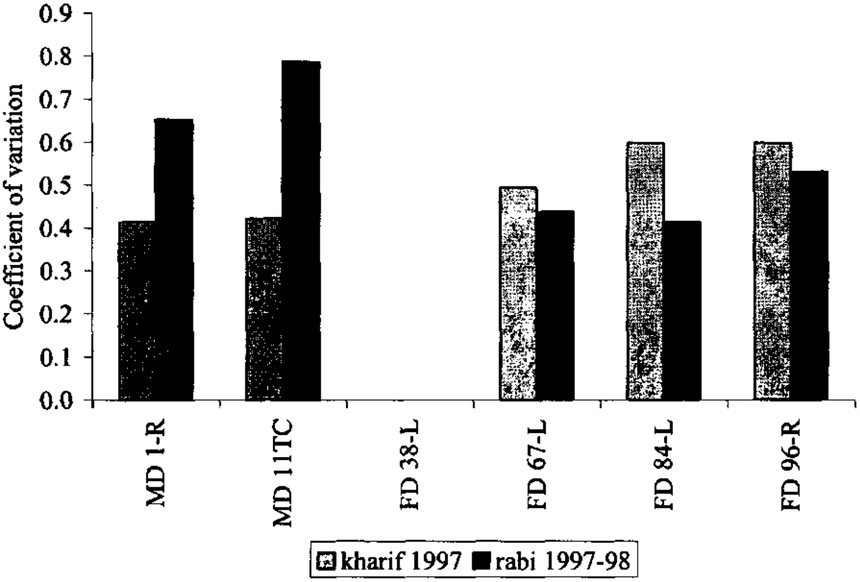

Figure 6.8: Co-efficient of variation of the mm of canal water available to all farmers within a watercourse: analysis done for six selected watercourses along the Fordwah and the Mahmood distributaries

The difference in the co-efficient of variation of two seasons in the rest of the three watercourses is mainly because of the difference in the cropping pattern of the farmers. Although most of the farmers in *kharif* are cultivating cotton there are still a considerable number of farmers with fodder as their main *kharif* crop. Access to tubewell water is also one of the factors influencing this higher disparity in the available canal water depths. Access to extra allowances - like use of water turn allocated for Government property by some farmers- make a difference in the variation in actual canal water depth available to the farmers within a watercourse command area.

This difference in availability of canal water depth at the farm-gate is highly related to the cropping pattern and hence to the crop water requirement of the different farmers. Table 6.3 presents the data on achievements for Relative Water Supply (RWS) by 225 farmers in the selected watercourses. The crop water requirements of the individual crops and effective rainfall were estimated with the help of the software CROPWAT 4.0 for Windows. The RWS was then calculated in the spreadsheet. Since this RWS is calculated at the farm level, application efficiency was not calculated, as it was difficult to estimate appropriate factors for such a diverse range of crops. However, allowing a general magnitude for application efficiency RWS should be between 1.00 to 1.25[22] if full crop water requirements are to be met. There is a large range in RWS[23], from 0.25 to 2.0, that different farmers are achieving.

Table 6.3: Farmers achieving different ranges of the Relative Water Supply in the six selected watercourses. MD is Mahmood and FD is Fordwah

	RWS Range	Number of Framers									% Total
		MD 1-R	MD 11-TC	FD[1] 38-L	FD 67-L	FD 84-L	FD 96-R	MD	FD	Total	
Kharif 1997											
1	<0.25	0	2	0	3	0	0	2	3	5	2
2	0.25 to 0.50	2	4	0	3	1	2	6	6	12	5
3	0.50 to 0.75	12	28	1	7	6	3	40	17	57	25
4	0.75 to 1.00	15	16	1	9	16	3	31	29	60	27
5	1.00 to 1.25	11	8	0	9	15	6	19	30	49	22
6	1.25 to 1.50	3	0	0	5	3	3	3	11	14	6
7	1.50 to 1.75	4	1	0	3	4	3	5	10	15	7
8	1.75 to 2.00	7	1	0	2	2	1	8	5	13	6
Total		54	60	2	41	47	21	114	111	225	100
Rabi 1997-98											
1	<0.25	0	1	0	0	0	0	1	0	1	0.4
2	0.25 to 0.50	1	6	0	1	0	0	7	1	8	4
3	0.50 to 0.75	10	9	0	4	3	2	19	9	28	12
4	0.75 to 1.00	23	22	0	11	21	8	45	40	85	38
5	1.00 to 1.25	13	14	1	16	15	6	27	38	65	29
6	1.25 to 1.50	2	2	1	5	4	2	4	12	16	7
7	1.50 to 1.75	1	3	0	2	2	2	4	6	10	4.4
8	1.75 to 2.00	4	3	0	2	2	1	7	5	12	5
Total		54	60	2	41	47	21	114	111	225	100
Year 1997-98											
1	<0.25	0	1	0	0	0	0	1	0	1	0.4
2	0.25 to 0.50	3	4	0	1	0	0	7	1	8	4
3	0.50 to 0.75	15	23	0	5	3	2	38	10	48	21
4	0.75 to 1.00	15	23	2	16	17	7	38	42	80	36
5	1.00 to 1.25	10	6	0	10	20	4	16	34	50	22
6	1.25 to 1.50	7	2	0	7	6	5	9	18	27	12
7	1.50 to 1.75	3	1	0	2	1	3	4	6	10	4
8	1.75 to 2.00	1	0	0	0	0	0	1	0	1	0.4
Total		54	60	2	41	47	21	114	111	225	100

[1] Actual RWS of these farmers is higher than this because they acquired additional canal water through siphoning which is not included in this analysis.

In *kharif* 1997 there is no farmer in the watercourses FD 84-L and FD 96-R with RWS less than 0.5, these also the watercourses with least gap between the irrigation water demand and supply at the watercourse level (see Figure 3.7a). MD 11-TC that has highest gap between the irrigation water demand and supply in *kharif* 1997 has highest number of farmers in the range 3 (0.50 to 0.75). Although irrigation water supply in all the six selected watercourses in

[22] Usually, the average application efficiency for surface irrigation system is taken as 75 %. But, it may very a lot between the different fields.

[23] One factor that influenced this big range is the length of the sowing period of one crop. For every watercourse the crop water requirement for each individual crop and effective rainfall for each season is calculated with the help of CROPWAT 4 program. The crop water requirement was calculated using the most common sowing date in the watercourse. However still the sowing period of many crops is spread over about two months.

rabi 1997-98 exceeded irrigation water demand (see Figure 3.7b) the RWS of the farmers varies within the watercourses. There are still some farmers who could not achieve RWS higher than 0.5 especially in the Mahmood watercourses. Which could be explained with the fact that other farmers in the same watercourses are achieving RWS of 1.25 or higher.

The percentage of farmers with RWS less than 0.50 and greater than 1.5 is quite low[24]. Low levels are also those partly abandoned their crops or have problems with the purchasing of tubewell water. This suggests that farmers are trying their best to achieve a reasonable water delivery. The highest percentage of farmers lie between the RWS range of 0.5 to 1.25: between 70 and 80 % of the farmers achieved RWS in this range. In *kharif* 1997 most of the farmers are concentrated in the ranges 3 and 4 (between 0.5 and 1.00). Most of the farmers in *rabi* 1997-98 are achieving RWS of ranges 4 and 5 (between 0.75 to 1.25).

Farmers with one major crop – one crop grown over more than 50 % of the total cultivated farm area – except fodder are achieving RWS mainly in two of the ranges. Table 6.4 presents the information related to RWS achieved by farmers growing different crops. Farmers are divided in 6 categories for *kharif* and 5 for *rabi* according to their cropping pattern: farmers growing 50 % or more of one crop (cotton, rice, sugarcane, wheat, fodder, and others[25]) and farmers having mixed cropping pattern (three or more number of crops cultivated under equal amount of land).

Table 6.4: Relative Water Supply of the farmers with different cropping patterns

	RWS Range	Cotton	Sugarcane	Rice	Fodder	Mix	Others	Total
Kharif 1997								
1	<0.25	2	1	0	2	0	0	5
2	0.25 to 0.50	6	4	0	2	0	0	12
3	0.50 to 0.75	11	29	3	7	7	0	57
4	0.75 to 1.00	27	15	7	6	3	2	60
5	1.00 to 1.25	27	9	1	5	6	1	49
6	1.25 to 1.50	10	2	0	1	0	1	14
7	1.50 to 1.75	4	4	0	5	2	0	15
8	1.75 to 2.00	0	0	9	4	0	0	13
	Total	87	64	20	32	18	4	225
Rabi 1997-98								
	RWS Range	Wheat	Sugarcane		Fodder	Mix	Others	Total
1	<0.25	0	0		1	0	0	1
2	0.25 to 0.50	3	0		1	2	2	8
3	0.50 to 0.75	16	6		0	6	0	28
4	0.75 to 1.00	52	24		3	6	0	85
5	1.00 to 1.25	41	15		5	2	2	65
6	1.25 to 1.50	12	1		1	1	1	16
7	1.50 to 1.75	6	1		3	0	0	10
8	1.75 to 2.00	5	2		2	1	2	12
	Total	135	49		16	18	7	225

[24] The farmers with RWS less than 0.5 are either brothers who are commonly cultivating their land(s) - they also have combined water turns, which sometimes makes it difficult to analyze their water supply situation separately – or are the ones who after losing their crop(s) gave away their water turns to their brothers. If these farmers are considered as one farmer then the RWS they achieve may becomes more higher than 0.5. They also have another source of income, like working as laborers.

[25] Others includes farmers growing 50 % or more vegetables , oilseed crops and melon.

Most of the farmers who are mainly cultivating rice lie in the ranges 4 and 8. Cotton and wheat growing farmers are in the ranges 4 and 5. Sugarcane growers could achieve RWS in the ranges and 4 in *kharif* 1997 and 4 and 5 in *rabi* 1997-98. Farmers who have a mixed cropping pattern – three or more number of crops cultivated under equal amount of land – are spread over several ranges. Fodder cultivators are also distributed over various ranges since in case of water scarcity others crops get priority for irrigation and in case of surplus water fodder is irrigated. Hence it is also found in extreme cases of water supply. The largest group (27 % of farmers in the *kharif* 1997 and 38 % in *rabi* 1997-98) was found in the range between 0.75 to 1.00. The farmers who have direct access to tubewell water[26] were able to achieve RWS between 1.0 to1.25.

The majority of the farmers are achieving the RWS in the range between 0.5 to 1.25. Therefore three farmers representing each range – 0.5 to 0.75, 0.75 to 1.00, and 1.00 to 1.25 were randomly selected to study the gap between the demand and supply over one full year. These farmers also represent the cropping pattern of their respective groups. Their total water supply – including effective rainfall, canal water availability at the farm, and groundwater use at the farm level – and evaporative demand of the crops are plotted for one year (*kharif* 1997 and *rabi* 1997-98). The weekly crop water requirement and the effective rainfall at selected farms were estimated with the help of CROPWAT 4 program for windows.

Farmer MD 11-TC CID 53: RWS in the range of 0.50 to 0.75

Farmer CID 53 is a lessee in the watercourse MD 11-TC. He has rented in about 7.5 acres (3.03 ha.) land from a landowner towards the tail of the watercourse. The land he cultivates is very close to the Azim distributary; therefore a high groundwater table is present. He has to rely on only canal water supply, as there is no tubewell installed on his land. Neither is there a tubewell installed in the neighbouring fields, therefore he has to purchase and transport pumped water from about 850 meters away. His main crop is sugarcane, which gives him a good profit and since he is close to a sugar mill, transporting the produce to the mill is also not difficult[27]. He also grows fodder and wheat: wheat mainly for domestic purposes and fodder for the cattle. Any surplus produce from wheat and fodder is sold.

In *kharif* 1997, he cultivated sugarcane[28] on 4 acres (1.6 ha.) and fodder on 2.4 acres (0.98 ha.), and in *rabi* 1997-98 he had sugarcane ratoon and planted wheat and fodder on 0.94 (0.38 ha.) and 2 (0.8 ha.) acres respectively. The rest of the land was left fallow in both the seasons. The water scarcity in *kharif* 1997 did not cause any change in the cropping pattern of this farmer, who probably knew that this water scarcity was temporary. Besides he had to take this risk, as cultivating cotton with a shallow groundwater table is more risky. Figure 6.9 gives an overview of his weekly crop water requirement and his efforts to meet this demand. The demand and supply curve shows a big gap that is also reflected in the harvest of major crop(s) sugarcane and wheat. The yield of sugarcane[29] is 25 tons/ha, which is about 25 % less than the average yield of sugarcane in this watercourse. His wheat yield was 0.82 tons per ha that is about 59 % less than the average wheat yield in the watercourse command area. Although

[26] Direct access means, either they own the tubewell or can operate tubewell of their landowner or a brother at any time they need to pump water for irrigation.

[27] Because he has rented in land, he is flexible in the choice of crops and the area he wants to cultivate.

[28] Sugarcane was planted in *rabi* 1996-97

[29] This yield is only for the *kharif* 1997.

the canal water supply situation in *kharif* 1997 was the major cause of lower yield of sugarcane, his sugarcane and wheat yield were also poor in the previous *rabi* season[30].

Canal water supply was more erratic than usual at the start and in the middle of the *kharif* 1997 (especially between May and August). Because it rained in these months, the farmer only used groundwater for once[31] (in the week of 25th June 1997) after about one month of irrigating from canal water. Another incidence that did fulfil the crop water requirement of his field was the breach of the Azim distributary in September; the amount of water that was used to match demand with supply is not reflected in this graph. Usually the farmers do not welcome this breach as it floods their fields, but it is possible that this year it did help a few farmers in matching demand with the supply. In *rabi* 1997-98 canal water is not available to the farmers in the month of January, in which most of the farmers use tubewell water for irrigation. This is also the time when many farmers have to give first irrigation to wheat, which is very important. Farmer CID 53 planted the wheat such that he gave first irrigation in the first week of December 1997. In *rabi* 1997-98 he used groundwater[32] only once, right after the canal closure. With all his irrigation management practices he could achieve the RWS of 0.51 in *kharif* 1997, and 0.61 in *rabi* 1997-98.

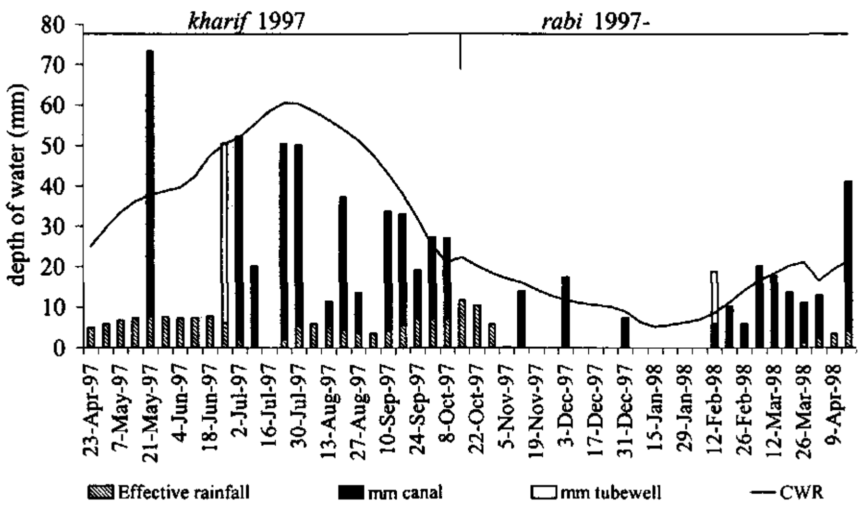

Figure 6.9: Meeting demand with the supply: weekly match between the supply and demand of the farmers CID 53 in the watercourse MD 11-TC

Farmer FD 67-L CID 6: RWS between the range of 0.75 to 1.00

Farmer CID 6 of the watercourse FD 67-L is a tenant of two landowner brothers in the head and middle reaches of the watercourse. He sharecrops 14.5 acres (5.87 ha) from one brother and 9.75 acres (3.95 ha) from the other, so in total he cultivates 24.25 acres (9.82 ha). The owners have a tubewell, which could be operated whenever additional irrigation water is

[30] In *rabi* 1996-97 the harvest of wheat and sugarcane were 1.2 and 26 tons/ha.
[31] He bought 12 hours of tubewell water at the rate of 100 Rs (40 US$) per hour.
[32] This time he did not pay in terms of money but he bought his own fuel to operate the tubewell. Water was pumped for 3.5 hours.

needed. He never purchases pumped water from other farmers[33]. Since he cultivates a reasonably big area he can grow a variety of crops[34], although his main crops remain cotton and wheat. However due to insufficient water available for high water demanding crops, the area under sugarcane remains modest

During 1997-98 he cultivated 2.93 acres (1.19 ha) of sugarcane during, which was grown in the fields around the tubewell. In *kharif* 1997 apart from sugarcane, he cultivated cotton on 10.43 acres (4.23 ha), and fodder on 0.5 acres (0.20 ha.). In *rabi* 1997-98 wheat was planted in 13.8 acres (5.59 ha), mustard in 3.67 acres (1.49 ha), and fodder in 0.87 acres (0.35 ha). The area under sugarcane remained the same in *rabi* 1997-98 as the crop was ratooned. The land left fallow was much more in *kharif* 1997 as compared to *rabi* 1997-98 because of high evaporative demand[35]. Fodder is mainly grown for the cattle, and mustard for oil. Sugarcane is grown mainly to produce raw sugar (locally called *gur*) for domestic consumption, which could also be sold in case of surplus. A weekly demand and supply situation of the CID 6, for one full year (two crop seasons), is presented in figure 6.10. Even after increased cropping intensity in *rabi* 1997-98 the match between demand and supply is very good.

There was hardly any canal water available at the start and in the middle of *kharif* 1997. However rain in those weeks helped farmers to cope with this water scarcity. Very often in *rabi* 1997-98 and sometimes in *kharif* 1997, it looks like he is over-irrigating. However it is not always the case: some of this water that appears to be over-irrigation is needed for on-farm distribution and application losses and other is needed for *rouni* (pre-irrigation). In the first week of *kharif* 1997 *rouni* irrigation for cotton was practised together with the irrigation to sugarcane and fodder. In the next few weeks either the canal water flow was extremely low or there was no canal water supply. Unlike farmers of the Mahmood distributary he did pump groundwater for irrigating sugarcane and for *rouni* (pre-irrigation) as well[36]. In fact groundwater was frequently used for irrigation throughout the year, although the amount of water pumped in *kharif* 1997 was much higher than the amount of water pumped in *rabi* 1997-98: the ratio was approximately 3:1. A gap of two weeks in operating the tubewell is observed when there was almost no canal water supply (in May and June) and it rained as well. Whenever canal water supply was there, groundwater was mixed with the canal water for irrigation. An over-irrigation in late October and (almost full) November 1997 is because of *rouni* irrigation for wheat and mustard[37]. During the canal closure (January 1998) the tubewell was again operated in two weeks to irrigate wheat, fodder and mustard. Irrigation to sugarcane is much less frequent in *rabi* than in *kharif*. With all his water control he achieved overall RWS of 0.92 with which he could get a good harvest of both cotton and wheat both. His cotton yield was 1.1 tons /ha and wheat yield was 2.0 tons/ha. - which were exactly the average yields of the crops in the watercourse for *kharif* 1997 and *rabi* 1997-98.

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[33] Only when the tubewell is out of order, he operates someone else's tubewell for which he does not pay in cash but uses his own fuel to pump the water.

[34] However, because he is a sharecropper, he has to discuss the cropping pattern and the cropping intensities with the landowners.

[35] It is also recommended that in case of limited irrigation water supply a higher total production of cotton can be achieved by spreading the irrigation over area and partially meeting crop water requirement, rather than by meeting full crop water requirement over a limited area (Doorenbos and Kassam, 1979).

[36] Because in this watercourse groundwater table depth is much lower than in the watercourses along the Mahmood distributary the chances of capillary rise are little.

[37] Sugarcane and cotton, which was still standing in some fields, were also irrigated.

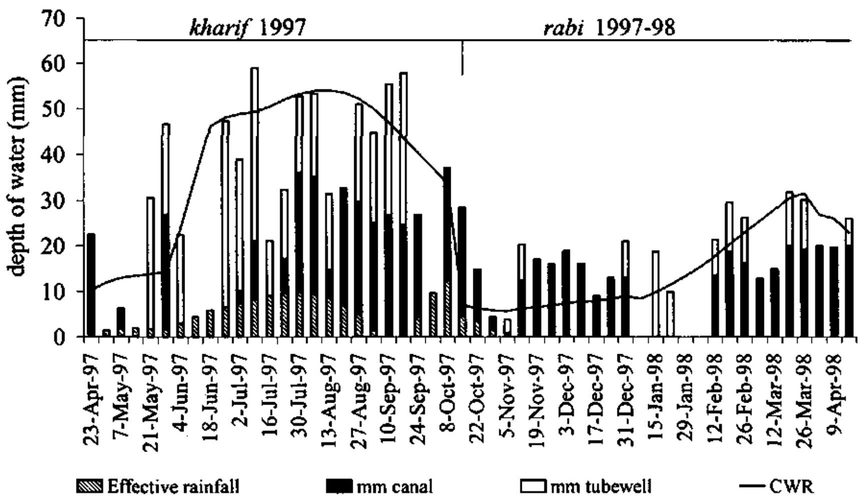

Figure 6.10: Weekly demand and supply situation of the CID 6 in the watercourse FD 67-L for one full year (*kharif* 1997 and *rabi* 1997-98)

Farmer FD 96-R CID 12: RWS between the range of 1.0 to 1.25

Farmer CID 12 cultivates about 6 acres (2.42 ha) of land in the middle reach of the watercourse FD 96-R. He owns 3.0 acres (1.25ha) out of the total land he cultivates, the rest of the land he has leased in from another farmer[38]. He also has many brothers cultivating their own land in the same watercourse command area. Because of this year of canal water scarcity he and a brother installed a private tubewell. Earlier he used to buy pumped water from another fellow farmer, but he had to transport that water for 780 meters. Cotton and wheat are the main crops he cultivates. Fodder and vegetables are other crops that he grows.

In *kharif* 1997 he planted cotton on 3.2 acres (1.29 ha), fodder on 0.4 acres (0.18 ha) and vegetables on 0.1 acres (0.015 ha.). In *rabi* 1997-98 wheat was planted in 4.1 acres (1.67ha), fodder in 1.6 acres (0.633 ha), and vegetables in 0.1 acres (0.051 ha). Fodder is needed for the cattle and vegetables are for domestic use, any surplus produce is sold in the market. Figure 6.11 shows the demand and supply curves of farmer CID 12 over a year. At times, this farmer seems to over-irrigate his crops[39]. First few irrigations at the start of *kharif* season are for pre-irrigation (that is called *rouni* in the local language). Then there were about one and a half months (from mid May to end of June 1997) with no canal water supply because of problems in the link canal. It is surprising to see no use of groundwater in those weeks, while one would expect a high groundwater pumpage in case of such a prolonged canal water scarcity. The reason for not extracting the groundwater in those weeks is the rainfall, though it did not completely fulfil crop water requirement. These were the days of initial stages of cotton that may also be one reason that farmers did not irrigate after it rained. Some water stress at the early stages of cotton is good for the root development (Doorenbos, and Kassam. 1979). When canal water supply was resumed in July 1997, CID 12 blended tubewell water

[38] This farmer owns 3.5 acres of the land, out of which he himself cultivates only 0.5 acres. He is a trader, therefore can not spare much time for agricultural activities.

[39] Some of this water is required for distribution and application losses.

with canal water and irrigated all his crops. There was again a gap of two weeks in the canal water supply that was partly filled by the rain. After this time, there is almost no week without irrigation until 10th December 1997, when canal water supply again stopped. A visible over-irrigation in late October and November is mostly the *rouni* irrigations for wheat, *rabi* fodder and *rabi* vegetables[40]. There is also one-month canal closure in January 1998. The first irrigation to wheat was given before the canal closure. Over-irrigation is practised when crops were irrigated after a long break about three weeks in December 1997. CID 12 achieved an annual RWS of about 1.14 and thus achieved good yield of major crops, cotton and wheat. His cotton yield was 1.15 tons/ha that is about 24 % higher than the average of the watercourse. His wheat yield, which was 2.5 tons/ha, was about the same (bit on a lower side) of the watercourse average (that was 2.6 tons/ha.)

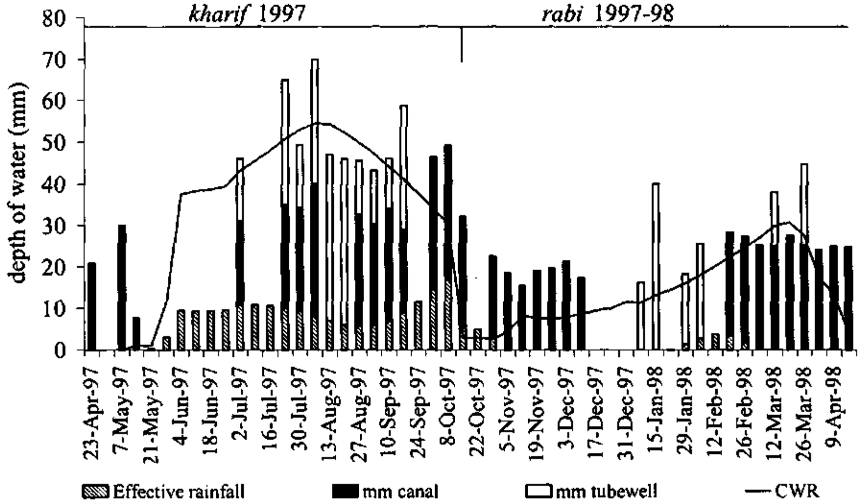

Figure 6.11: Irrigation water demand and supply of the CID 12 of the watercourse FD 96-R in *kharif* 1997 and *rabi* 1997-98

6.7 CONCLUSIONS

The impacts of actions taken for water management have been analysed in terms of amount of water available to the farmers at their *nakka* (farm-gate), examining both individual and collective actions. These actions were conjunctive water use, exchange of canal water turn, refusal to surplus canal water supply, desilting of the watercourse and acquisition of additional canal water by enlarging the *mogha*. At the end of the chapter a combined effect of all the farmers' actions was demonstrated on the variation in depth of canal water available to the farmers at the farm-gate, and a demand-supply situation for selected farmers was presented to show the way farmers with different water depths practice irrigation.

Half of the actions studied in this chapter are illicit. Exchange of canal water turn, closing the *mogha* to refuse to accept surplus canal water supply, and acquiring additional water for the

[40] In October, this over-irrigation is also due to rainfall

whole watercourse command area by enlarging the *mogha* are all illicit practices. While Conjunctive use of canal and groundwater, draining the water in the waterlogged area or *budh* and desilting a watercourse are legal.

If a watercourse has a *pakka warabandi* farmers should not deviate from this fixed schedule of water distribution. However, in practice farmers are deviating from their fixed *warabandi* turns very often by exchanging full or part of their water turn. This flexibility in *warabandi* helps them improve timely availability of canal water required to irrigate desired number of bunded units in an irrigation water turn. The more flexible water distribution does not effect farmers of the other watercourse command area.

The conjunctive water management of canal water and groundwater is another very common and important individual water management activity. It is more common in the watercourses along the Fordwah distributary than the sample watercourses along the Mahmood distributary. This practice of conjunctive water management helps farmers to deal with the variable and unpredictable canal water supply, and helps them avoid yield reduction from water stress especially for the crops like cotton.

Farmers along each watercourse desilt their watercourses to increase the velocity of the water. This activity improves equity, by reducing the conveyance losses, in terms of water availability and time to irrigate a unit area. It has a limited effect on the total water availability at the end of the season though.

In some watercourses farmers try and get additional canal water by getting their *mogha* enlarged. This activity, on one hand improves adequacy within a watercourse command area however it creates inequity among the watercourses as the water supply is only increased to few watercourses at the cost of others.

During the season of excessive rain and at the end of a crop season, when water is not needed for irrigation, farmers do not accept canal water for irrigation. This happens more in the watercourses along the Mahmood distributary than the watercourses along the Fordwah distributary. In case of excessive canal water supply farmers close their *mogha*s if there is no drainage infrastructure available, or drain the water in the *budh* or water logged area. Or otherwise irrigate crops that are not effected much by over irrigation. However, closing of the outlet is illegal, Irrigation Department seems to have developed a tolerance for this action. This action helps farmers to prevent crop failure due to over-irrigation and thus improves the productivity of the crop.

A high variation in canal depth available to different farmers within a watercourse command area has shown that the impact of all the water management activities is different for different farmers. On one hand this depends on the crop water requirement and on the other hand on the water availability at the *mogha* and physical location of the farm along the watercourse. An in-depth study matching demand with the supply over time for the selected individual farmers revealed that almost all the farmers try to keep their soils wet, even if they cannot supply full water depths: they give frequent irrigation with small depths in case of low canal water supply. They irrigate very often if it does not rain. Farmers with a high groundwater table depth give less heavy *rouni* as compared with the farmers having land in the area with the low groundwater table depth.

To conclude, all these actions help farmers to improve the water control at the farm level and increase water availability at the farm-gate at a given point of time. The combined effects of these actions enable many farmers to irrigate with reasonable levels of water supply indicating how these actions do improve 'performance indicators'. Hence it is assumed that they also improve productivity. Some of the activities, like exchange of canal water turn and desilting, have a temporary timely influence and therefore their impact on the water availability is difficult to demonstrate. Whereas activities like conjunctive water management and acquisition of additional canal water have a more long-term impact. Management of excess water is the activity that is undertaken in response, so if there were no excess of canal water this activity would not be undertaken. Nevertheless, all the activities are equally important for the good water management.

7 SUMMARY AND CONCLUSIONS

This study started with the aim to study the impact of farmers' actions for water management on local water delivery performance in a conjunctive water use environment. However already at the start of the study it was found that **current performance studies and criteria are not able to show the realities of social relations shaping water availability**. These performance studies and criteria are mainly concerned with monitoring and improvement of management of the main irrigation system, and cannot focus on the way farmers appropriate the irrigation water. Besides very often, these studies are not able to include conjunctive use of canal and groundwater in the framework of performance assessment of canal irrigation systems. By incorporating the way farmers intervene with the system and thus appropriate water delivery, performance studies could analyse a system and suggest recommendations based on realities to improve the functioning of the irrigation system. This study used a performance study as a base to demonstrate the outcome of the farmers' actions. It was not used as something static, but was considered dynamic that is changing every time farmers take action to influence water delivery (to a distributary, a watercourse and eventually to a farm). The following question was posed to gain more insights on how farmers cope with and amend the dysfunctional water supply system:

> *How and why do farmers intervene in irrigation water supply, what conditions shape their actions and what is the impact of their action on water delivery in a large scale irrigation system of Punjab, Pakistan?*

This chapter is organised in four sections: The first section summarises and discusses the key findings of the study. In the second section theory and research methods are revisited, the third sections presents findings that have implications for the current debates on environmental deterioration in salinity, water-logging and overuse of groundwater, and Participatory Irrigation Management (PIM) in Punjab, Pakistan. The fourth section briefly indicates some future research issues. The final conclusions restate the active concern of farmers in their water delivery.

7.1 FARMERS ACTIONS AND THEIR INFLUENCE ON WATER DELIVERY PERFORMANCE: KEY FINDINGS

This study has shown that **farmers are knowledgeable and capable actors who take many actions that improve their water supply and compensate for dysfunctional water delivery**. They adapt different strategies to manage irrigation water. The foremost objective of a farmer is to attain as much water control as possible, which gives him better room to manoeuvre: he can plan cropping intensity and cropping pattern of his farm in a better way. The 'water control' framework was helpful to study farmers actions by looking at technical control (influencing physical processes or technology for example tampering with the *mogha*), organisational control (by interacting and negotiating with other farmers for management of irrigation water) or social or political control (by influencing the process of water distribution at the main and tertiary level sub-system)[1]. Farmers, in the sample watercourses, who manage to receive higher canal water supply, are growing rice and

[1] See Chapter 2 for detailed discussion.

sugarcane, crops that require higher amount of irrigation water. In addition they also grow cotton, fodder and vegetables. Whereas farmers from the watercourses with relatively less canal water supply are mainly growing cotton, and wheat with some fodder and vegetables. Farmers by undertaking all these water management activities try to match irrigation water demand with the supply. They are usually aware of the crop water requirement and stages of the crop that are more sensitive to water stress or water abundance. Table 7.1 summarises the impact of farmers' actions on water delivery and yield in the sample watercourses. The table shows that while farmers with better canal water supply (DPR >1) achieved better yields of high water demanding crops (sugarcane and rice). However, farmers from the less privileged watercourses still get equally good yields of less water demanding crops (wheat and cotton). They filled the gap between the demand and supply mainly by pumping groundwater. With conjunctive water use, the RIS in all watercourses was 0.7 or higher in *kharif* and *rabi* seasons. Compared to other watercourses a higher percentage of farmers of watercourse FD 84-L (one with the low DPR) managed to achieve a RWS between 0.75 to 1.25 in *kharif* 1997 when canal water supply was disrupted because of a damaged link canal. Similarly in case of surplus water supply farmers are clearly aware of when to start getting rid of the excess water. Although farmers do not measure the water delivery, figure 6.7 showed the match between calculated RWS value and farmers' refusal, and farmers almost always drained off the water when RWS exceeded 1.5. Thus farmers are capable and knowledgeable actors who through their practices and interactions with the Irrigation Department staff, politicians and other farmers, shape and reshape their canal water delivery to their *mogha* and farm.

To improve water delivery to a watercourse, and thus to farms, farmers intervene below and above the *mogha*. Figure 7.1 presents how farmers actually intervene with the system and at what level. Farmers evaluate the water delivery to their farm-gate and *mogha* over time. If this water is not enough to fulfil the perceived crop water requirement of their crops over time, or if this discharge is more than the perceived crop water requirement, action has to be taken. This could be either within the farm, within the watercourse or at the higher lever of the irrigation system. A farmer first figures out the problem and the cause of the problem within the watercourse. For example there could be several reasons for an increasing (perceived) gap between canal water supply and (perceived) demand of crops. An increased gap between demand and supply could be due to 1) the total water delivery to the *mogha* has been decreased; 2) the capacity of the watercourse to carry irrigation water has been reduced; 3) someone upstream is stealing water. The first two causes are found more over time while the third cause is more a temporary one and can only happen during the irrigation water turn[2]. Depending on the cause of the increased gap between demand and supply or decreased water delivery at the farm-gate farmers choose the point of intervention. If canal water supply was disturbed because of less discharge at the *mogha* farmers' intervention would be focused on the *mogha* and the distributary. If the discharge at the *mogha* is more or less according to the farmers' expectations then something has to be done within the watercourse, for example watercourse desilting - or for a longer term solution watercourses has to be lined. It may also be possible that irrigation water demand of a farm has been increased and therefore the water delivery at the farm-gate is not enough to match this increased crop water requirement: then tubewell is installed, or tubewell water is purchased and changes in water turns are pursued. In case of surplus canal water supply farmers have to get rid of this water. For that they can either completely refuse to accept this water by closing the *mogha*, or by draining the surplus

[2] Such water thefts were not found in the selected watercourses.

water[3]. If this situation prevails for somewhat longer time, they try to influence the operation of the main system by influencing the Gauge Reader to close the whole distributary.

The negotiation processes, power relations, resource mobilisation, and the agrarian conditions of a farmer and a watercourse all influence the interventions that take place to improve water delivery to the watercourse and farm. For intervention within the watercourse, conflict resolution among the shareholders is also very important, although in the sample watercourses no serious conflict related to water distribution was noticed[4]. Farmers have to negotiate with other shareholders, fellow farmers, within the watercourse command area to organise collective for water management activities: for example watercourse desilting and lining of the watercourse. Any conflict among them can hinder achievements of a common goal of the whole group. They also have to negotiate with the Irrigation Department to get additional canal water supply for their *mogha*. Or for shutting down the gates of the distributary in case of surplus canal water supply. Resources in terms of money – to give as a bribe - or manpower – to desilt a watercourse or a distributary – are very important for execution of some activities. Power relations also play an important role in the undertaking of water management activities. Within the watercourse command area farmers who are more influential can get favours from the Irrigation Department without less influential farmers objecting to it. For, instance a farmer can get a higher allocation in his *warabandi* turn and other shareholders do not take any action against it, as shown in section 5.4. At the higher level, farmers try to influence the management of irrigation system through politicians. Another factor that influences the interventions is the agrarian condition. Large number of tenants make actions more difficult. A big landowner is most likely to be the influential farmer as well: one way to acquire influence is to obtain relatively higher landholding size. A farmer cultivating high water demanding crops may be more active in the interventions taken to administer water within a watercourse command area. Similarly farmers from a watercourse with high irrigation water requirements, as a whole, will be more willing to increase the discharge at the *mogha* by influencing the operation of the system, as was observed in the sample watercourses along the Mahmood distributary. All these actions, which are taken by farmers to manage irrigation water improve water delivery at the farm-gate.

[3] In case of absence of the drainage infrastructure water is drained and dumped in the water-logged areas or fields.

[4] However, people had differences in opinion, which were sometimes shared openly. Some had objections and reservations on actions of farmers (for example in MD 1-R some farmers objected when CID 58 got his water right back (see Box 5.1) but no one took any action).

Table 7.1: Impact of farmers' actions on water delivery and yield in the six sample watercourses

	Level of Organisation			MD 1-R	MD 11-TC	FD 38-L	FD 67-L	FD 84-L	FD 96-R
		Design discharge (ft^3/s)		1.26	1.48	0.38	1.38	0.95	0.64
		DPR (Nov 1996 – Apr. 1998)		1.51	1.45	1.03	0.65	0.65	0.88
		CV of discharge (Nov 1996 – Apr. 1998)		0.50	0.57	0.63	0.55	0.51	0.49
Water Acquisition									
Remodelling of the *mogha*	Collective	Average increase in discharge in one year (%)							20
Conjunctive water use at watercourse level	Individual	% Farmers practising conjunctive water use		69	70	100	98	98	88
		RIS with only CW							
		Kharif 1997 – Canal water supply disrupted		0.51	0.57	0.41	0.29	0.24	0.36
		Rabi 1997-98		0.88	1.22	1.37	0.75	0.50	0.72
		Year Apr. 1997-Apr. 1998		0.61	0.74	0.69	0.44	0.34	0.48
		RIS with conj.water							
		Kharif 1997 – Canal water supply disrupted		0.92	0.68	0.71	0.72	0.86	0.86
		Rabi 1997-98		1.05	1.29	1.37	1.06	1.04	1.16
		Year Apr. 1997-Apr. 1998		0.95	0.84	0.90	0.83	0.93	0.96
Siphoning[1]	Individual					Yes		Yes	
Desilting of the watercourse	Collective	% increase in water availability along the watercourse		0.5-8	0 - 13			0.3 – 17	0.4 - 14
Compound effects		% farmers achieving RWS between 0.75 and 1.25							
		Kharif 1997 – Canal water supply disrupted		26	24	50	18	31	9
		Rabi 1997-98		36	36	50	27	36	14
		Year Apr. 1997-Apr. 1998		25	29	100	26	37	11
		CV of canal water depth within a watercourse							
		Kharif 1997 – Canal water supply disrupted		0.41	0.42	0.00	0.49	0.60	0.61
		Rabi 1997-98		0.65	0.79	0.00	0.44	0.41	0.53
		Average yield (tons/ha)	Punjab yield (tons/ha)						
		Wheat	2.3	2.3	2.0	2.4	2.0	2.5	2.6
		Cotton	1.5	1.1	0.9	1.0	1.1	0.8	0.8
		Sugarcane	40	45	34	55			
		Rice	1.4	3.0	2.7		2.2		

[1] water acquired through siphoning is not included in the analysis.

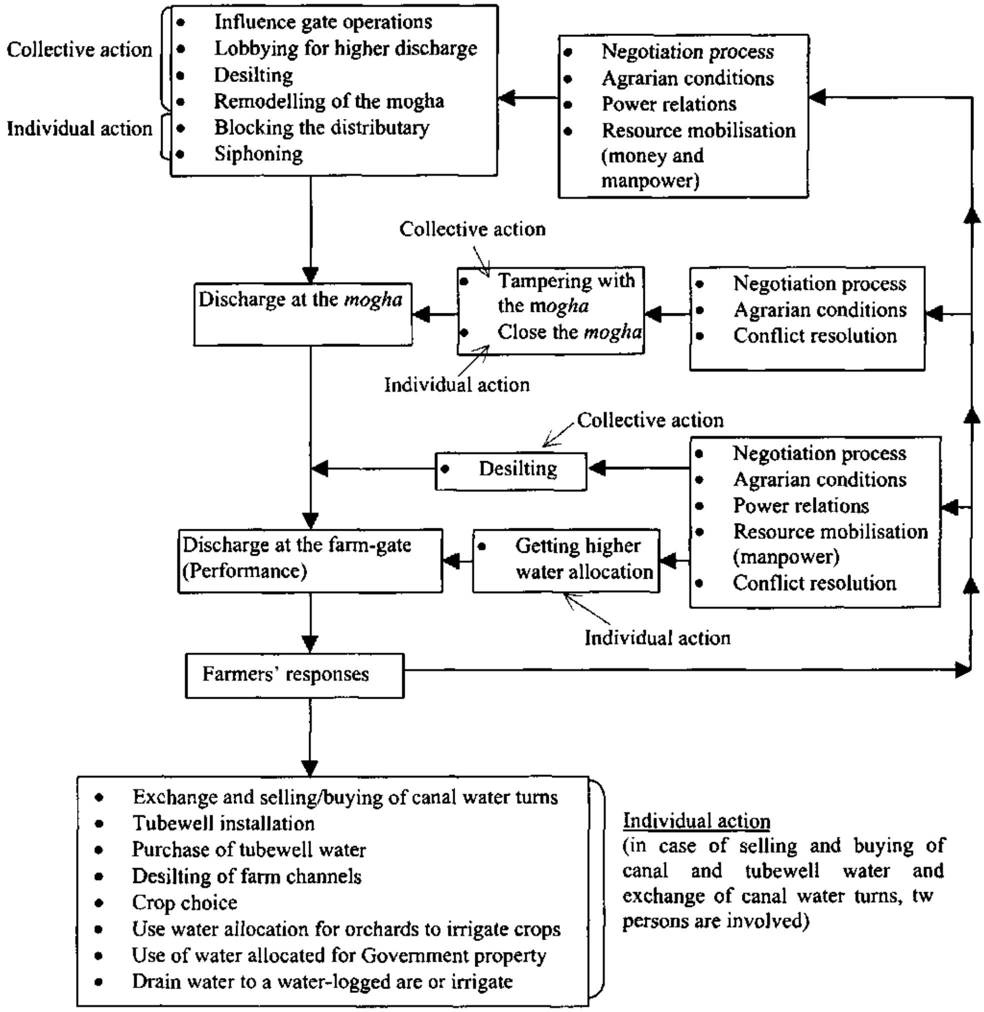

Figure 7.1: Farmers' interventions at the different levels of the irrigation system

Farmers[5] not only take actions to improve water delivery, **their actions are also sensible technically and economically and their actions have motives beyond just economic benefit**. Chapters 4 and 5 have demonstrated the financial rewards of farmers' actions. These chapters have shown the savings of farmers, in terms of money and water, as a result of taking certain choices of actions. Chapter 6 has shown the impact of these actions on the water availability at the farm-gate. These chapters have shown that these activities are

[5] An effort was also made to classify farmers on the basis of water management actions they undertake. Cluster analysis technique was used with the help of SPPS software. But no significant clusters were identified on the basis of farmer's actions for water management. However, in an analysis of water management activities and agrarian features some clusters emerged identified by landholding size and tenancy status of the farmers. It is not unreal to generalise that water management strategies followed by individual farmers in one watercourse do not differ much between them, some agrarian characteristics may bring differences.

undertaken to improve adequacy and reliability of the irrigation water supply in cost-effective ways, and increase flexibility in the use of irrigation water.

To increase flexibility and ease in irrigating the desired number of bunded units in one *warabandi* turn, farmers exchange their canal water turn which, according to the Canal and Drainage Act 1873, is illegal. However, these small exchanges of irrigation turns help farmers to provide the perceived optimum irrigation depth to the crops and give them more room for manoeuvre. Sometimes these water exchanges result in loss of some water for some of the farmers – they give away more water than they receive even if the time of the turns exchanged remains the same.

Farmers desilt their watercourses several times in a year to improve the conveyance efficiency of the channel. This activity is more effective if the entire watercourse is collectively cleaned at the same time. A watercourse may lose its capacity to carry water if this activity is not performed at all. Farmers in the study area, in general have no problems or very few problems in undertaking collective action for watercourse desilting. Which in a way increases the equity of water distribution within a watercourse command area; and improves the flexibility in terms of availability of higher amount of water at a given place and at a given point of time (See chapter 4 for details).

Water for irrigation purposes is not needed during the monsoon rains and at the time of harvesting of crops. Farmers try to protect their crops, from over-irrigation and their land from flooding, by simply refusing to accept the surplus canal water. They close the *mogha* (which they are not legally allowed to do) or drain the water to the water-logged area in case they have an access to the drainage infrastructure. Closing of a *mogha* in the upper reaches of a distributary may create problems for farmers downstream. In the absence of drainage infrastructure farmers at the extreme tail[6] of the distributary are left with the no choice but to spread the water, otherwise the distributary may suffer a breach if not closed. Some farmers irrigate crops like fodder, that can resist over-irrigation when they have no choice but to irrigate.

Social dynamics also influence the happening of the water management activities and the way farms are managed by the farmers. Very often, farmers from one family (father and sons)[7] jointly cultivate their farms even if the land has been distributed among the family members. Officially they do have a combined *warabandi* turn which in practice is (re)allocated to everyone. The canal water turn exchanges are very common among such farmers. They can also freely pump water from each other's tubewells. Chapter 6 (section 6.4) has also shown how farmers from one family help each other at the time of water scarcity – they exchange their water turns among themselves without getting any

[6] In case of the selected distributaries, farmers from the middle and tail reach of the Fordwah distributary do not often close their *mogha*. Farmers from the extreme tail are happy to receive at least some canal water, although not at the wrong time. Tail farmers from the Mahmood distributary drain this water in *budh*. However, some landless farmers use some area in budh for cultivation (mainly rice). These landless farmers complain about the damage to their crops by this drained water.

[7] In some cases the father only provides guidance and sons cultivate. Therefore the decisions regarding the cropping pattern and other factors like installing a tubewell are taken in the consultation between father and sons. In other cases sons are independent as far as the decision making is concerned but still help each other whenever needed.

compensation for that - which shows that they, sometimes, take decisions in the interest of an extended family and not just for a nuclear family[8].

Farmers, politicians and Irrigation Department staff, have various kinds of interdependencies. The influential farmers within a watercourse help the non-influential farmers by representing their view to the Government Departments, like the Irrigation Department, or by helping them at a time of domestic need[9]. In return non-influential farmers sometimes provide labour to the influential farmers and also do not object on some favours given to him by the Irrigation Department[10]. Farmers also try to lobby for additional canal water through their politicians, who in return get votes from these farmers. The Irrigation Department staff gets money from the farmers and provides them with the water, or by co-operating with the politicians they get transfers. These findings agree with Mollinga's (1998) model of water control. It is kind of a win-win situation for people involved in this circle. However somewhere in the system some farmers get deprived of their water right, and the main system objective of equitable water distribution disappears.

The dilemma in performance assessment and improvement of Pakistan's Irrigation systems is that performance is looked at from the system's perspectives of equity, reliability and adequacy whereas adequacy was never an objective of the system[11]. Moreover, different stakeholders have different standards of performance of the irrigation system. For instance a farmer judges the performance of irrigation system by timely and sufficient water supply to his farm, whereas for the Irrigation Department a system is performing well if the tail of the system is getting water. However the performance parameters and indicators to evaluate and demonstrate farmers actions may be different than the performance parameters and indicators used by the managers of the main system. Farmers' actions do improve adequacy - through acquiring additional irrigation water - and usability - through exchanging canal water turn and desilting the watercourse – that are the two main concerns of farmers. However, farmers are also concerned about the reliability or what Gowing *et al.* (1996) call predictability[12] of canal water delivery. Farmers in the sample watercourses are concerned about reliability however they did not take much action to try and change it during the study period[13], perhaps because they knew that it will be difficult to influence this at the tail of the system. This might also be one reason why they put in so much effort to try and get some additional canal water supply wherever possible to improve adequacy and short-term predictability. It is easier

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[8] Terpstra (1998) rightly notes that sometimes even after the informal land division after inheritance, farmers from one family (brothers or nephews and uncles) still cultivate their lands more or less jointly. In fact they keep their water turn as combined and can install a tubewell jointly, which improves flexibility in the availability of irrigation water and eliminates the costly installation of a separate tubewell for each family member.

[9] For example if some one from the house of non-influential farmer is ill and has to be taken to the hospital, an influential farmer with his car (and in some cases driver) can offer help by driving them to the hospital, etc.

[10] For instance in one of the selected watercourse, one influential farmer owns an agency to sell fuel. He gives this fuel to the farmers on credit as well. He is also very active in organising water management activities. In return farmers do not object on the extra 15 minutes of *nikal* (time to drain the watercourse) time that he gets with his *warabandi* turn.

[11] Moreover, the increasing role of private tubewells - in the large scale irrigation systems in Punjab, Pakistan - in the irrigation water availability and thus cropping pattern has made performance evaluation of canal irrigation systems even more difficult (Murray-Rust and Snellen, 1993)

[12] Gowing *et al.* (1996) suggest that farmers are mainly concerned about the predictability, convenience, and tractability. Predictability is referred to the knowledge of future water supplies and the degree of its certainty. Convenience is referred to the time of arrival of water at the farm-gate: for example day or night? a working day or a weekend?. Tractability is referred to the ease with which the water user can control the flow rate.

[13] The reliability was very bad in *kharif* 1997 because of damaged link canal but considerably improved in *rabi* 1997-98.

for farmers of the Mahmood distributary to discuss this issue at the distributary level and approach Irrigation Department officials. But it takes a lot more efforts to organise farmers of the Fordwah distributary simply because of its magnitude - farmers prefer to take actions that require fewer hassles (Hoeberichts, 1996). Although some of the actions by farmers can be called reactive management, in general farmers do plan their irrigation management activities and they have learned through experience to manage their irrigation system. **Their management can not be classified as 'contingent management' and is rather performance oriented.**

7.2 REVISITING THEORY AND RESEARCH METHODS

In a multidisciplinary socio-technical study of irrigation system, one needs different concepts to study and understand the dynamics of the water management activities happening in the system. This study, however, focused more on the water delivery, looked at both physical quantification of water supply and processes involved in irrigation simultaneously – in short this study looked into the 'Water Delivery Environment' of the sample watercourses. All the concepts used in the study were useful to understand the 'Water Delivery Environments'. While, the concept of different kinds of water control helped to identify different actions undertaken by different farmers for water acquisition, – technical water control was especially helpful to study farmers' intervention with the infrastructure. A framework of infrastructure that encompassed canals as well as outlets and gates (of the distributaries) was important to study the locations and actions of farmers. It was not possible to compare intervention around different technologies since both the distributaries were designed for proportional distribution, and tampering and remodelling occurred with almost all the outlet types. ID staff themselves and under the influence of farmers try to 'actualise' the management but canal water is so scarce that it is difficult to fully 'actualise the management of the system. Individual strategies of farmers helped to illustrate the way they cope with the fluctuating canal water supply.

The concept of human agency was found very helpful in studying the way people interact with each other and their motives behind these interactions. The monitoring of interactions between the actors in the ID and farmers, and among farmers themselves, helped gain insight into the way water control is negotiated and different water management activities are organised, who plays an active role in organising these activities and why.

This study attempted to see how farmers try to change water supply in terms of equity, reliability, adequacy, and productivity. It was not easy to develop different indicators for these performance parameters at the watercourse and farm level. Two indicators, RWS and RIS, were found helpful for showing the impact of farmers' actions on performance. Some conventional indicators like DPR, CV of discharge and yield per unit of area also helped to understand the choice of action undertaken by farmers. The water delivery indicators gave insight in the level of dysfunctionality of the water supply, and yield per unit of area helped to study the impact of all farmers' actions together. Observations and unstructured interviews with the farmers were very helpful in understanding the way farmers manage irrigation water and the complexity of the situation. More insight was gained through process monitoring and observing water management activities – for example desilting and water distribution. Use was made of participatory tools during farmers' meetings and interviews that helped facilitate discussions between the farmers and the researchers.

Activities for water management
An adapted version of Uphoff's typology of water management activities was used, which was found quite useful as a starting point. Later as the research progressed, different activities were identified to have great importance and were monitored in the field. The activities studied were water allocation, water distribution, watercourse maintenance, and drainage. While some actions are inevitable to take, others depend on the opportunities available to undertake them. For example, watercourse desilting is required to retain the capacity of the watercourse to carry water, however water acquisition by using canal water allocated for a Government's property depends upon the presence of such an allocation in a watercourse command area. Depending on the nature and need to undertake the activity, farmers choose the organisational level, that is collective or individual.

There is no standard set of water management activities nor are they strictly planned in the study area. Farmers' actions are mostly subject to their need for water, however one can still see some of the water management activities that are inevitable to operate the system. The actions taken and the way and time these activities are organised and performed is difficult to predict in advance. But that does not mean that farmers do not plan these activities. In fact they plan their cropping season based on the knowledge that they can undertake these actions for water management or not.

In the selected watercourses some water management activities do exist at both levels of the organisation. The water management activities and the level of organisation of these activities in the study area are summarised in Table 3.5, "Yes" shows that the activity happens at the level mentioned in first column. Not all the activities are organised at all levels in the selected watercourses, and the need to perform the activity is mainly shaped by the Water Delivery Environment of the watercourse command area or a particular farmer. For example watercourse maintenance is an activity performed at both the levels: individual and collective. All the farmers of the watercourse command area desilt the main watercourse together whenever needed. The branches of a watercourse are cleaned by the farmers using water from these branches; therefore same activity is collectively performed by a smaller group of people. They also clean farm channels that are used and cleaned only by individual farmers. They undertake desilting activity depending on which of the water channel needs desilting. Since official water allocation is done by the *patwari* in the case of *pakka warabandi*, re-allocation of water turns between tenants and landowners is an individual activity.

Table 7.2: Water management activities and their organisational level in six selected watercourses

Level of Organisation	Water Acquisition	Water (Re)Allocation	Water Distribution	Watercourse Maintenance	Management of Excess water
Individual	Yes	Yes	Yes	Yes	Yes
Collective	Yes			Yes	

The level of organisation of the activities highly depends on the prioritisation of the farmers to undertake this activity.

Individual and Collective action
Better control over irrigation water at the farm level could be achieved by undertaking individual or collective action. In large irrigation systems water is very often assumed to be managed collectively. However, since every farmer also has individual interests and priorities

that could be conflicting with other farmer's objectives, individual actions also take place. Individual actions of water management are very often researched in relation to the collective action. Researchers like Ostrom (1993) and Uphoff *et al.* (1990) have looked at the incentives for farmers to participate in collective action and difficulties of it. Others (like Mirza and Merrey, 1979) studied agrarian and social factors promoting collective action for water management. They also looked at the factors that inhibit collective action and generally lead to individual actions or no action at all. Merrey (1986a) found *biradari* as one of the major factors influencing effective organisation of farmers for watercourse maintenance. In one of the sample watercourses of this study watercourse desilting was organised according to *biradari*, but it did not play an important role in the performance of other water management activities. This study has shown that depending on the need and the resources available, some of the activities are performed by most farmers regardless of their economic status or influence, because they are needed to avoid any damage to crop(s). For instance every farmer would clean the farm channels whenever it is needed and every farmer has to get rid of the water excess during his water turn. Nevertheless the level of action highly depends on the activity to be undertaken, for instance (re)allocation of water to a tenant is more likely to be an individually undertaken activity whereas water acquisition could be done collectively as well as individually[14]. The assumption that watercourses are managed collectively because of the fact that farmers are grouped together is an over-simplification of the realities in which water management takes place in a watercourse command area. In fact different actors are involved in managing a watercourse (or a tertiary unit), and different management domains emerge through their interactions and negotiations (Manzungu, 1999). These domains are shaped by power relations and possibilities to intervene for water delivery (Van der Zaag, 1992; Mollinga, 1998). Figure 7.2 presents an example of emergent domains of interaction in the study area.

The main reason, found in this study to organise collective action for water management are the need to acquire canal water, and mutual benefit. Two main factors that were identified as enabling collective action for water management are clear leadership and greater involvement of farmers in agriculture. It was recognised that if farmers have off-farm employment they have less time to organise and to take part in the collective action. Thus, if collective action is not undertaken that does not mean there is no consensus on the need to undertake collective action, but the efforts involved in the collective actions are higher than the benefit gained by it. A higher number of shareholders in a watercourse command area seemed to have an influence on maintenance of the watercourse: the gap between the perceived and actual desilting activities per year was higher in the watercourses with higher number of shareholders. Location of the *chak* also influences the collective action for water management. If the *chak* is close to a city or a larger town, the dynamics of the city also influences the *chak*. Farmers have more awareness of job opportunities available outside farming if they live close to a city. The main factors found to restrict farmers for organising collective action is '*zid*'[15] and relatively equal distribution of power. The main water management activities for which collective action is taken are the desilting of the watercourse and water acquisition through physically intervening with the system. The former is a legal

[14] However, more often the collective action leads to a more permanent solution. As in case of water acquisition, if a farmer steals water it is only for limited time - he has to take this action again to get the benefit, besides there is more risk involved in this action. Whereas if all the farmers in the watercourse command get their *mogha* enlarged through the Irrigation Department it is a more permanent solution, that at least lasts for one crop season and everybody benefits from this action. The benefit is not always in economic terms; it could also be in terms of social gains like "*izzat*" means pride (Merrey, 1986a) likewise the loss may also be seen as loss of face (De Klein and Wahaj, 1998).

[15] Being stubborn. See chapter 3 for the details.

action whereas latter is illegal. Chapter 4 discussed the water management activities undertaken collectively.

Most of the actions that are undertaken - individually or collectively – to acquire additional canal water supply are illicit. These include getting higher discharge through distributary gate operations, siphoning, remodelling of the *mogha*, exchange and selling/buying of canal water turn. The only legal way to acquire additional water is to install a tubewell, which requires a high capital investment.

Generally different farmers are informally responsible for organising different water management activities. For instance one farmer is unofficially responsible for organising the watercourse maintenance, another farmer to organise more water at the *mogha*. However, sometimes this distinction is not very clear and one person may lead more than one activity or more than one person could be responsible for different parts of the activity. For instance a well-respected influential farmer is usually responsible for mobilising resources within a watercourse command area. These resources could be money or manpower[16], for any water management activity. A farmer, who is regarded as more knowledgeable and has more exposure to the 'outside world', is also considered suitable by fellow farmers to negotiate with the other group of farmers[17] and with the Irrigation Department. A typical example of farmers responsible for water management activities is shown in figure 7.2.

To conclude, farmers as individuals do their best under existing constraints to try and improve water control at the farm level. In doing so they use different organisational levels – the individual level or the collective level - to perform water management activities. The choice of level to use depends on the need or urgency of undertaking the activity and the efforts involved in undertaking the activity. In other words it depends on the efficiency and efficacy of performing or undertaking the activity. For instance, watercourse maintenance is mainly done collectively since it is more efficient to do it that way: it is difficult to desilt the whole watercourse by an individual farmer. Similarly water acquisition through an enlarged *mogha* is done collectively since it is more efficient and effective way to acquire additional surface water as compared to individual efforts require to get additional water through siphoning. For undertaking these activities, farmers very often have informal rules that may and may not be followed by all in practice. Some farmers play more important and active role(s) to organise the collective action: usually these farmers are the ones who benefit most from the activity, either by attaining economic benefits or social gains.

[16]Resource mobilisation in terms of money means collection of funds for any activity, for example watercourse lining and *mogha* enlargement, and in terms of manpower means gathering the farmers for a meeting or watercourse desilting.

[17] For instance, in case of desilting of the Mahmood distributary, farmers from three tail watercourses have to negotiate about the time and task division.

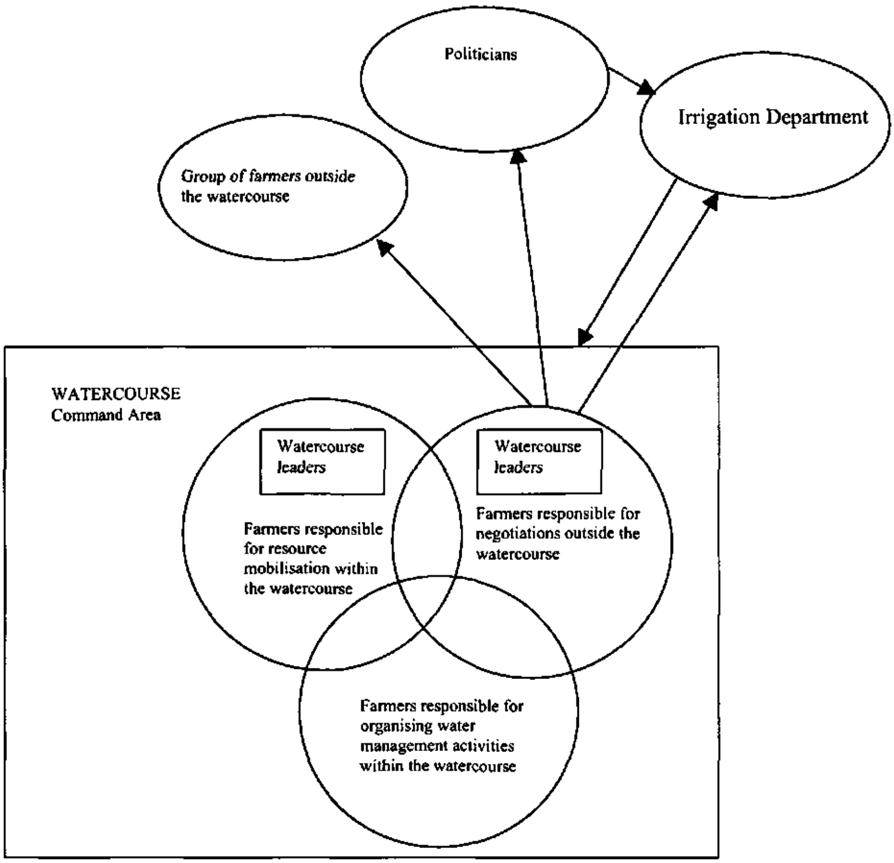


Figure 7.2: Emergent domains of interaction for water management

Selection of the distributaries and watercourses

This research was undertaken in the two perennial distributaries - Mahmood distributary and Fordwah distributary - of the Fordwah canal irrigation system. These distributaries were selected despite big differences in size because of the difference in their water delivery, and their position at the end of the system. The smaller Mahmood distributary receives a relatively higher discharge in relation to its design discharge. The discharge of its tail watercourses is also higher than their respective design discharges. The tail of the bigger Fordwah distributary on the other hand is dry for the most of the time even when the design discharge is received at its head. The watercourses for detailed monitoring were selected on the basis of their canal water supply and tubewell density per 100 ha. in order to see how farmers, as a group or individually, from different water supply conditions react to water scarcity and water abundance. Four watercourses from Fordwah distributary and two from Mahmood distributary were selected. The framework was able to show up different patterns of overall water availability, and especially differences in canal water supply. One watercourse selected had only two people, but was retained - and showed up a very specific issue – how they were influential enough and linked together to siphon water on a large scale.

Siphoning was also possible because of their much longer irrigation turns (3.5 days each). Agrarian conditions were not an initial criteria for selection, however the watercourses selected did have differences in livelihoods, castes and land-tenure, which were also an influence on water management actions.

7.3 POSSIBLE IMPLICATION FOR FUTURE WATER MANAGEMENT POLICIES

Conjunctive water use

Canal infrastructure and water supply limit the control of individual farmers over canal irrigation water that is vital in the crop production system. Farmers in the *warabandi* system are expected to adapt their crop calendar to their *warabandi* schedule: planned scarcity was foreseen to lead to the efficient use of surface water supply. However at the same time there is no legal provision for farmers to increase individual control over their surface water supply in this supply driven irrigation system. The only legal way is to install a tubewell that requires capital - which is not a practical solution for all the farmers because of relatively high capital investment.

At farm level, groundwater provides a reliable access to irrigation water. In total irrigation water applied to crops, groundwater is almost equal to canal water supply in *kharif*, whereas in *rabi*, it contributes only 22%. The majority of the farmers (83%) are using groundwater for irrigation purposes, but it is generally considered a source of supplemental irrigation, mainly because it is of lower quality, and is expensive to use as compared to canal water. Farmers, therefore, take into account the canal water supplies as a base for their agricultural decision-making, and consider the use of groundwater in peak periods of demand only, which is highly efficient. Groundwater use is very important in the study area. However, in this study actions in canal water were studied in more depth also because groundwater extraction was considered as a response to inadequate and unreliable canal water supply.

Groundwater use makes a significant contribution in enhancing agricultural productivity at farm level. However, there is a productivity gap between farmers who purchase groundwater and those who own their own tubewells, as both the amount and the timing of irrigation is important for good crop production. A farmer with direct access to tubewell water is more flexible in irrigating his crops. They first use their tubewell water for irrigating their own fields, and sell water afterwards. Therefore, farmers with no direct access to tubewell water either delays irrigation until canal water comes again or have to wait until tubewell owners sell their tubewell water. Therefore, there is a need to identify factors that promote more equitable sharing of groundwater resources.

This study has shown that canal water supply is highly variable and unpredictable therefore farmers have to rely on the extraction of groundwater. That sometimes causes over irrigation, however, this over-irrigation is because of two reasons, 1) farmers use groundwater while they are not receiving canal water and also irrigate when they get canal water, 2) they intentionally over-irrigate some areas to wash out salts from the root-zone. However, in the Fordwah distributary gross inflow (that is canal water supply + rainfall) is lower than the total water available for irrigation at the farm-gate: thus mining of groundwater at this rate may lead to serious future problems of groundwater depletion. Groundwater levels in the Fordwah distributary showed a considerable fall by the end of the *kharif* 1997 (October) however they rose again in *rabi* 1997-98 because of less groundwater extraction and better canal water supply in the *rabi* season[18]. In Mahmood distributary, on the other hand, the water table is rising because of much better canal water supply and less groundwater extraction. Farmers in the watercourse MD 1-R already have problems in growing cotton because of shallow water table; rice is second major crop in *kharif* besides sugar cane. If this situation prevails water-logging may create problems in future.

The patterns of conjunctive water use at the farm level suggest that in future groundwater will have to continue to provide significant amount of water for crop production. At times of scarcity farmers in Fordwah distributary continue to irrigate even with very bad quality groundwater that is considered to be unfit for irrigation (see section 5.2). Farmers do take some measures to control salinity build up, like applying heavy pre-irrigation with canal water and blending the canal water with tubewell water, but Kuper (1997) found that these measures have a smaller effect than a change in a significant quantity and quality of irrigation water. He suggests to re-allocate canal water for salinity and sodicity control: higher allocation of canal water to the areas effected by salinity will reduce the groundwater pumpage and salinity. However his modelling results showed that this re-allocation would result in significant decrease (about 40 %) in an area of considerable or high sodicity risk, it would also increase the area with low sodicity risk by 23 %, which may not be a desirable situation for many farmers. Besides the re-allocation may result in increased cropping intensity in the watercourses with high canal water allocation (Kijne, 1998). This study has also shown that farmers with better canal water supply grow high water demanding crops. Therefore, more actions are needed to ensure sustainable use of groundwater. This sustainability can be ensured by taking measures like a) improving reliability of canal water delivery, b) devising appropriate operational management strategies and technologies for groundwater extraction such as skimming wells (Asghar *et al.*, 2001)[19], and c) by incorporating the issue of groundwater extraction rights in the legislation of the PIDA acts as recommended by other researchers (Punjab Private Sector Groundwater Development Project Consultants, 2000: Technical Report No. 38, 42, and. 45).

Participatory Irrigation Management (PIM)

The irrigation system in Pakistan is going through institutional changes. The World Bank, Asian Development Bank and the Government of Japan are assisting[20] the Government of Pakistan to undertake these institutional reforms. Merrey (1997) identified two models of Irrigation Management Transfer: the Asian model and the World Bank model. The Asian model takes the grass root level as the starting point and is therefore more interested in the situation already existing. Whereas the World Bank model aims for rapid and intensive institutional reforms, but which still requires farmers' participation. Because of the high involvement of the World Bank in Pakistan's economy it is possible that part of the irrigation systems are turned over to the farmers organisation at higher speed than the Asian model proposes (De Klein and Wahaj, 1998)

Whichever model is used in executing the proposed irrigation sector institutional reforms, farmers organisations in several distributaries[21] and watercourses are being formed for pilot-testing of the viability of these organisations and their capacity to operate and maintain the

[18] Because of insufficient availability of data decline in groundwater level could not be studied for a year.

[19] A well which can extract relatively fresh groundwater from an aquifer underlain by saline groundwater for instance a multi-strainer shallow well, dugwell, compound well, etc.

[20] In fact the World Bank threatened Pakistan to stop loans if they do not agree with the institutional reforms in irrigation sector proposed by the World Bank.

[21] This pilot testing is underway in all the four provinces of the country.

secondary and tertiary levels of the irrigation systems (Starkloff and Zaman, 1999). However in reality farmers are already managing and maintaining the system at the tertiary level, specifically in day to day management, with little or no interference of the Irrigation Department.

This research has shown that many informal initiatives are organised at the watercourse level and in some cases even at the sub-distributary level - like in the case of desilting of the Mahmood distributary. However, these organisations are not formal but have certain rules[22], which are acknowledged and followed by the farmers. For example it has been demonstrated in chapter 4 that the watercourse desilting is organised in a very systematic way and farmers have developed their own rules to acquire additional canal water through remodelling of the *mogha*. Similarly although *warabandi* becomes flexible in practice, it remains the reference point for all the farmers when it comes to water allocation and rules for water distribution. This shows that farmers do have potential to manage their system as a group at watercourse level. However, at the same time farmers opt for *pakka warabandi* whenever they are unsure of their equitable arrangements of a *katcha warabandi*. Which implies that they need an unbiased outsider whom they can trust for the conflict resolution when it comes to their water rights.

It has also been observed that as a group they feel accountable to their fellow farmers within a watercourse. For example, in the case of watercourse maintenance, a social pressure of loss of face in front of others has been seen as an incentive to join the collective efforts to clean the watercourse[23]. When it comes to the Farmers Organisations at the higher level in the system where people do not know each other that well, they may feel less obliged to take part in the group activities (De Klein and Wahaj, 1998). This study has also revealed that while farmers do not steal water from another shareholder of the same watercourse, they do steal water from the distributary through siphoning[24]. However farmers from three tail tertiary units of Mahmood distributary collectively desilt their distributary, other farmers from upstream tertiary unit have tried to prevent this desilting in June as the whole distributary has to be shut down for cleaning. Farmers from a distributary can pressurise the Gauge Reader to increase the discharge of their distributary without considering the fact that this increase in discharge in their distributary will result in decrease in the discharge of another distributary. That shows that these farmers feel less obliged and accountable to other farmers at the higher level of the system, who they do not know very well. This means that political power may still be able to ensure privilege in the new water management structure. However, the interaction between the Farmers Organisations and other farmers may improve the accountability between them.

This research has also shown that farmers as individuals and as groups try and exploit all the water resources and manipulate every opportunity to acquire additional canal water. Starkloff and Zaman (1999) opine that most of the farmers' illegal actions to minimise relative water scarcity are individualised rather than collective in nature. However this research suggests that the most effective and commonly undertaken action to acquire additional canal water is the remodelling of the *mogha*, and is collectively performed. In all the selected watercourses it was at least discussed even if it was not materialised. It is not necessary to have formal organisations for a range of effective action to take place. Influential farmers can get higher

[22] These rules are made by farmers themselves.

[23] See section 4.5.1 for details.

[24] Though the percentage of farmers who are practising this is not very big, it depends on the opportunity a farmer gets to indulge in this practice: usually farmers who have their irrigation turn at night do it.

benefit as compared to the small and less influential farmers in a watercourse. There is a question whether people can come out of this circle of contested water control after the turnover of irrigation management from the agency to the farmers, who at present do not let go of any opportunity, legal or illegal, to try and get additional canal water supply. Will small farmers, who are dependent on influential and big farmers so much so that they do not even object to the existing inequities, be able to object to the inequities in the water distribution and get their fair share? And will they get fair representation in Farmers Organisations (FOs)? Starkloff and Zaman (1999) found that the small farmers, with landholding size 10 acres (4.04 ha.) or less are under-represented in the pilot FOs[25]. They recommend a higher participation of small farmers in FOs – something that does not seem an easy task considering the political nature of the irrigation management in Pakistan. More recently, in 2001, a meeting to review the pilot testing of the Farmers' Organisations was held in which participants, who included those involved in organising the farmers, reviewed the future of National Drainage Programme[26] (NDP) and the strategies. Two of the major concerns of the participants of the meetings were misuse of power by influential and sustainability of Farmers' Organisations (NDP, 2001). The following concerns are stated in the minutes of the meeting:

- *The inherent danger in a rapid transition are the misuse of these forums by vested interests to the detriment of the small farmers and a breakdown of the operational and regulatory controls especially in a water shortage scenario as experienced on 4-R Hakra distributary where 50 % outlets were found tampered with by FO Members*
- *....... Three FOs registered in Bahawalnagar Canal Circle were brought up under FESS[27] with the social mobilisation in about 5 years through very costly input by IIMI/OFWM, Even these FOs are not yet sustainable.*

With these concerns on board and considering the political nature of the irrigation management and water control PIM has a tough task ahead. Care has to be taken to involve non-influential farmers in the process and to safeguard interests of these small farmers.

7.4 ISSUES FOR STUDY IN FUTURE

This research can be used as the benchmark to compare farmers' actions for water management before and after the irrigation management reforms are implemented. It is also interesting to go back to the study area after a few years and see what is happening after part of the system is handed to the Farmers Organisations. For that an intensive data collection program is not needed, a fair amount of information can be gathered by observations and talking to the farmers. More recently Gowing *et al.* (1996) have presented a research method with farmers to rate their satisfaction with water supply that does not depend on extensive discharge measurements. This approach uses fuzzy set theory to quantify farmers linguistic expressions use to rate the water supply that they call 'utility of supply'. However, while this method has been tested usefully at different places - including large-scale canal irrigation schemes in Sudan (Gezira scheme) and two schemes in Egypt), it is not recommended for a comparative assessment of water supply. This method of assessing water supply utility could still give an insight into how water users rate their water delivery and whether or not they are

[25] Farmer' Organisation will eventually take over the responsibility of a) maintenance of the distributary b) equitable water distribution within a distributary, and c) collection of *abiana* from the farmers.
[26] NDP is the long term programme through which funding is channelled in the irrigation and drainage sector in Pakistan.
[27] FESS is Fordwah Eastern Sadiqia System

satisfied with the level of irrigation delivery service. In the new set-up of Participatory Irrigation Management in Pakistan - that is considered to be more service oriented - this method could be useful for improving or 'actualising' water distribution. However, more research is required to find out if this method is applicable in the 'Water Delivery Environment' of Pakistan[28] – the large-scale irrigation systems with conjunctive water use, very diverse farm level cropping patterns and diverse socio-economic conditions. The schemes in Sudan and Egypt where this method was tested mainly had more or less fixed cropping patterns with almost no groundwater extraction.

This research was done in two perennial distributaries. It would be interesting to study the difference in the water management activities undertaken by the farmers from the non-perennial distributary that receives water only for one season.

Another interesting (desk) study would be to compare indicators calculated by Remote Sensing with the primary field data analysis making use of studies like this study. The current study considered to compare the two methods for watercourse level – especially for the yield - but it was not possible since watercourse level remote sensing data was not available to the researcher.

Many questions about the water use by farmers and their yields arose during this study. Some initial efforts are made here to initiate the discussion for further research. However more systematic studies of farmer water use practices, on when and how much water they use - such as that by groundwater – are recommended to give more insight into social and technical reasons for patterns of water use at the field level. The discussion on two issues - how do farmers' water use patterns influence the yield of major crops?, and how do farmers' irrigation frequencies match the scientific irrigation scheduling for major crops? – is initiated with a brief analysis in the following paragraphs.

Water use and productivity

Farmers with different agrarian conditions and water availability use water differently. While, it was not possible to show different water use pattern for major crops in the area an attempt was made to get an overview of water depth applied and yield of the two major crops: cotton and wheat. Farmers from only three Fordwah watercourses (FD 67-L, FD 84-L, and FD 96-R) were considered in the analysis. The information on fertiliser/pesticide use was inadequate to include in analysis. More studies could be done on yield response curves achieved by farmers with different production conditions and water supply.

<u>Cotton</u>

Fig 7.3 presents the irrigation water depth applied to cotton and crop yield corresponding to each depth. Depth of water applied is averaged for every 50 mm and so is yield for corresponding depths. The depths of water applied and their corresponding yields range from 247 mm to 942 mm and 0.13 to 1.34 tons/ha, respectively. The highest cotton yield (1.34 tons/ha) was achieved when the depth of water available at farm-gate was 786 mm - RWS approximately equal to 1. The crop water requirement of cotton in the area is 790 mm for 1997.

[28] The results obtained by such research methods could also be compared with other studies – such as this study - which are based on intensive field data collection at farm and watercourse level.

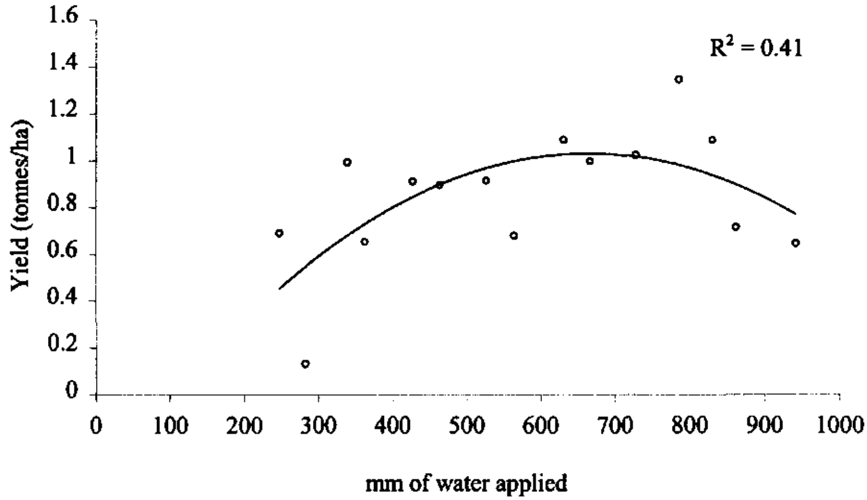


Figure 7.3: Depths of water applied to cotton versus cotton yield of farmers along Fordwah distributary

Wheat

Fig. 7.4 shows depths of irrigation water applied to wheat and crop yield corresponding to each depth. Irrigation water depths applied are averaged for each 50 mm and so is yield for corresponding depths. Variations in depths of water applied and in yields are high, and range from 91 to 867 mm and from 1.5 to 2.6 tons/ha, respectively. The highest yield (2.6 tons/ha) was achieved when the water depth was 419 mm - RWS = 0.93. The crop water requirement of wheat in the area is 450 mm for 1997-98. This yield response curve shows that farmers are achieving about 58 % of the highest yield (2.6 tons/ha.) even with a very modest water supply, which is about 22 % of the water depth (i.e. 419 mm) with highest yield. This shows the need for more in-depth study of the farmers differential water supply to different crops during one water turn.

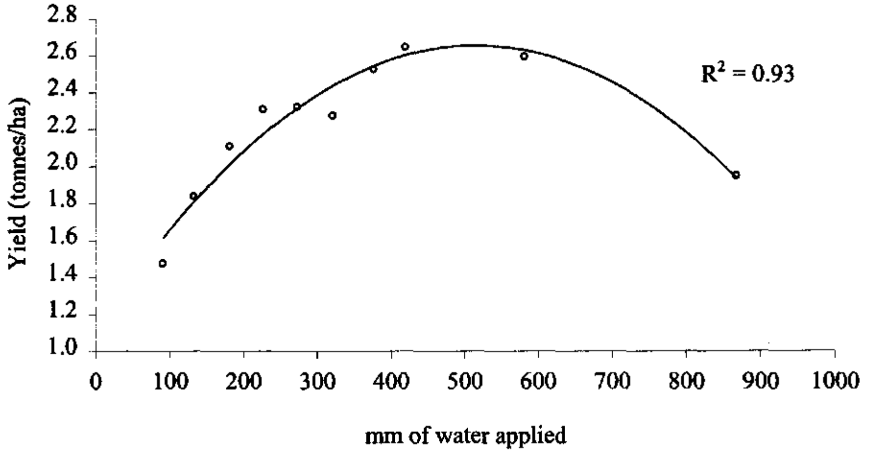


Figure 7.4: Depths of water available at farm-gate versus wheat yield of farmers along Fordwah distributary

Comparing irrigation frequencies of farmers with the irrigation scheduling

The yields of different farmers vary in the study area, depending on the irrigation and other production choices made by the farmers. It would be interesting to make further studies of the frequency and the depth of water applied by farmers with those recommended by computer software. Table 7.3 compares the depth of water applied by a farmer FD 84-L CID 12 to cotton crop and the depth for same irrigations suggested by computer software CROPWAT 4 for Windows. CID 84-L 12 is an owner cum cultivator who has direct access to tubewell water. He mainly cultivates cotton and wheat. In *kharif* 1997 cotton was 70 % of his cultivated area. With medium textured soil and actual irrigation interval followed by the farmer, irrigation depths suggested by CROPWAT 4 for Windows are higher than the actual applied depths, except for first irrigation. In calculating actual depth applied a general value of 75 % field application efficiency was considered which might bring in some errors, as application efficiency could be much higher in a water-scarce environment. The CROPWAT suggests that this farmer will have about 26 % of yield reduction. The actual cotton yield of this farmer was 0.6 tons/ha., which was 25 % less than the average yield of cotton in this watercourse, and about 60% less than the average yield in Punjab for that season. Whether farmers are practising deficit irrigation, or there remains a question on computer software for assessing irrigation water requirements, is a research issue for the future.

Table 7.3: Comparing depth of water applied to cotton by a farmer with the depth proposed by computer software CROPWAT 4 for Windows

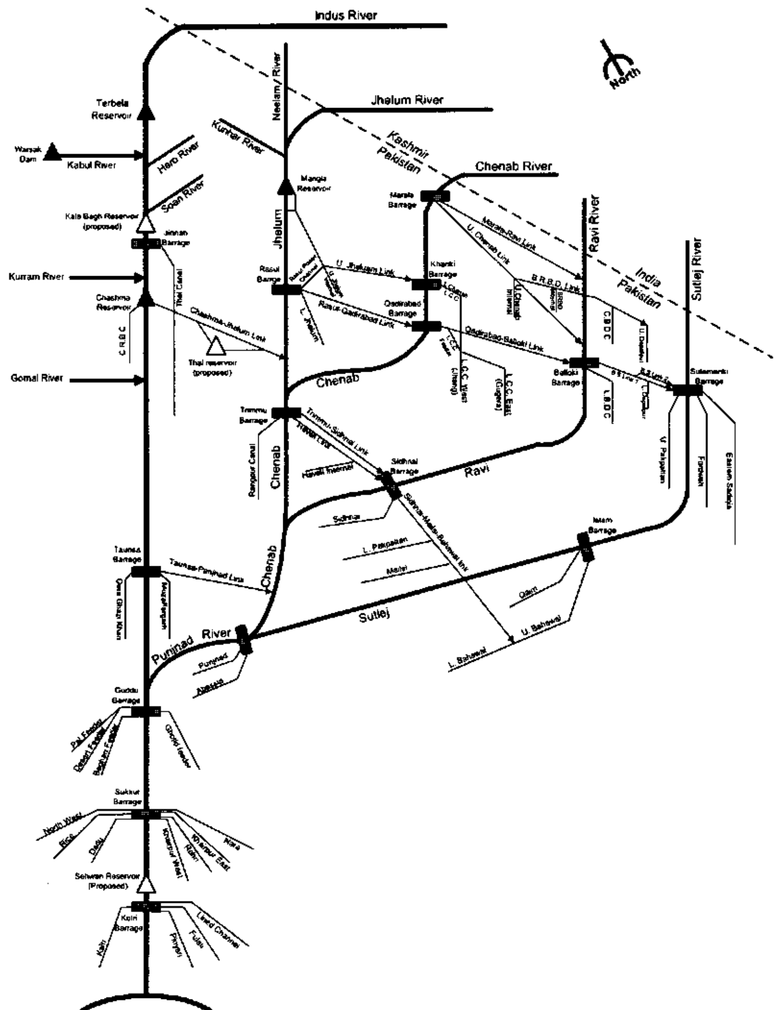
Irrigation	Irrigation interval (days)	Depth suggested by CROPWAT (mm)	Actual depth applied (mm)	Deficit (mm)
Pre-irrigation (*Rouni*)		150*	120	30
Sowing				
1	30	30	79	-49
2	25	59	48	11
3	20	79	63	16
4	20	84	42	42
5	25	61	52	9
6	25	34	32	2
Total		497	436	61
Irrigation Water Requirement		497		
* Soil assumed to be at field capacity				

7.5 CONCLUDING REMARKS

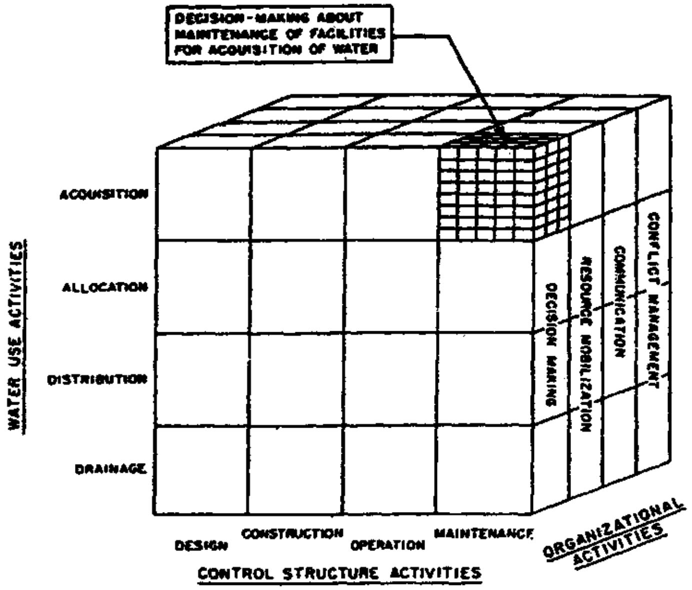
This empirical study was conducted to gain more insight in the roles already played by farmers in shaping the water availability at the tertiary outlet and farm-gate in an agency managed supply-based irrigation system with a dysfunctional water supply that is going to experience some drastic institutional changes in the near future. Presently, farmers are not suppose to have any role in the management of main irrigation system. However this study has demonstrated that direct or indirect roles of farmers in water distribution are extensive - through their interventions at different levels. Already, farmers as individuals and as groups are trying their best to achieve as much water control as possible and it seems they will continue to do it. Participatory irrigation management or not, with or without new Farmers Organisations, farmers will continue to try and acquire control over irrigation water, since for them control over irrigation water is like control over their own lives - as water is life.

APPENDICES

APPENDIX I: LAYOUT OF THE INDUS BASIN IRRIGATION SYSTEM, PAKISTAN



APPENDIX II: UPHOFF'S CUBIC MATRIX OF IRRIGATION TASKS



Source: Uphoff 1986

APPENDIX III: TRAJECTORY METHOD OF DISCHARGE MEASUREMENTS

The discharge of a horizontal pipe could be estimated with the trajectory method that consists of measuring horizontal (X) and vertical (Y) co-ordinates of a point (see figure III-I) in the jet issuing from the end of a pipe (Stock, 1995, in USBR Water Management Manual, 1997).

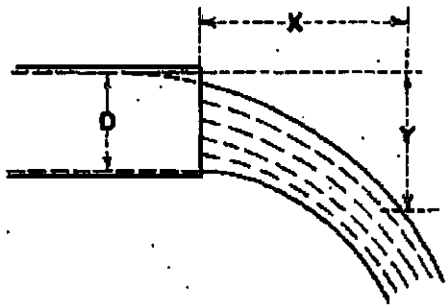


Figure III-I: Co-ordinate method tubewell discharge measurement.
Source: USBR Water Management Manual, 1997.

The equation for discharge from a fully filled pipe is as follows:

$$Q = CAX\sqrt{g/2Y}$$

Where
Q = Discharge ft^3/sec
C = Co-efficient
A = Area of the pipe in ft^2
X = X-co-ordinate in ft
Y = Y co-ordinate in ft
g = Acceleration due to gravity in ft/sec^2

The value of C commonly used in calculations is 1 (Michael, 1978). The flow from partially filled pipes is estimated by multiplying the flow obtained from the equation mentioned above by the percentage area of the pipe that is filled at the end of the pipe.

APPENDIX IV: TENANCY ARRANGEMENTS IN THE SELECTED WATERCOURSE

(Slightly adapted from Terpstra 1998)

Three kinds of tenancy agreement are legal. One is sharecropping, where the tenant and the landowner have a 50 percent share in production. The second is leasing. In this case the cultivator pays a fixed price for a certain time for use of the land. The third one is shareholding. Here, a permanent labourer provides manual labour for 1/5th or 1/10th of the yield. This person does normally not invest in land or crops.

However, one person can be involved in more than one tenancy agreement with one or more farmers. For example, people who cultivate their own land (owner-cum-cultivators) might lease and/or sharecrop in more land. Landowners might rent or sharecrop part of their land out, while cultivating the other part themselves. Even landowners might rent out their own land and sharecrop or rent in another piece of land in the next watercourse. The following combinations are found in the study area (OC = owner-cum-cultivator, OL = leasing out land; OT = sharecropping out land; L = leasing in land; T = sharecropping in land):

OC	OC/L	OC/L/T	OC/OL	OC/OL/OT	OC/OL/L
OC/OL/L/T	OC/OT	OC/T	OL	OL/L	OL/L/T
OL/OT	OL/OT/T	OL/T	OT	L	T
T/L					

Note that these combinations are the sum of contracts an individual farmer has in different watercourses. For example, a farmer who is landowner in more than one watercourse might lease land out in one watercourse, cultivate his land in another watercourse, and lease in extra land in the same watercourse (OC/OL/L).

In short six categories can summarise all the above-mentioned combinations:

I Owner-cum-cultivators; An owner who cultivates his own land

II Owner-cum-tenants (owner-cum-cultivators who are also sharecropping or renting land in);

III Owner-cum-cultivators who sharecrop or rent part of their land out;

IV Landowners who sharecrop or rent out all their land (landlords);

V Landless cultivators who sharecrop or rent land in;

VI Mixed strategy.

In category I we find landowners who do not rent or sharecrop land in or out. They are dependent on their own fields and are not involved in tenancy contracts. Farmers in category II are owner-cultivators who seek extra land to cultivate; either by renting land, sharecropping land, or both (OC/L, OC/L/T, and OC/T). In category III the farmers are the owner-cultivators who have more land than they can or want to cultivate, and sharecrop or rent part of their land out, while they keep on cultivating themselves (OC/OL, OC/OL/OT, OC/OT). Category IV consists of landowners who do not cultivate themselves anymore. Not everyone in this category is an absentee landlord. Some have found a (good) job outside agriculture, and simply do not have the time for cultivation anymore. Some just sit at home while receiving the rent. These landowners are not involved in agricultural activities anymore (OL, OT and OL/OT). Category V is a group of landless farmers. They are involved in agriculture because of tenancy relationships with one or more landowners. Category VI is a somewhat vague category of people who both rent land in and out, or sharecrop land in and out, or have their own land that they rent out, and sharecrop another piece. The ratio behind these strategies differs per individual.

Different terms and conditions for sharecropping and leasing contracts are now reviewed.

SHARECROPPING

Sharecropping for 50 percent of the yield is the most common, even dominant, practice in sharecropping. Only some cultivators sharecrop for 25 percent, or even for 1/6th or 1/8th of the harvest. Sharecropping for 50 percent is an arrangement in which the cultivator provides labour, pays 50 percent of the inputs, and has a 50 percent share in the yield. Cultivators, who sharecrop for 25 percent provide labour, pay 25 percent of the inputs and get a quarter of the yield. Sharecroppers for 1/8th, however, provide labour, get 1/8th of the yield, but do not pay for inputs. In sharecropping the whole household is involved in providing labour. The contract is made with a household or family rather than with one person.

The sharecropping contract

Generally, sharecropping contracts are verbal commitments between a landowner and a cultivator. The parties do not always discuss a specific time period of duration of the sharecropping contract. The norm is that it is for at least one year (one *kharif* and one *rabi* season). When relations between the landowner and the tenant are good, the contract is likely to be prolonged. Some tenants work on the same fields for more than 20 years. Both parties can end the contract at the end of the *Rabi* season, when the wheat is harvested. It is an unwritten rule to end the contracts in this period, both for sharecropping and renting. This unwritten rule is hardly violated, except when serious conflicts between the parties arise. The party who wants to end it should inform the other party in time, to give him the chance to look for a new tenant or a new piece of land.

The terms and conditions of sharecropping contracts are more or less fixed. Normally, the costs of inputs, like fertiliser and pesticides are shared on a 50-50 basis. When the tenant purchases inputs, he ought to get 50 percent back from the landowner, and when the landowner purchases inputs he has the right to ask 50 percent back from the tenant. The costs are balanced at the end of the season either in cash or in an equivalent part of the harvest.

The expenditures on seeds are 100 percent paid by the tenant. Often an exception is made for expensive seeds, like sugarcane, fodder and potato. Then the costs are shared on a 50-50 basis. If tubewell water is purchased the costs are shared. When the landowner has his own tube well, the tenant can use this water if he arranges the fuel to run the tube well. Mostly the tenant has to pay the fuel; sometimes he gets 50 percent of these costs back. The costs for hired labour are 100 percent for the tenant, as he is responsible for all the labour on the fields. Instead of hiring labour, many tenants prefer to exchange labour with neighbours and friends, or make use of family labour. Sometimes, sharecroppers are (agricultural) wage labourers themselves to earn more money. In the study area only in one instance the tenant paid only 50 percent of the costs for hired labour[1]. Tenants also pay 50 percent of *abiana* (water tax). When cultivators break the *mogha,* the *Patwari* (with permission of SDO) imposes a penalty upon the landowners. Tenants have to pay 50 percent of the fine back to the landowner. It is felt that the tenant directly benefits from the extra water. In case officials from Irrigation Department are bribed for increasing the size of the *mogha*, tenants do not have to pay a

[1] In the study area only in one instance the tenant paid only 50 percent of the costs for hired labour. He said that the reason for this is that he works very hard, and the landowner earns about Rs 8.000 to 10.000 per acre, which is much more compared with the tenant he had before.

share[2]. People see this as a more permanent arrangement for improving water availability, although it happens that farmers have to bribe every year for changing the size of the *mogha.*

Normally, the landowner pays big expenditures, like lining the watercourse, maintenance of the watercourse, and installation of a tube well. The tenant provides labour in these activities. The tenant bears responsibility for paying the more common or general management activities, like for the costs for hiring equipment for levelling the fields, ploughing, harvesting, transport of manure and loading of sugarcane and wheat.

In a sharecropping contract for 25 percent, the landowner arranges all the inputs, because the tenant can mostly not afford them. The tenant does all the manual work, like weeding, irrigation and harvesting.

In a few instances, landowners give their land on sharecropping for 1/8th of the share. In this contract the tenant has no expenditures on inputs whatsoever, but is supposed to do all the work. In this way a landowner can get a permanent labourer for the whole season, who helps him with manual labour. Often the tenant does not have permission to work with machinery, like ploughing with the tractor, which is done by the landowners' family.

Task-division and decision-making

Sharecropper families are the actual contemporary cultivators. They bear responsibility for all cultivation activities that involve manual labour, like ploughing, irrigation and daily maintenance of the fields, maintenance and desilting of the watercourses, application of fertiliser spray, making boundaries on the fields, harvesting etc. The tenants make decisions on daily management activities. For non-daily management activities, like levelling the fields, applying fertiliser or spray, growing a certain crop, or purchasing water for irrigation, they often need permission from the landowner. Applying fertiliser and spray is sometimes done under supervision of the landowner.

Generally, decisions are made through mutual discussion, especially important decisions like which crops to grow, although the landowner has veto-right. Room for decision-making by the tenants differs in the following situations:
Landowner does not take part in decision-making and actual cultivation; just takes part of the yield (e.g. absentee landowner and some big landowners);
Landowner advises, but leaves actual decision-making for tenants;
Landowner (or family) tells the tenant what to do and make all the decision himself. He sometimes criticises tenant's work that a tenant perceived as 'teasing'.

The degree, to which a landowner leaves room for the tenant to cultivate in his own way, depends on three factors. These are the attitude of the landowner, the socio-economic position of the landowner and the tenant, and whether the landowner is absentee or not.

<u>Attitude</u>

A few landowners are not much interested in agriculture, and just want their share of the yield. They leave decisions to the cultivator, who is more interested in agriculture and more experienced. To avoid conflicts some landowners allow their tenants to cultivate in the way they like. Both the owner and the tenant benefit if the crop grows well on that piece of land.

[2] In this case tenants are not even involved in the discussion and negotiation process unless he is also a landowner in the watercourse command area. However, in one of the watercourse FD 67-L tenants are usually involved in this process of acquiring additional canal water.

If the tenant grows a crop that does not give much yield, he knows for the next year that the crop is not suitable for that piece of land, and will listen to the landowner. Most landowners keep an eye on the tenants' work in order to maintain control over the crop, soil, and water.

Socio-economic position

A tenant may have a higher socio-economic status than the landowner. In this case it is very likely that the tenant is the principal manager of the land. A nice example is a landowner on 6 *killa* who sharecrops the land from a widow without sons. This person expressed his preference for a 'weak' owner, because in this situation he makes the decisions on which crops to grow. The advantage for this woman to give the land in sharecropping is that she gets half of the yield at the end of the season.

Landowners mostly like tenants who are poorer than them, because they are perceived to work harder and better to get a (fair) share. They should be able to bear the expenditures of sharecropping though. In this way the landowner also has a certain authority over the tenant, which would be hard to exercise if the tenant is richer. At the same time tenants do not prefer very rich or big landowners, as the landowner might ask them to do extra work like in the traditional landlord – *kammi* relationship. This decreases their honour and the time they can spend on cultivation. Moreover, if the landowner has more or less the same social-economic status, the tenants feel free to go to him frequently and discuss management activities or ask permission for certain activities. Sharecroppers often prefer smaller landowners because they cannot bear the expenses of cultivation on large fields.

Absentee landowners

A tenant has much more decision-making authority, when the landowner is absentee; that is when he lives in a far away village or town, or even abroad (Saudi Arabia). When the landowner is living nearby, he can often meet the tenant, like once in 2 or 3 days and sometimes every day. Hence can interfere more in day to day decision making process, for example when to apply fertiliser, whether to purchase tube well water or not, etc. An absentee landowner might visit the fields now and then, or check the condition of the fields every year. Still, the tenants have much more responsibility for maintenance and management of the fields and the watercourses.

Landowners, who give the land on sharecropping for less than 50 percent share, consider the tenant to be a permanent labourer to be paid in part of the yield, instead of in money. The landowner is the sole decision maker and bears costs of all the inputs. Labourer does all the physical work including physically irrigation of the fields, fertiliser application etc. However all the work related to machinery, for example ploughing, is done by the landowner.

RENTING

Renting land means that the renter is not only the contemporary cultivator; he is also the contemporary owner. The real landowner will still be the legal landowner, but after paying the rent the renter has full decision-making power over the land for the duration of the contract.

Factors that increase the rent of a piece of land are:

Good condition of the soil: fertile land;

Availability of tube well water;

Fields close to the main watercourse branch;

Less amount of land available for renting in the area;

Inflation.

Factors that devalue a piece of land are:
Sandy soil;
Bad condition of the soil in general;
Problems of water logging;
Problems of salinity;
Fields far away from the main water channel.

The renting contract

When the contract is discussed between the future renter and the landowner, the rent and the duration of the contract is one of the most important points for discussion. In this area a landowner can ask Rs 5000 (US$ 125) for one acre of fertile land on which a tube well is available. On sandy lands where no tube well is available the rent rate is around Rs 2000 (US$ 50). Fields of bad quality, but with access to tube well water are leased out for about Rs 3500 (US$ 88) per acre, and the same counts for fields of good quality, but without tube well.

The rent rate for a piece of land also depends on the bargaining power of the landlord and the tenant, e.g. a landowner who urgently needs money reduces the rent to find a tenant quickly. Most contracts are for one or two years. There are a few exceptions: when a landowner is in urgent need of money, he might gives the land on rent for 3 or 4 years, since the money for the whole period is paid in advance. Among family members the duration of the contract is sometimes more than average. After one or two years, the contract can be extended if both parties agree. Some renters take care of one field for the last 5 to 8 years, but this is exceptional.

Usually the maximum time for a renting contract is five years. The reason behind this is not only that landowners want to increase the rent as often as possible. There are examples of renters who have tried to occupy land that they rent by transferring it to their name. So people are afraid that after five years the renter might not want to leave the land anymore[3].

Normally, the rent should be fully paid in advance, although there are exceptions. Sometimes the renter and the landowner agree that the rent will be paid after the *kharif* cash crop (cotton or sugarcane). In that way the renter gets the chance to earn the rent from his cultivation practices, so that he does not have to invest a lot of money in advance.

The rent is fixed until the end of the contract; after the contract the rent may increase or decrease. The landowner increases the rent before the next contract when the yield is good, there is more canal water or a tube well has been installed. Farmers say that landowners like short-term contracts of one or two years, so that they can increase the rent. When the yield is disappointing the lessee may ask the landowner to decrease the rate. Renters often like longer-term contracts than their landowners for the same reason. If they know the land is theirs for more than one year, they have more security, and feel more responsible for the land. After one or two years lessees also know which crops are suitable for that soil, and they get higher yields.

[3] In the study area an exception is a person who first sharecropped land for many years and than rented the same land for 8 years more. He says that the landowner knows that he would not try to occupy the land, and this thrust is why the contract is prolonged every year.

Task-division and decision-making

Once the rent is paid all the costs and benefits are for the renter. The owner has no concern with the land anymore. An owner cannot prevent excessive use of chemical fertiliser or (bad quality) tube well water, as he cannot interfere with the renter's cultivation practices. There are a few things that the landowner remains responsible for. These are:

Matters related with the government like changing the size of the *mogha*, taxes and paying the fine for breaking the *mogha*. Often the renter has to pay these costs back to the landowner, as he is the one who benefits from the land;

Planning the making of new watercourses;

Paying for big long-term investments, like installation of a tube well (that will be the property of the landowner), or lining the watercourse;

Trees on the land and on the boundaries remain the property of the landowner. Tenants cannot cut them (even a branch from it) without his permission;

Making decisions about matters related with neighbouring land, like straightening a watercourse on the boundary of two fields.

So the landowner still has some tasks and decision-making power in a renting contract. The owner plans the big, long-term investments. If the owner wants the lessee to participate in activities like levelling the land, dig a new watercourse or help installing a tube well, he has to ask these things at the time contract is agreed upon. A lessee is interested in these things if he takes the land for 4 to 5 years. If he leases the land in for only one year, there is less advantage for him to participate in these activities.

Usually the lessee also has right to use water turn allocated to the piece of land he rents in. He can sell the water turn if he wants, or give it to another cultivator whenever he does not want to use his water turn. He also does not have to share the cost of lining of the watercourse but he has to bear the cost of maintaining the watercourse and levelling the land. However, there are some exceptions, in some cases a lessee needs permission of landowner for giving or selling the *warabandi* turn to someone else, and the landowner participates in costs for maintenance of the watercourse and levelling land.

The responsibilities of a lessee are:

Full responsibilities for daily maintenance of the land and the watercourses in the fields;

Decisions about non-daily management activities, like which crops to grow, whether to cultivate with oxen or tractor, how much fertiliser he applies, whether he applies chemical fertiliser or manure, how often he sprays, etc. Whether he leaves the land fallow or not, that is of no concern for the owner;

Bears all the costs of all inputs, and the whole yield is for him;

He pays 100 percent of *abiana,* bribes and penalties imposed by the Irrigation Department for breaking the *mogha*. A penalty is on the name of the official landowner, but the lessee pays for it, because he is the one who benefits from the additional water during the *warabandi* turns.

Normally, if the landowner has a tube well on the land, the renter does not have to pay for its use; he just arranges the machinery and the fuel to run it.

APPENDIX V: MAIN TASKS AND RESPONSIBILITIES OF THE ID STAFF

Main Tasks and Responsibilities of the Irrigation Department Staff as considered by the staff themselves are listed here. These responsibilities can also be found in the Revenue Manual.

Patwari

1. Making *warabandi*: Making and remaking of *warabandi* of a *chak* if requested by the farmers.
2. *Gardawari*: Visit villages every 15 days or one month to record cropping pattern for *abiana* calculations.
3. Reporting water theft: Check the area on which stolen irrigation water has been used and report the incidence to his officers.

Sub-Engineer

1. Surveying: Surveying of the distributary channel once every three years.
2. Maintenance of the distributary: Strengthening of the bank of the distributary channel after every five years.
3. Water distribution: Equitable water distribution within the distributary. Check dimensions of the outlets - B, Y and H - of the outlets every month.
4. Water theft: Deal with water theft and tampering with the *mogha*.
5. Checking of watercourse condition: If farmers do not maintain their watercourse, and waste canal irrigation water report to XEN and SDO who are supposed to take action against farmers - collect fine and get the watercourse maintained.

Sub-Divisional Officer (SDO)

1. Water Distribution: Equitable water distribution of available water within the sub-division.
2. Maintenance: Strengthening of banks of the distributary channels after every five years.
3. Other tasks – like communicate with the other SDOs upstream and downstream about the

Executive Engineer[4]

1. Water Distribution: Equitable water distribution within the division
2. Revenue assessment
3. New supply to barren lands on request by farmers
4. Other management work - for example estimate of demand for the whole sub-division, and make estimate for maintenance of channels etc.
5. If farmers complain that the discharge to their outlets is less than the design discharge then ID measures the discharge.

[4] Apart form these tasks XEN of the study area also felt that he has to work for Member of Provincial who influence water distribution. The ID staff gets transferred or suspended if they do not follow the instructions of MPA.

APPENDIX VI: OUTLETS TYPES IN THE SELECTED WATERCOURSES

The standard design and functioning of the three different types of outlets of the selected watercourses are described in this section after Mahbub and Gulhati (1951).

Adjustable Proportional Module or Adjustable Orifice Semi-Module

The Adjustable Proportional Module (APM) is a long throated flume with a roof block at the upstream end of a parallel throat (see Figure I). The roof block is adjustable and is attached with the flume through a couple of bolts. To prevent it from tampering, the bolts are secured by a masonry key.

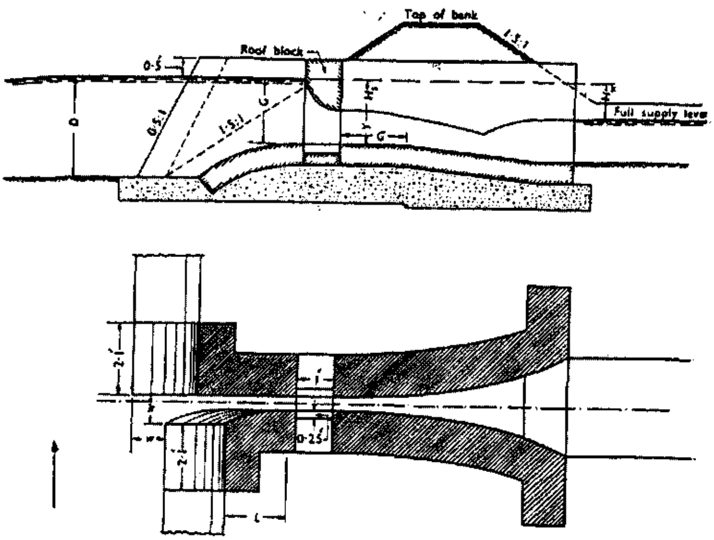


Figure VI-I: Sketch of Adjustable Proportional Module (APM)

As is clear from its name, it is a modular structure: modularity is ensured by the introduction of standing wave, and so long as the wave is steady and remains clear of the exit of the orifice, the discharge coefficient does not alter. The roof block is such that "the jet is made to fill the exit of the orifice and jet contraction is suppressed. Also by extending the parallel throat to a distance G below the exit, curvature of the jet is avoided thereby ensuring a uniform velocity—distribution over the section of the jet". Thus the discharge is dependent on $\sqrt{H_s}$. The discharge formulae is as follows:

$$q = 7.3 B_t Y \sqrt{H_s}$$

where:

q	=	Discharge (ft^3/s)
B_t	=	Width of the opening (ft)
Y	=	Elevation of the roof block above the crest of an outlet (ft)
H_s	=	Height between the upstream water level and the suffit of the roof block (ft)

In the case where water does not touch the roof block the outlet behaves like weir and hence a weir formula should be used to calculate the discharge.

In the beginning the APM outlets were designed for proportional water distribution. But with the time it was found that this type of outlet created a problem of siltation in the distributary therefore the crest of the outlets were lowered (from 6/10 to 8/10) which solved the problem of silt but made it more rigid. It was not proportional anymore. This new modified form of an APM outlet was called the Adjustable Orifice Semi-Module (AOSM) (Mahbub and Gulhati, 1951). Later as experience was gained and some experiments were carried out, some more changes were made in the design of AOSM. For example the length of the gullet was 2 feet for all the cases. The sidewalls below the gullet were given a fixed radius of 25 feet, the curves starting tangentially from the throat. Instead of roof block having a horizontal base, a lemniscate curve with a tilt of 1 in 7.5 is provided (see figure II).These changes helped improved the proportionality of the outlet.

Gulhati after some experiments found out that the discharge formulae for AOSM remains the same as for APM.

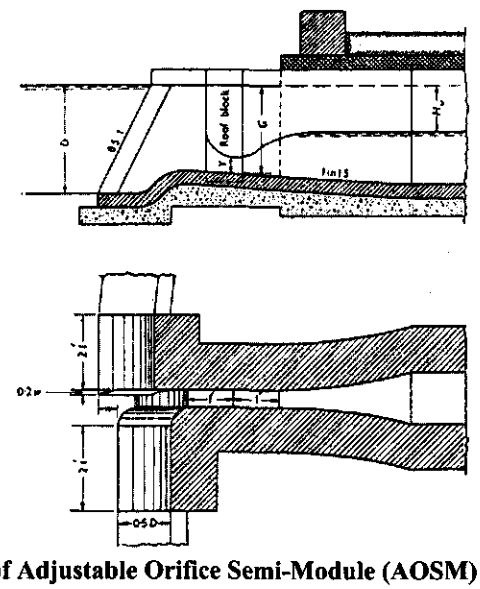


Figure VI-II: Sketch of Adjustable Orifice Semi-Module (AOSM)

The outlet is difficult to tamper with, however it could not be fully ruled out. The roof block could be raised bodily and then re-fixed, although it is easier to detect the tampering. A wooden block inserted at the downstream side of the roof block could increase the discharge since it forms an airtight roof in continuation of the roof block. The discharge is increased due to imperfect aeration of the jet.

Open Flume

The Open Flume (OF) Outlet is like a weir and is mostly found in the tail clusters[5] as in the case with the watercourse MD 11860 TC. Figure III presents the sketch of Crump's open flume outlet that is generally in use in Punjab, Pakistan. The advantage of this type of outlet is that it can draw water even with the minimum small head. However, in most of the cases the outlet is either deep & narrow, which can easily be blocked or wide and shallow that makes it hyper-proportional. Due to this reason this outlet is often installed at the tail.

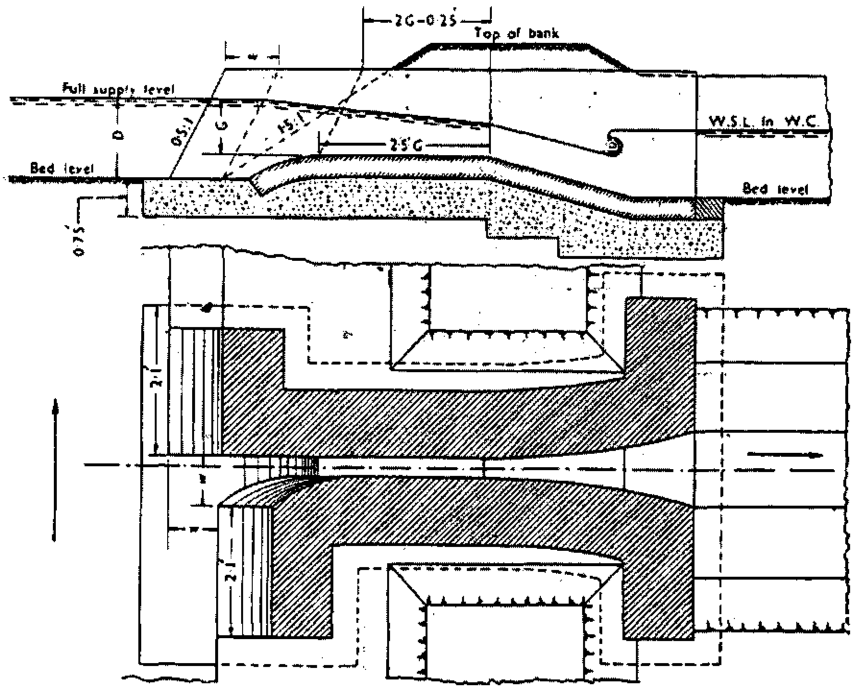


Figure VI-III: Sketch of Open Flume (OF)

The discharge formula for the open flume outlet is:

$$q = KB_t G^{3/2}$$

Where,

q	=	Discharge (ft^3/s)
K	=	Coefficient of discharge
B_t	=	Bed width of the outlet (ft)
G	=	Depth of water over the crest of outlet (ft)

[5] The group or cluster of outlets at the tail of the distributary or any irrigation channel.

The Open Flume outlet is not easily adjustable: if adjustments have to be made the structure has to be either partially or fully constructed. It is proportional if installed at 0.9 of the depth of the depth of the distributary. Silt drawing capacity is highest if installed at the bed level: the higher the crest of the outlet compared with the bed level of the distributary, the less is the silt drawing capacity of the outlet (OF).

Open Flume with Roof Block

The Open Flume with Roof Block (OFRB) was originally the Open flume outlet: the roof block was added to open flume outlets to prevent excessive discharge to these outlets in the case of the water level increases in the parent channel[6]. The OFRB (see figure IV) works as Open Flume if the water level in the distributary is lower than the roof block and works as orifice if the water level touches the roof block[7].

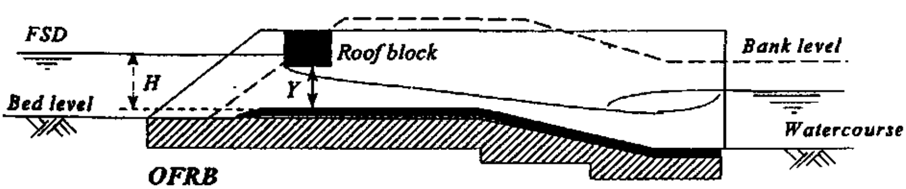


Figure VI-IV: Sketch of Open Flume With roof Block (OFRB)
Source: Visser (1996)

The discharge formulas for OFRB, when it behaves as an orifice is:

$$q = CBY\sqrt{2gH}$$

where:

q	=	Discharge (ft^3/s)
C	=	Discharge coefficient
B	=	Bed width (ft)
Y	=	Elevation of the roof block above the crest of an outlet (ft)
g	=	Gravitational constant (ft/s^2)
H	=	Water level above the suffit of the roof block (ft)

The OFRB behaves as an open flume when water is not touching the roof block. The roof block is sharp-edged, therefore a further increase in the water level results in slower increase in the discharge as compared to the OF. However, farmers can increase the discharge by placing a slanting brick or bundle of grass in the aperture of the flume. This converts the effluent into a jet from an orifice with a slanting roof provided that the jet flows free of the roof block.

[6] In case of Fordwah distributary the placing of roof block resulted in the non-proportionality of the channel (Hart, 1996).

[7] Most of the time these kind of outlets behave like orifices in case of Fordwah distributary (Hart 1996).

APPENDIX VII: *WARABANDI* AS MADE BY A *PATWARI*

If a farmer wants to convert a *katcha warabandi* to *pakka warabandi*, he is required to submit an application to the Divisional Canal Officer. This application then goes through several officers to fulfil official requirements and investigations. The Canal *Patwari* finally prepares the hand-sketch of the outlet command area according to the details given in the Part Watercourse Plan (sanctioned *chak* plan) (Bandaragoda and Rehman, 1995). The *Patwari* prepares the *warabandi*, which goes to the Sub-Divisional Officer through other Irrigation department Officers. The *Patwari* then arranges a meeting of the Sub-Divisional Canal Officer, who functions as a Canal Magistrate, and the farmers. The Sub-Divisional officer announces the proposed *warabandi* in an open court. If any farmer has an objection that is discussed in the open canal court. The Sub-Divisional Officer announces judgement and sanctions the *warabandi*. A copy of the new *warabandi* is also handed over to the *Numberdar* (or *Lambardar*). The way a *Patwari* prepares a *warabandi* schedule is explained in the following paragraph.

Making of the *Warabandi*

The first step in preparing the *warabandi* is to estimate the number of minutes per acre. To calculate number of minutes per acre a *Patwai* first calculates the total minutes availavble for irrigation in 7 days by estimating the time needed for filling (*bharai*) and draining (*nikal*) of portions of the watercourse. The *bharai* is subtracted from the total time to compensate for the time needed to fill that part of the watercourse leading to the farm. Similarly a farm may continue to receive water from a filled watercourse even if water is diverted to another farm from upstream. In this case, total *nikal* time is added to the minutes available for irrigation in one week. Usually *Patwaris* use 5 minutes[8] per 67 meters[9] of the watercourse for both *nikal* and *bharai*. The average water allocation time per acre is then calculated based on Culturable Command Area (CCA) with the following formulae:

$$\text{Average allocation time } (T_A) = \frac{10080 - \text{total } bharai + \text{total } nikal}{\text{CCA (acres)}}$$

Based on this average allocation individual irrigation water turn is calculated with the following formulae:

Water turn = (Average allocation time * Area) + *bharai* time – *nikal* time

Where area is in acres and time in minutes.

For example, consider a watercourse with:

CCA	= 300 acres
Total *bharai* time	= 123 minutes
Total *nikal* time	= 66 minutes

And a farmer with:

Total culturable area	= 10 acres
Bharai time	= 15 minutes
Nikal time	= 5 minutes

[8] In some cases this time could also be 3 minutes.

[9] This is one side of an acre (220 feet).

Then,
The average allocation time in the watercourse will be

$$T_A = \frac{10080 - 123 + 66}{300} = 33.41 \text{ minutes/ acre} = 33 \text{ min/acre}$$

and the allocation for the farmer will be:

Water turn of the farmer = (33 * 10) + 15 – 5 = 340 minutes (5 hours and 40 minutes)

Same formulae is used to calculate water turns of all the farmers in a watercourse. After allocating water a 7 day schedule is prepared with the specific days and time for all the farmers in a watercourse command area.

***Patwari's* influence**
Although this procedure of making *warabandi* is theoretically quite transparent, a *patwari* can still influence it. For example in case of average allocation comes up to be in fraction like in this case the *Patwari* round it off to the next nearest digit, like in this case it was rounded off to 33 from 33.41. At the end all this fractions would add up and some minutes will remain extra. *Patwai* can allocate these minutes to the farmers he likes. According to a *Patwari* interviewed during the field work of the current study *Patwari*s give these minutes to the farmers who help them in conducting surveys for preparing outlet command area or who offers money.

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ENGLISH SUMMARY

FARMERS ACTIONS AND IMPROVEMENTS IN IRRIGATION PERFORMANCE BELOW THE *MOGHA*

How farmers manage water scarcity and abundance in a large scale irrigation system in South-Eastern Punjab, Pakistan

The irrigation systems of Punjab, Pakistan are not functioning effectively in relation to design criteria or farmers' needs. This under-performance is attributed to among others, scarcity of irrigation water, changes in cropping intensity and mis-allocation of available resources. Farmers at the receiving end play an important role in shaping the performance of the irrigation system. A farmer continuously monitors and evaluates water delivery to his farm based on which he takes individual or collective action to improve water delivery and intervene with the system. To develop appropriate recommendations for reforming system operations, more knowledge is required about irrigation conditions at the watercourse level and the actions that farmers take to improve water availability at their farm head, in order to understand and evaluate the results of this human action on the performance of the Irrigation system. The present study was conducted to study the impact of farmers' water management actions in a conjunctive water use environment of Fordwah Irrigation System. The central research question of the study is:

> *How and why do farmers intervene in irrigation water supply, what conditions shape their actions and what is the impact of their action on water delivery in a large scale irrigation system of Punjab, Pakistan?*

In the past most performance assessment frameworks were developed to study performance of the main and secondary level irrigation system. However, as rightly noted by Perry (1995), the performance evaluation of an irrigation system at primary and secondary sub-system levels, in isolation from the performance evaluation of an irrigation system at watercourse and farm level, would not provide full understanding of the system. Since the focus of this study is the farmers' actions and their influence on water delivery, a multi-disciplinary socio-technical approach is needed that keeps technology-in-use as a central point while studying relations around it.

A comparative study method was used to analyse farmers' actions for water management. The research was undertaken in the Fordwah Irrigation System, which serves a command area of 232,000 hectares. Six watercourses along the two distributaries (at the tail of the system) were selected based on their canal water supply and tubewell density per 100 hectares. Fieldwork was conducted between November 1996 to April 1998. This covered three crop seasons, two winter seasons and one summer season: *rabi* 1996-97, *kharif* 1997 and *rabi* 1997-98. A wide range of quantitative and qualitative data was collected in the field. A measurement and regular monitoring plan was followed to collect data on water flows, crop production and climate. To collect data on water management practices and social relations un-structured and semi-structured interviews were conducted, and observation of water management practices were made. However, use was also made of some participatory tools during farmers' meetings to discuss water management.

The book is organised in eight chapters. Chapter 1 introduces the central theme of the book and the area of the study. After a literature review the research framework for this study is presented in Chapter 2. Chapter 3 describes the 'Water Delivery Environment' of the studied watercourses. In Chapter 4 and 5 farmers' actions for water management are described and the financial rewards of these actions are estimated. Chapter 6 presents the impact of farmers' actions in terms of improved water delivery to their farms. The study is summarised and concluded in chapter 7.

In Chapter 2, after reviewing the strengths and the weaknesses of the existing models to study irrigation system management and its performance, a framework to study inter-relatedness of issues at tertiary level is formulated. This research framework studies the outcomes of interaction between technology, people and water based on the socio-technical approach. The actions of people, collective and individual are studied to understand the transformations they achieve in water supply by changing the irrigation technology.

Chapter 3 describes the 'Water Delivery Environment' – that is the context of people, technology and water supply in which farmers take actions for water management - of the study area. The settlement pattern, social relations and other agrarian conditions suggest that the research site is transforming through population growth, and urban employment. Off-farm activities and markets shape production and market choices as well as water supply. However despite these changes some social institutions like *Panchayat* abide. The analysis of canal water delivery situation of the two distributaries shows the level of dysfunctionality of the system. One distributary is water-short whereas, other is privileged with actual water supply more than double its design discharge. The water delivery to the watercourses also shows inadequacy and unreliability of canal water supply especially in *kharif* season. The actual dimensions of the tertiary outlet show that farmers (as a group) try to increase water delivery to their watercourse through outlet remodelling, that influences the water distribution within a distributary. One of the reasons for inadequacy is also the high actual cropping intensity that is far exceeding the cropping intensity for which the system was designed. To compensate for insufficient and variable canal water supply farmers are extracting groundwater. Through a range of actions farmers manage to transform a dysfunctional canal irrigation system to achieve reasonable yields of their major crops.

The collective efforts of farmers to improve canal water delivery to their watercourse are discussed in Chapter 4. Two activities, canal water acquisition and watercourse desilting are identified to be the most important collectively performed activities to manage irrigation water, the former to improve the adequacy of water supply to a watercourse and the latter to improve the water flow in a watercourse. Additional canal water is acquired either through getting higher discharge in the distributary - a strategy adopted by the farmers of the distributary with high canal water supply - or through remodelling of the tertiary outlet - a strategy that is usually adopted by the farmers of the relatively water scarce distributary. A watercourse is desilted several times during a year, however the frequency varies in different watercourse command areas.

This chapter also describes the institutionalisation of these activities. The rules in practice, and roles and responsibilities of the farmers in organising these activities are explained. Generally different farmers are informally responsible for organising different water management activities. Although, sometimes this distinction is not very clear and one person may lead more than one activity or more than one person could be responsible for different parts of the activity. At the end of the chapter factors influencing the collective action are identified. The need for canal water is considered to be the deciding factor for farmers to undertake collective action and mutual benefit, provided that no conflict occurs within the group. Two factors, relatively equal distribution of power among the farmers of a watercourse and *zid* (being stubborn) were identified as having negative influence on collective action in the watercourses studied.

Chapter 5 discusses the strategies of individual farmers to increase water control at the farm level. It is argued that main concern of farmers is to meet evaporative demand of their crops, hence water delivery to their farm is very important for them. They are not really concerned about the technical causes of fluctuating water supply. To get a higher quantity of irrigation water and to manage available water efficiently at individual level, they try to take actions that require less resource mobilisation and less efforts in terms of organisation. Sometimes individual actions also benefit more than one farmer.

Farmers take several actions to manage irrigation water. Some actions are undertaken to acquire additional water for irrigation and others to reduce hassle or increase the usability of irrigation water. Actions taken to acquire irrigation water include groundwater pumpage, use of canal water turns allocated for Government property and stealing water from the distributary. Trade of canal water turn (also illegal) is another strategy to acquire additional canal water at the individual level. Actions that seem to improve usability are exchange of canal waters, desilting of farm channels and disposal of excess water.

The most widely practised individual actions found in the study area are conjunctive use of canal water and groundwater and canal water exchanges. Groundwater is the main source of additional irrigation water. About 83 % of the farmers in the study area are using groundwater for irrigation, in which 40 % have direct access to the tubewell water whereas the rest 60 % purchase pumped ground water from the tubewell owners. The demand-supply curve for different farmers who are using only canal water for irrigation and farmers practising conjunctive water use of canal and groundwater is presented to show the gap between the supply and demand of these farmers. The gap between the demand and supply for farmers using only canal water for irrigation was much higher than for the farmers practising conjunctive water use. This was also reflected in the difference in their yields especially of sugarcane and rice: respective yields of sugarcane and rice of the farmers using both canal water and groundwater for irrigation are about 96 % and 46 % higher. Although not officially allowed, farmers frequently exchange full or a part of their canal water turns, which helps them to irrigate the desired number of bunded units in one irrigation turn. The financial rewards of these activities are estimated to show the incentives for farmers to undertake these actions. This data shows the sound assessment and planning of farmers in choosing actions to improve water supply.

Usually it is assumed that water distribution in large-scale irrigation systems is effective through collective action and that most individual actions for water management are a result of lack of collective action. However this chapter shows that there are still several individual actions that would be undertaken by farmers regardless of existence of collective action within the watercourse command area.

The outcomes of the most widely undertaken collective and individual actions for water management to improve water delivery are presented in Chapter 6. Farmers' responses to water scarcity and water abundance are quantified. Two indicators, Relative Water Supply and Relative Irrigation Supply are used to demonstrate the impact of farmers' actions on water availability. It shows how farmers from different Water Delivery Environments are matching water demand with supply. Variation in water depth at the farm level suggests that the impact of water management activities is not same for all the farmers within a watercourse command area. The demand and supply situation over time of some selected farmers is presented and the actions they undertake are explained to present the management of individual farmers to meet evaporative demand of their crops. It is concluded that the combined effects of the actions for water management enable many farmers to irrigate with reasonable levels of water supply and hence improve 'performance indicators'.

Chapter 7 presents summary and conclusion of the study. It presents the key findings of the study. The usefulness and limitations of the approaches and some study tools are also discussed. All the different concepts used in this study were found helpful to study different elements of the 'Water Delivery Environment'.

It is recognised that there is neither a standard set of water management activities nor they strictly planned, in the study area. Farmers' actions are mostly subject to their need for meeting water supply with the demand, however one can still see some of the water management activities that are inevitable to operate the system. The actions taken and the way and time these activities are organised and performed is difficult to predict in advance. Collective action is undertaken more at the watercourse or higher level in the irrigation system, whereas individual actions are mainly undertaken at the farm level.

Farmers are not passive recipients of water delivery to their farms: they respond to the water availability at the farm-gate. However, their response depends on the severity of the problem(s), which is related to water scarcity or water excess and the political and financial risks they are ready to take in selecting specific actions. The level of organisation of the activities highly depends on the prioritisation of the farmers to undertake this activity. A farmer is more likely to undertake individual actions in the case that he is the only one to benefit from it, or if collective action requires more efforts than the benefit gained from the action. Whereas, collective action would happen if individuals expect benefits that outweigh the efforts involved in organising the collective action (Ostrom 1993). Moreover, more often the collective action leads to a more permanent and sustainable solution.

The four main findings of the study are: 1) that farmers are knowledgeable and capable actors who take actions that improve water supply and compensate for dysfunctional delivery; 2) Farmers actions are not only technically and economically sound but also have motives other than just economic benefit; 3) Farmers' management can not be classified as 'contingent management' and is rather performance-oriented; and 4) Current performance indicators, which are not able to show realities of social relations shaping water availability, could be improved by including criteria to assess performance of irrigation system from the perspectives of different actors. By incorporating the way farmers intervene with the system and thus appropriate the water delivery, such new performance studies could portray local water dynamics of a system and support recommendations based on reality to improve the functioning of the irrigation system.

The study contributes to the debate on Participatory Irrigation Management and overuse of groundwater in Pakistan. The patterns of conjunctive water use at the farm level suggest that the in future groundwater will have to continue to provide significant amount of water for crop production. It was suggested to take some measures for the sustainable use of groundwater. These measures include improving reliability of canal water, devising appropriate technologies - such as skimming wells - for relatively fresh groundwater extraction (Asghar *et al.*, 2001), and incorporating issues of groundwater extraction rights in the PIDA legislation (Punjab Private Sector Groundwater Development Project Consultants, 2000: Technical Report No. 38, 42, and. 45).

The findings of this study and others suggest that political power may still be able to ensure privilege in the new water management structure. Concerns are raised regarding the involvement of non-influential farmers in the Farmers' Organisation and safeguarding the interests of small farmers.

NEDERLANDSE SAMENVATTING

Dutch Summary

BOEREN ACTIES EN VERBETERINGEN IN HET FUNCTIONEREN VAN IRRIGATIESYSTEMEN IN HET TERTIAIRE VAK

Hoe boeren waterschaarste en -overschot managen in een grootschalig irrigatiesysteem in het Zuidoosten van de Punjab, Pakistan

De irrigatiesystemen in de Punjab, Pakistan, functioneren niet effectief gemeten naar de ontwerpcriteria, noch in vergelijking met de behoeften van de boeren. Dit slecht functioneren wordt toegeschreven aan onder meer: de schaarste aan irrigatiewater, veranderingen in de gewasintensiteit en de slechte verdeling van het aanwezige water. De boeren spelen een belangrijke rol in het uiteindelijke functioneren van het irrigatiesysteem. Een boer controleert en evalueert continu de toevoer van water naar zijn velden. Op basis van deze evaluatie zal hij individueel, of samen met andere boeren, actie ondernemen om de toevoer van water te verbeteren. Om te komen tot aanbevelingen voor het verbeteren van het gebruik van de irrigatiesystemen is het nodig meer te weten over het werkelijke functioneren van het irrigatiesysteem in het tertiaire vak en de acties die de boeren ondernemen om de watertoevoer naar hun land te verbeteren. Deze kennis kan gebruikt worden om de effecten van de acties van de boeren op het functioneren van het irrigatiesysteem te evalueren. In het gepresenteerde onderzoek zijn de gevolgen van de boerenacties op het gecombineerde gebruik van kanaal- en grondwater onderzocht in het Fordwah irrigatiesysteem. De hoofdonderzoeksvraag luidt:

> *Hoe en waarom interveniëren boeren in de waterdistributie, welke condities beïnvloeden hun acties en wat is het effect van de acties op de waterdistributie in een grootschalig irrigatiesysteem in de Punjab in Pakistan?*

Eerdere studies naar het functioneren van grootschalige irrigatiesystemen concentreerden zich voornamelijk op het hoofdsysteem van primaire and secondaire kanalen. Echter, zoals terecht opgemerkt door Perry (1995), een goed begrip van het functioneren van een irrigatiesysteem ontstaat alleen dan wanneer men de analyse van het hoofdsysteem alsmede het secondaire, tertiaire en veld niveau met elkaar combineert. Om een onderzoek te doen naar de acties van boeren en de invloed daarvan op de waterdistributie is een sociaal-technische aanpak vereist die het gebruik van technologie en de relaties daaromheen analyseert.

Een vergelijkende studie werd uitgevoerd om de boerenacties te analyseren met betrekking tot het waterbeheer. Het onderzoek vond plaats in het Fordwah Irrigation System, met een te irrigeren areaal van 232.000 hectare. Zes tertiaire kanalen (watercourses) langs twee secondaire kanalen (distributaries) in de tail-end van het systeem werden geselecteerd op basis van de kanaalwatertoevoer en dichtheid van grondwaterpompen (tubewells). Van november 1996 tot april 1998 werd veldwerk uitgevoerd tijdens drie irrigatieseizoenen: *rabi* (winterseizoen) 1996-97, *kharif* (zomerseizoen) 1997 en *rabi* 1997-98. Verschillende kwalitatieve en kwantitatieve gegevens werden verzameld in het veld. Data werd verzameld over de waterdistributie, gewasproductie en klimaatkarakteristieken in een meet- en observatieprogramma. Niet gestructureerde en semi-gestructureerde interviews werden gehouden, naast veldobservaties, om data te verzamelen over de waterbeheerspraktijken. Tevens werden er participatieve methoden gebruikt tijdens boerenbijeenkomsten om het waterbeheer met de watergebruikers te bespreken.

Dit boek heeft acht hoofdstukken. Hoofdstuk 1 introduceert het centrale thema van het boek en het studiegebied. Na de presentatie van het literatuuronderzoek wordt het onderzoekskader voor dit onderzoek toegelicht in hoofdstuk 2. Hoofdstuk 3 beschrijft de context van het waterbeheer in de bestudeerde secondaire kanalen. In hoofdstuk 4 en 5 worden de acties van de boeren ten aanzien van het waterbeheer beschreven en wordt een inschatting gemaakt van de financiële opbrengst van deze acties. Hoofdstuk 6 presenteert de gevolgen van de boeren acties op de watertoevoer naar hun velden. Hoofdstuk 7 geeft een samenvatting van de studie en de conclusies.

In hoofdstuk 2 wordt, na een beschouwing van de sterke en zwakke punten van bestaande modellen om waterbeheer te bestuderen, een kader ontwikkeld om de complexe interrelaties tussen technische en sociale factoren binnen het tertiaire vak te onderzoeken. Dit raamwerk beschouwt de uitkomsten van de interacties tussen technologie, mensen en water, en is gebaseerd op de 'sociaal-technische benadering' ('socio-technical approach'). De activiteiten van mensen, zowel collectief als individueel, worden bestudeerd om de transformaties in watertoevoer, die zij bereiken door veranderingen in de irrigatietechnologie, te begrijpen.

Hoofdstuk 3 beschrijft de 'De context van het waterbeheer'. Dat is de configuratie van mensen, technologie en watertoevoer waarbinnen boeren acties ondernemen. De bevolkingsspreiding, sociale relaties, en andere voor de landbouw belangrijke omstandigheden suggereren dat het onderzoeksgebied transformeert door bevolkingsgroei en migratie naar de steden. Activiteiten buiten de landbouw en markten beïnvloeden de productie en marktgerichtheid als mede de watertoevoer. Ondanks deze veranderingen blijven bepaalde sociale instituties zoals de '*Panchayat*' (soort dorpsbestuur) bestaan. De analyse van de kanaalwaterdistributie in de twee secondaire kanalen laat zien hoe slecht de systemen functioneren. Een van de secondaire kanalen heeft een water tekort, terwijl in het andere kanaal meer dan twee maal zo veel water stroomt als het ontwerpdebiet. De waterdistributie in de secondaire kanalen is inadequaat en onbetrouwbaar, vooral in het *kharif* (zomer) seizoen. De afmetingen van de inlaten, die de tertiaire kanalen voeden vanuit het secondaire kanaal, laten zien dat (groepen) boeren proberen de toevoer naar hun tertiaire kanaal te vergroten door de inlaten aan te passen. Dit beïnvloedt de totale waterdistributie in een secondair kanaal. Eén van de redenen voor de inadequate toelevering is de hoge gewasintensiteit, die de oorspronkelijk bedoelde intensiteit ver overstijgt. Boeren gebruiken grondwater om het tekort aan kanaalwater te compenseren. Dankzij een scala van activiteiten lukt het de boeren een redelijke oogst te verkrijgen van de belangrijkste gewassen, ondanks het slecht functionerende irrigatie systeem.

Hoofdstuk 4 beschrijft de collectieve acties van de boeren om tot een betere kanaalwatertoevoer te komen. Het verkrijgen van meer kanaalwater en het schoonmaken van het kanaal, bleken de meest gebruikte activiteiten. Additioneel kanaalwater wordt verkregen door meer water te bemachtigen in het secondaire kanaal – een strategie gebruikt door de boeren in het secondaire kanaal met veel water – of door de inlaat naar het tertiaire kanaal te vergroten. Deze laatste strategie wordt gebruikelijk toegepast door de boeren met tertiaire kanalen langs het waterschaarse kanaal. De tertiaire kanalen worden verschillende keren per jaar schoongemaakt. De precieze frequentie verschilt per kanaal.

Dit hoofdstuk beschrijft ook de institutionalisering van deze activiteiten. Hierbij wordt ingegaan op de regels, de taken en de verantwoordelijkheden van de boeren in de organisatie van de activiteiten. Normaal gesproken zijn verschillende boeren informeel verantwoordelijk voor het organiseren van verschillende waterbeheer activiteiten. Echter, de verdeling van de taken is niet altijd duidelijk. Soms heeft een persoon meerdere taken en soms zijn meerdere personen verantwoordelijk voor verschillende delen van één activiteit. Aan het einde van het hoofdstuk worden de factoren die collectieve acties beïnvloeden geïdentificeerd. Het blijkt dat de behoefte aan kanaalwater de doorslag gevende factor is om te komen tot collectieve actie met wederzijds voordeel, met als voorwaarde dat er geen conflicten ontstaan binnen de groep boeren. Twee belangrijke factoren die collectieve actie bemoeilijken waren: relatief gelijke verdeling van macht binnen de groep boeren, en *zid* (koppigheid).

Hoofdstuk 5 bediscussieert de strategieën van individuele boeren om meer controle te krijgen over de toevoer van water naar hun veld. Belangrijkste doel van de boeren is om aan de watergewasbehoefte te voldoen. De boeren zijn niet echt geïnteresseerd in de technische redenen van de fluctuaties in de watertoevoer. De boeren proberen acties te ondernemen die minder kosten en organisatie vereisen om een hogere water gift te verkrijgen en het aangeleverde water efficiënter te gebruiken. In bepaalde gevallen bevoordeelt een individuele actie meer dan één boer.

Boeren ondernemen verschillende acties ten aanzien van waterbeheer. Sommige acties worden ondernomen om meer water te verkrijgen, om het geleverde water beter te gebruiken, en andere om 'geregel' te verminderen. Acties om meer water te bemachtigen zijn: het gebruik van grondwater, het gebruik van kanaal water dat bestemd is voor overheidseigendommen (scholen, bossen), en het stelen van water uit het secondaire kanaal. Het verhandelen van een irrigatiebeurt (ook illegaal) is een andere strategie om additioneel water te verkrijgen op veldniveau. Acties ter verhoging van de bruikbaarheid van het geleverde water zijn: ruilen van irrigatiebeurten, schoonmaken van kanalen en het verwijderen van overtollig water.

De meest gebruikte individuele acties van boeren zijn het gezamenlijk gebruik van grond- en kanaalwater en het ruilen van irrigatiebeurten. Grondwater is de belangrijkste additionele waterbron. Ongeveer 83 procent van de boeren in het studiegebied gebruiken grondwater voor irrigatie, van wie 40 procent directe toegang heeft tot een pomp (tubewell) en de overige 60 procent het grondwater koopt van de pomp eigenaren. Het verschil voor de watervoorziening van de gewassen tussen de boeren die alleen kanaalwater gebruiken en degene die zowel kanaal- als grondwater gebruiken wordt gepresenteerd. Het tekort aan water voor de gewassen was veel groter voor de boeren die alleen kanaalwater gebruiken. Dit kwam ook tot uiting in de gewasopbrengsten, speciaal voor suikerriet en rijst. Boeren die zowel grond- als kanaalwater gebruiken hadden hogere opbrengsten voor deze gewassen: respectievelijk 96 en 46 procent. Het ruilen van de gehele of een deel van een irrigatiebeurt gebeurt vaak, alhoewel dit officieel niet is toegestaan. Dit helpt hen de irrigatiebeurten beter te benutten. De financiële voordelen van deze activiteiten worden geanalyseerd in dit hoofdstuk, om de beweegredenen van de boeren beter te begrijpen. Uit deze analyse blijkt dat de boeren wel overwogen beslissingen nemen ten aanzien van de keuze van te ondernemen activiteiten ter verbetering van de watertoevoer.

De gebruikelijke aanname is dat grootschalige irrigatiesystemen efficiënt kunnen zijn vanwege collectieve actie, en dat individuele actie ten aanzien van waterbeheer alleen voortkomt uit een gebrek aan collectieve actie. Dit hoofdstuk, echter, laat zien dat er goede redenen zijn voor boeren om individuele acties te ondernemen, terwijl er ook collectieve acties worden ondernomen.

Hoofdstuk 6 presenteert de gevolgen van de meest voorkomende collectieve en individuele acties in het waterbeheer. Een kwantitatieve analyse wordt gemaakt van de reacties van boeren op water schaarste en water overschotten. Er worden twee indicatoren gebruikt om de effecten van de boeren acties te meten op de waterbeschikbaarheid: Relatieve Water Toevoer (Relative Water Supply) en Relatieve Irrigatie Gift (Relative Irrigation Supply). Dit laat zien hoe boeren in verschillende omstandigheden vraag en aanbod van water op elkaar afstemmen. De verschillen in watergiften voor verschillende boeren in het gebied van één tertiair kanaal tonen aan dat de effecten van het waterbeheer verschillen per boer. De waterbehoeften en irrigatiegiften van enkele geselecteerde velden worden gepresenteerd, met daarbij een uitleg van de acties van de desbetreffende boeren. Hieruit wordt geconcludeerd dat het gecombineerde effect van de activiteiten is dat veel boeren redelijk kunnen voldoen aan de waterbehoeften van de gewassen, en daarmee de indicatoren van het functioneren van het systeem verbeteren.

Hoofdstuk 7 geeft een samenvatting en de conclusies van het onderzoek. Het presenteert de belangrijkste bevindingen, de bruikbaarheid en beperkingen van de gebruikte benaderingen, en bediscussieert het gebruik van enkele onderzoeksmethoden. Alle gebruikte concepten bleken nuttig in het bestuderen van de verschillende elementen van de 'water distributie context'.

Het wordt onderkend dat er in het studiegebied geen standaard waterbeheer activiteiten zijn, noch een strikte planning. Sommige activiteiten, zoals het schoonmaken van het kanaal zijn alleen gedeeltelijk afhankelijk van de watertoevoer, andere activiteiten vinden alleen dan plaats wanneer de watertoevoer dat vereist. Het type en de timing van de acties die worden ondernomen kan niet worden voorspeld. Collectieve actie wordt meer ondernomen op het niveau van tertiaire kanaal, of hoger in het irrigatiesysteem, terwijl individuele acties vooral worden ondernomen op het veldniveau.

Boeren zijn geen passieve ontvangers van het water op het veldniveau: zij reageren op de watertoevoer naar hun veld. Echter, hun respons hangt af van de ernst van de problemen, zij het water schaarste of overschot, en tevens de politieke en financiële risico's die zij bereid zijn te nemen. De graad van organisatie van de activiteiten hangt samen met de prioriteit die de actie heeft voor de boeren. Een boer is meer geneigd een individuele actie te ondernemen als het profijt alleen hem toekomt, of in het geval de collectie actie meer moeite zou kosten dan het voordeel dat het oplevert. Collectieve actie vindt plaats als individuen meer baat dan kosten verwachten van het organiseren van collectieve actie (Ostrom 1993). Bovendien leidt collectieve actie vaak tot een meer permanente verbetering van de watervoorziening.

De vier belangrijkste bevindingen van het onderzoek zijn: 1) dat boeren kundige en bekwame actoren zijn die acties ondernemen om de watervoorziening te verbeteren en zo de slechte watertoevoer compenseren; 2) de acties van boeren zijn technisch en financieel goed onderbouwd, maar worden ook door niet economisch factoren beïnvloed; 3) Het waterbeheer van de boeren kan niet worden aangemerkt als 'ad hoc' beheer en is uitkomstgericht; en 4) De nu gebruikelijke indicatoren die gebruikt worden om de irrigatie waterdistributie te evalueren kunnen niet de sociale relaties laten zien die de waterdistributie vorm geven. Dit zou verbeterd kunnen worden door de indicatoren aan te passen aan de perspectieven van de verschillende actoren. Door de interventies van de boeren, en daarmee de toe-eigening door de boeren van de waterdistributie, mee te nemen in de evaluatie van het functioneren van het irrigatiesysteem, kan de lokale dynamiek geïncorporeerd worden in de evaluatie. Op die manier kunnen aanbevelingen geformuleerd worden, gebaseerd op de werkelijke situatie, die het functioneren van het systeem kunnen verbeteren.

De studie levert een bijdrage aan het debat over het Participatieve Waterbeheer van Irrigatiesystemen en de uitputting van de grondwatervoorraden in Pakistan. Het patroon van gecombineerd watergebruik van kanaal- en grondwater suggereert dat grondwater in de toekomst een significant deel van de waterbehoefte van de gewassen zal dekken. Enkele suggesties worden gedaan voor maatregelen voor duurzaam grondwaterbeheer. Enkele van deze maatregelen zijn: het verbeteren van de betrouwbaarheid van de kanaalwater leveringen, het gebruik van geschikte technologie - zoals de 'skimming wells' - voor extractie van relatief vers grondwater (Asghar *et al.* 2001), en het incorporeren van rechten ten aanzien van grondwatergebruik in de PIDA wetgeving (Punjab Private Sector Groundwater Development Project Consultants, 2000: Technical Report No. 38, 42, and. 45).

De bevindingen van deze studie suggereren dat politieke macht ook in de nieuwe waterbeheerstructuur privileges kan bieden. Bezorgdheid wordt geuit omtrent de lage participatie van de kleine boeren in de watergebruikers-organisatie. Zij kunnen op die manier niet hun belangen veilig stellen.

Curriculum Vitae

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