INVESTIGATING IRRIGATION SYSTEMS' PERFORMANCE UNDER TWO DIFFERENT GOVERNANCE SYSTEMS IN PAKISTAN

by

Sajjad Ahmad

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Natural Resources Management

Examination Committee:	Dr. Sylvain Roger Perret (Chairperson) Dr. Roberto S. Clemente Prof. Ganesh P. Shivakoti Prof. Jayant Kumar Routray
External Examiner:	Dr. Marcel Kuper CIRAD / Institute Agronomique et Veterinaire Agricultural University, Morocco
Nationality:	Pakistani
Previous Degree:	Master of Science in Natural Resources Management Asian Institute of Technology, Thailand
Scholarship Donor:	Higher Education Commission (HEC), Pakistan – AIT Fellowship

Asian Institute of Technology
School of Environment, Resources and Development
Thailand
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Abstract

Pakistan has the largest contiguous supply-based irrigation system in the world, most notably in Punjab where arid conditions prevail. While sound management of irrigation is necessary for agricultural development, irrigation systems in Punjab have long shown low performance and efficiency. In order to improve irrigation systems' management and performances, in line with the global trend of Irrigation Management Transfer (IMT), the Government of Pakistan initiated governance reforms. This study investigated the performances in water supply and services at system level, and the performances and technical efficiency at the farming system's level. Two case study schemes under contrasted governance conditions were selected in Punjab Province, Pakistan. One is a Farmer-Managed Irrigation Scheme (FMIS, in Burala Canal Irrigation Scheme), and the other is a Government-Managed Irrigation Scheme (GMIS, in Upper Pakpattan Canal Irrigation Scheme). The Mapping System and Services for Canal Operation Techniques (MASSCOTE) approach was used to assess the irrigation scheme-level performances through rapid appraisal procedure, questionnaire survey and field observations. Farm survey, crop budgeting and techno-economic analysis were used to assess farming systems performances. Data Envelopment Analysis (DEA) was used for assessing the technical efficiency of farms. The CROPWAT model was used to assess the crops' irrigation water requirements. Volume of annual groundwater withdrawal was estimated by the number of irrigations with tube wells and time required for each irrigation under diverse cropping system at scheme level. Under the hypothesis that land size had a strong impact on farm performances and efficiency in Punjab, farms were classified as per landholding size for analysis.

Organizational structures for irrigation management of FMIS and GMIS are properly established and have good institutional support and jurisdiction accordingly. However implementation of rules and enforcement systems points weaknesses in the governance systems of both irrigation schemes. Assessment of governance indicators show that FMIS is performing better than that of GMIS in terms of transparency level, monitoring of water resource, responsiveness and provision of respect and well treatment by authorities of water users' associations (WUAs), farmers organizations (FOs), and area water board (AWB). In average, farmers' organizations (FOs) are able to solve ~ 12 cases of water disputes and $\leq$ 7 cases of water disputes annually.

This study identifies and documents many weaknesses in the water supply system and elements towards modernization and improved operation are suggested of both schemes in terms of canal operation, financial aspects, management units and infrastructure. Although most internal indicators related to water delivery services and canal operations are well below par in both systems, the overall performance of FMIS is better than that of GMIS. However, the sensitivity of offtake structures is higher in FMIS (with average 3.25 m^{-1} and median 2.76 m^{-1}) than in GMIS (with average 2 m^{-1} and median 1.83 m^{-1}). As a results 0.1 m change in the water level in the main canals leads to 32.5% variation in the discharge of secondary canals in FMIS and 20.1% in GMIS. Operational, management and maintenance (MOM) expenditures are 5 US$/ha in FMIS and 4 US$/ha in GMIS however, MOM expenditures are higher than the collected fees for irrigation service in both schemes. Cost recovery ratio is 0.33 in FMIS and 0.67 in GMIS. Revenue collection performance is 62% in FMIS and 85% in GMIS. Fee collection rate has been sharply declining over the years in FMIS, following IMT, with a standard deviation of 22.6% annually. Nevertheless, water delivery services have improved in FMIS in terms of reliability and equity from secondary

to tertiary canals and at farm level while GMIS shows more equitable service at main to secondary canals and more flexibility at secondary to tertiary canals and at tertiary to farms. In both schemes, a significant gap is observed between water supplies and actual irrigation water requirements at farm level with multiple cropping systems. Access to groundwater allows farmers to match their needs, especially in GMIS; overall, canal irrigation only cannot sustain any intensification-diversification to improve incomes from crop production. Agricultural output is higher in GMIS (4,013 US$/ha) than that in FMIS with 2,271 US$/ha. Similarly, agricultural water supply per unit of water supply is higher in GMIS (0.357 US$/m^3) than that in FMIS with 0.267 US$/m^3.

The results at farm level reveal a strong positive correlation between farm size, crop diversification, cropping intensification, income; large farms perform better in both schemes, while landholding size is larger in GMIS than in FMIS. In spite of its low profitability, wheat production remains a key strategic choice in both schemes; it is quite specialized, requires low amounts of inputs, especially irrigation water, which is crucial in small farms with minimum direct access to groundwater due to minimum ownerships of tube wells and expensive ground water markets. Poor financial basis and lack of extension services contribute to hinder intensification in smaller farms. Conversely, maize and rice fit well in the diversification and intensification strategies leading to higher farm income per hectare, although only large farms grow these crops, especially in GMIS. Farm efficiency analysis does not show a clear effect of farm size on technical efficiency along the whole size range; yet, smaller farms systematically show poorer results in mobilizing production factors to generate income. Specific sources of inefficiency are identified: pesticide use in FMIS and land-renting in GMIS.

Overall, productivity, intensification and farm size are closely interlinked in a general context of poor functioning of irrigation system and institutional reforms. The study concludes that collective action on canal management, implemented through IMT in FMIS, has not been conducive to key improvements; it cannot solve all pending, structural issues. Infrastructural and institutional issues, and farms' low capabilities (lack of tube wells, low capital, small size) and performances still prevail. Public intervention on, inter alia, institutional strength, land size, financial support, extension, and marketing are necessary in FMIS as well as in smaller farms while modernization and service-oriented approaches should be implemented in both transferred and non-transferred irrigation schemes. Policy makers should also consider the access to and management issues of groundwater in the future strategies of IMT. A new sharing criteria and contribution model by both external and internal players has to be developed.

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List of Abbreviations

ADB	Asian Development Bank
AWB	Area Water Board
BCC	Banker, Charnes, and Cooper
BCIS	Burala Canal Irrigation Scheme
CCI	Council of Common Interest
CCR	Charnes, Cooper, and Rhodes
CE	Chief Engineer
CRS	Constant Return to Scale
CMS	Cubic Meter per Second
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
FIR	First Information Report
FMIS	Farmers-Managed Irrigation Scheme
FO	Farmers' Organization
GM	General Manager
GMIS	Government-Managed Irrigation Scheme
GDP	Gross Domestic Product
IMT	Irrigation Management Transfer
IPD	Irrigation and Power Department
IRSA	Indus River System Authority
ISF	Irrigation Service Fee
IUCN	International Union of Conservation for Nature
IWMI	International Water Management Institute
IWR	Irrigation Water Requirement
MAF	Million Acre Foot
MASSCOTE	Mapping System and Services for Canal Operation Techniques
MCM	Million Cubic Meter
M&E	Monitoring & Evaluation
Mha	Million hectares
MNA	Member of National Assembly
MOM	Management, Operation and Maintenance
MPA	Member of Provincial Assembly
O&M	Operation & Maintenance
OT	Offtake
PCA	Principle Component Analysis
P&D	Planning & Development
PIPD	Punjab Irrigation & Power Department
PIDA	Provincial Irrigation and Drainage Authority
PILDAT	Pakistan Institute of Legislative Development and Transparency
PIM	Participatory Irrigation Management
RAP	Rapid Appraisal Process
SE	Superintendent Engineer
SGVP	Standardized Gross Value of Production
UPCIS	Upper Pakpattan Canal Irrigation Scheme
VRS	Variable Return to Scale
WAPDA	Water and Power Development Authority
WP	Water Productivity
WUA	Water Users' Association

Chapter 1

Introduction

1.1 Background of the study

Water management has become a key global development issue especially considering that agriculture in many countries of the world depends on surface canal irrigation systems to boost production. Surface canal irrigation systems serve about 250 million ha of agricultural lands worldwide (Renault et al. 2007). In the case of Pakistan, water and arable land are among the country's major natural resources. As a matter of fact, about 25% of the total cultivated land area of Pakistan avails of surface canal irrigation systems. However, the performance of several irrigation canals is low in terms of management of water resource, services provided to irrigate agriculture lands, and financial management in terms of costs of infrastructures that could provide effective water delivery services. Surface canal irrigation systems are particular important for arid to semi-arid regions such as the Indus plains in Pakistan. Water resources of Pakistan have therefore been serving as driving force in the uplift of the country's economy primarily through agriculture. Pakistan has the largest contiguous irrigation systems in the world, with long history of extension with respect to the surface area improvements in order to efficiently provide water services (MWP, 2002) especially to the country's agricultural areas. Nevertheless, it is dismal to note that full potential of irrigation as a key contributor to agricultural development may have not been achieved (World Bank, 2007).

The irrigated agricultural lands in Pakistan largely depend on the Indus River System for surface water owing to the country's arid climate. Its agriculture sector, which consumes approximately 97% of water, is the largest user among other competing sectors in the country (Committee on Foreign Relations, 2011), and accounts for 24% of the GDP. Although the sector employs 48.4% of the country's total labor force, still about 22.3% population is living under the poverty line, while 65% of the population living in rural areas is directly or indirectly connected with agriculture for their livelihoods (ADB, 2009). As a result of the construction of large number of irrigation mechanisms (canal networks) since the country's independence, the irrigated area of Pakistan had increased from 8.35 million ha in 1947 to 17.14 million ha in 2000 (PILDAT, 2003).

In most Asian countries, where agricultural production contributes largely to their respective national economies, irrigation management is one of the most important concerns. Pakistan, which is becoming a water scarce country, its massive agricultural development and continuous population growth contributed to increased water utilization. In spite of the country's most extensive irrigation system, water remains the most limiting factor in the sustainable development of its agriculture agricultural sector. Briscoe & Qamar (2005) mentioned that "Pakistan is now essentially at the limit of its surface water". Committee on Foreign Relations (2011) further reported that country's existing agriculture system has become more water-intensive but more inefficient in addressing the increased water demands for irrigation. In order to improve agriculture production in arid to semi-arid conditions, better management of the available water for irrigation has become very crucial for success which will even be more important in future (Bossio et al. 2011). In the new paradigm of water management, water scarcity is not the only reason for crisis but it is good governance which is crucial to address policy failure in the past and the present (Pahl-Wostl et al. 2011).

The existing Indus Basin Irrigation System, which was constructed at the start of the 19th century, does not operate on the actual water requirement of crops in the command area. Water is allocated to canals based on their design capacity which were initially designed for 65% of cropping intensity in the Indus Basin River System. The intensified requirements for irrigation water by farmers and the decreasing capacity of water deliveries from the canals resulted in more limited availability of water per unit of irrigated land over time. Farmers had been observed to adopt some ill-practices such as free riding, paying bribes and using political powers in a bid to receive favor in terms of increased water supplies from canals (Rinaudo, 2002). Further, in order to fulfill the higher requirements of irrigation water by agriculture after the green revolution in Pakistan, dependency of farmers on ground water has been increased as a conjunctive use. Seckler et al. (1999) argued that access to groundwater is instrumental role in food security. Shah et al. (2000) reported the overexploitation of groundwater and its increasing pumping costs arising from deepening of water table in Pakistan. Therefore, improving the management and efficient use of irrigation water should be urgently undertaken as this is vital to the country's economy (Seckler et al. 1999; Committee for Foreign Relations, 2011).

The Indus Basin Irrigation System encounters major water related issues that have critical social, economic and environmental implications. At the current situation, referring to mismanagement of canal water, more than 60% water is lost from canal heads to root zones (Bosshard & Lawrence, 2006) although it is a major source of recharging underground water table; increasing the demand due to agricultural development but decreasing water availability, and weakening the infrastructures as a result of inefficient operations and maintenance, over-exploitation, discriminatory canal water deliveries, inefficient irrigation service delivery and weak governance which in part is due to lack of users' contributions and collective actions. So, the full potential of irrigation as key contributor to agricultural development is not fully taken advantage of (World Bank, 2007).

Prior to Irrigation Management Transfer (IMT), Poor functioning of the irrigation system in Pakistan has been a source of major concern for the last few decades. In fact, at some point in time this issue had been the subject of considerable external assistance and internal policy reforms. Consequently, in accordance with the global "Irrigation Management Transfer" process, and on the proposal of World Bank with heavy investment, the Government of Pakistan introduced institutional restructuring measures in irrigation and drainage subsectors to promote necessary improvements through the promulgation of the Provincial Irrigation and Drainage Act 1997. Under these reforms, governing system has been changed and management at secondary and tertiary canal levels had been handed over to the Farmers Organizations (FOs) and Water Users Associations (WUAs) respectively in pilot areas (Latif and Pomee, 2003). The new irrigation policy put emphasis on participatory approach of irrigation management by transferring of management responsibilities from government to users. The main vision of the institutional reform is *"to provide adequate, equitable and reliable irrigation supplies to the cultivatable lands of Punjab, aiming at enhancing agricultural productivity"*, and eventually through such reforms resource governance could be improved.

In order to address the issues and to overcome the constraints, public policy considers the Irrigation Management Transfer as one solution to improve performance through governance reforms by rectifying the water delivery systems and minimizing the level of ill-practices in the irrigation sector of Pakistan. This is considering the rule that "effective water governance improves water management, enhances capacity of people, degree of empowerment, social mobilization and equity" (UNDP, 2004). Despite the efforts exerted on irrigation development and management, the performance of government-managed irrigation sector is still unsatisfactory (Barker and Molle, 2005). However, it is considered that community-centered institutions can make a difference by enhancing the self-governing capacities of the people (Raza et al. 2009). Under such, there will always remain a challenge for community-centered institutions to increase irrigation water supply to enhance agricultural production throughout the Pakistan (Muhammad, 2008).

1.2 Problem statement

Researches efforts have been undertaken on institutional decomposition and analyzing institution-performance interaction by Saleth and Dinar (2004) among others, but most of those studies did not explicitly measure the exogenous influencing factors. Similarly, Lam (1998) among others, analyzed the institutional performance of the irrigation sector but he did not consider the influence of institutional aspects on the sector, considering that the social and political context determines the institutional arrangements which in-turn affects performance of irrigation system in terms of cost recovery, canal operation and collective role of farmers. In the context of effective operation of canal water deliveries, it is critically important to analyze the irrigation systems with multidimensional options such as the external environment of the irrigation system including produce market, banks for credit, public sector, institutions, and service providers (Perret and Touchain, 2002). While good mechanism for relationships and coordination among stakeholders of the water resource is necessary, it is also significant to enhance governance as it provides the road map towards sustainable development (Ayer and Callway, 2005). The questions regarding model of irrigation institutions and role of the state should therefore be answered with reference to the changing socio-economic and political situations. In order to address these critical challenges, it is necessary to analyze the interaction of irrigation institutions with the economic, social and political diversity as well as its ultimate effects on the performance of irrigation systems.

Current information had been directed towards the weakening performance of gravity-based irrigation systems. The main causes of poor performance include inadequacies in institutional capacity (technical and human resources); insufficiency of database to be used for planning and developing large irrigation projects; poor and disjointed irrigated-agriculture support services; and the intractability of many interconnected institutional, technical and socioeconomic aspects of overseeing average and huge irrigation systems (David, 2004). However, as a common but major challenge, insufficient water delivery services have caused various consequences at farm level such as poor crop productivity and changes in cropping systems, mistrust among all stakeholders, corruption in water delivery services, and water related conflicts among farmers. Farmers will not be willing to pay for irrigation service fee when services remain unreliable as these could comprise the obstacles for development and sustainability of the water services-providing institutions of the Indus Basin Irrigation System.

Crop yields and income of farmers in Pakistan are lower than the international benchmarks and even much lower than the neighboring country India, which has almost similar biophysical and climatic conditions and water resources as Pakistan (Briscoe and Qamar, 2005). An explicit goal of water-management should be to increase productivity of available supply of water. Improved water management helps enhance the reliability of water supplies that influence farmers to invest more in terms of farm practices and agricultural inputs that ultimately lead to high productivity per unit of water consumed

(Molden et al. 2003). In this regard, the quantification of crop productivities in relation with the quality of water services offered by governance mechanisms should be taken as an important concern in a bid to improve the economic outputs of irrigation systems. It is therefore important to uncover the ways of enhancing agricultural production through a careful assessment of the performance of existing irrigation systems and quantify such performance with respect to the efficiency of irrigated farms.

Most researches on water focus on improving water productivity, irrigation efficiency, crop management or hydraulic infrastructure, issues that are extremely important and thus, deserve much attention. However, governance issues in contrast, do not receive the same kind of attention as those aforementioned (Molle, 2009). Prior studies have not also focused much on policy changes (IMT) and governance models (institutional settings) for irrigation management and their performance both at scheme and farm levels under contrasted governance systems. It is still a major concern and thus, should be considered as an important research area for better understanding of the impacts of governance change on the different aspects of irrigation management and for policy adjustments in the future.

1.3 Research questions

Based on the foregoing discussion, the following questions are addressed in this study:

1) What are the governance modes in the two irrigation schemes of Punjab, under two different institutional systems?

2) What are the comparative performances in water supply functions of these two selected irrigation schemes under different governance systems?

3) What are the comparative technical and economic performances of farms with respect to these schemes?

1.4 Objective of the study

The overall objective of this study is to assess the performance of irrigation systems, and to identify and discuss the potential effects of governance mode onto the performance at both system and farm levels in Punjab, Pakistan.

The specific objectives are:

1) To analyze and describe the contrasted governance modes at play in the selected case study schemes, and more generally, the ongoing irrigation management reforms (IMT) taking place in Pakistan.

2) To assess and analyze the performance of the selected irrigation schemes in terms of water supply system and delivery services.

3) To assess and analyze the performance and efficiency of the irrigation farms with respect to the selected irrigation schemes.

4) To develop recommendations on the management of both types of systems and on future transfer programs.

1.5 Scope of the study

This study intends to provide information on the performance of selected irrigation schemes of Pakistan in the particular context of the contrasting governance systems. The scope of the study therefore includes:

1) Punjab Province, which has the largest irrigated area in the whole of Pakistan, divided into Bari, Rechna and Chaj Doabs. However, this study is confined to the Burala Canal command in "Rechna Doab" and Upper Pakpattan Canal command in "Bari Doab" as part of the Indus Basin Irrigation System. Nonetheless, the results of this research study could be generalized to reflect the situation of the whole irrigation systems within Punjab Province.

2) For the performance assessment of the irrigation systems, this study made use of primary and secondary data including qualitative and quantitative data.

3) Major part of the study is based on indicators designed by the author. However, MASSCOTE approach was also applied to obtain an insight assessment of the performance of the irrigation systems under a particular context of contrasted governance modes in Punjab.

1.6 Study limitations

Some limitations of this study could include:

1) The inability of the study to compare the two governance systems from the performance view point due to insufficient number of case studies and the very recent changes in the systems. The study therefore focused only on drawing some recommendations from the analysis and in identifying the issues and factors related to poor performance and efficiency of both systems.

2) While this study emphasized only on water supply systems at scheme level and production systems at farm level, other external supporting systems such as credit, inputs, supplies, and marketing systems were not considered due to time limitations in scholarship period and limited financial support. Although, aforementioned external supportive services are very important to measure for agricultural development under diverse and unequal access to these services by farmers particularly in Pakistan.

3) Secondary data collected from offices of various departments, on which analysis was based on, could be biased and may not depict the exact and true picture of the systems. Moreover, the primary data were based mainly on the perceptions and memories of the farmers and interviewees.

4) Changes in the governance system impact on the performance of the irrigation systems over time but the study attempted to be synchronic in its research design.

5) Groundwater was calculated based on the number of irrigations applied to crops by tube wells keeping in view the general cropping calendar at whole scheme level on annual basis however field to field crop situation may differ.

Chapter 2

Literature Review

Fresh water is a limited natural resource, and with the passage of time, competition between irrigated agriculture and other users of water has been increasing. While irrigated agriculture provides food and other agricultural products to the rapidly increasing population, the utilization of water resources should be improved in order that such resources could continue fulfilling the water requirements of the ever increasing population. In this connection, Playan and Luciano (2006) emphasized on the need for modernization of irrigation systems. While it is expected that the world's population will increase to 8100 million by 2030, the demand for food as well as water from the different water sectors will also increase. To fulfill the increasing demand for food, an increase of 49 percent in production due to irrigation and 81 percent in terms of irrigated areas must be achieved by 2030 (Playan and Luciano, 2006). In developing countries, irrigated areas had doubled from 1962 to 1998 but such rapid increase in irrigation area may no longer be possible in the coming years because of water scarcity. Therefore, water productivity which refers to the quantity of crop produced per unit amount of water used should be enhanced by increasing crop yield and reducing losses of irrigation water. In describing the modernization and optimization approaches to improve outputs, Playan and Luciano (2006) cited that in previous decades, modernization of irrigation system put more emphasis on the improvement of irrigation structures without considering that modernization of irrigation management could give much better economic returns than just structural improvements. However, Molden et al. (2003) found roots of water scarcity in the management, ill-functioning of policies and institutions. Pahl-Wostl et al. (2011) also emphasized to improve water governance on the face of global water scarcity. In the large-scaled Indus Basin Irrigation system of Pakistan, maintenance and rehabilitation of old infrastructure, management-induced water scarcity, poor governance, and deficit crop productivities are common concerns.

2.1 Concepts, principles and issues of water governance

The most commonly used definition of water governance was given by the Rogers and Hall (2003) as follows: *"Water governance refers to the range of political, social, economic and administrative systems that are in place to develop and manage water resources, and the delivery of water services, at different levels of society"*.

The concept of water governance has wider meaning in bigger contexts but it refers broadly to the way water supply services are delivered, i.e. whether the efficiency and equity of distribution are ensured, whether the delivery process is transparent, accountable, participatory and responsive, and whether the citizens are empowered and the powers are delegated to enhance their welfare (Ballabh and Balooni, 2002).

Since the Dublin Conference in 1992, the concept of water governance had been raised and had since then gained meaning. Such concept had also been reinforced by a number of agreements such as those that were reached during the 2000 World Water Forum in Hague, the Bonn 2001 Freshwater Conference, and in the UN 2000 Millennium Assembly as well as the Global Water Partnership (GWP) Framework for Actions in 2000 and the 2000 Hague Ministerial Declaration.

The said concept also incorporates many of the ideas that make governance a rich theory as it endorses a range of actors and agents to manage the water resource which is much broader than the government. Moreover, the concept of water governance covers a range of dimensions of water resources as well as delivery services at various levels of society making it broader than the management functions of individual authorities. Under such governance systems, the unique concern of marginal groups such as the poor and small-scale water users, and water users with less access to the water resource, are addressed while access of society to water is mediated by recognizing the actors and agents, agencies and power, and resources through necessary mechanisms and processes at different hierarchy of the society (Rogers and Hall, 2003).

Significance of governance in water resource management

The definition of water governance should be distinguished from government, governance and management. While government implies the formal structures through which the State runs water-related affairs, management comprises the allocation and delivery of water resources by recognizing the actual mechanisms and processes. Governance includes both government and management which encompass the peoples' access to water.

A common situation occurs when water and infrastructure are available and cultivation techniques are known, and yet people do not have ready access to water. For example, lack of water is often not the cause of head–tail problems. Another example is when poor people are excluded from infrastructure developments and do not have equal access to the benefits that could be derived from any project. Management-induced scarcity has a variety of causes which include poor infrastructural development and maintenance, and more often than not, finding its roots in the inappropriate or ill-functioning policies and institutions (Molden et al. 2003).

The performance of irrigation systems depends on management as a whole including the management of information and control of people (working in irrigation organization and farmers) as well as of other inputs besides water. While management revolves around water and its control, management without control and objectives does not always result in possible success (Mohan, 1986). For such reason, Pahl-Wostl et al. (2011) emphasized among others on the significance of water governance and reported that water scarcity is no longer a natural resource crisis as it turned out that the actual crisis lies with governance because of policy failure.

Principles of good governance principles in irrigation systems

Ostrom (1990) first established that an irrigation system is a common pool resource (CPR) which means that it could be subjected to collective action. Indeed, the suitable and efficient use of CPRs requires participation, negotiation, tradeoffs, collective action, and the principles of good governance. Ostrom (1990) proposed eight principles for governing the commons in irrigation systems. As presented in Table 2.1, the eight principles of governance can be considered for benchmarking governance situation in any given irrigation system. Moreover, as shown later in Chapter 4 and Chapter 5 of this dissertation, the results and discussions have been organized taking into consideration important aspects of governance.

Table 2.1. Design principles of governance illustrated by long-enduring CPR institutions

	Principle	Description
1	Define clear group boundaries	Individuals or households who have rights to withdraw resource units from the CPR must be clearly defined, as as well as the boundaries of the CPR itself.
2	Match rules governing the use of commons goods to local needs and conditions	Appropriation of rules, restricting times, place, technology, and/or quantity of resource units are related to local conditions and to provision of rules requiring labour, materials, and/or money.
3	Collective-choice arrangements	Most individuals affected by the operational rules can participate in modifying such operational rules.
4	Monitoring	Monitors those who can actively audit CPR conditions and appropriators' behavior, and are accountable to the appropriators or are the appropriators.
5	Graduated sanctions	Appropriators who violate the operational rules are likely to be assessed with graduated sanctions (depending on the seriousness and context of the offense) by other appropriators or by officials accountable to these appropriators or by both.
6	Conflict-resolution mechanisms	Appropriators and their officials have rapid access to low-cost local arenas in resolving conflicts among appropriators or between appropriators and officials.
7	Minimal recognition of rights to organize	The rights of appropriators to devise their own institutions are not challenged by external government authorities.
8	Nested enterprises	Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in the multiple layers of nested enterprises.

Source: Ostrom, 1990

Irrigation governance in Asia and global context

Since agriculture is the backbone of national economies for many developing countries, this makes the water sector very critical to increase crops productivity especially for the Asian countries. While describing the Asian irrigation water projects in the past few decades, despite various efforts exerted, the irrigation sector has been showing unsatisfactory performance with respect to the economic development of many Asian countries (Barker and Molle, 2005).

In the global context, water institutions have unprecedentedly been undergoing changes and that such changes in water institutions have been following the same patterns and trends. The bureaucratic approaches in national irrigation systems contribute significant roles in the operation and maintenance, however in South Asia and elsewhere, these approaches failed to achieve an efficient performance of the systems (Chambers, 1988). Therefore, it is necessary to make improvements in the structure of government agencies in order that irrigation systems are appropriately managed. It is towards this end that many developing countries such as Bangladesh, India, Philippines, and Nepal have opted to adopt the irrigation management transfer scheme (Vermillion, 1991; Shah et al. 2000).

Nevertheless, government-managed irrigation systems have seemingly shown less efficient performance than the farmers-managed irrigation systems (Lam, 1998; Shivakoti and Ostrom, 2002). Based on some empirical evidences, farmers-managed irrigation systems contribute to higher agricultural productivity as well as higher income to the farmers (Shivakoti and Ostrom, 1993). Moreover, in terms of effectiveness of organizations, the users-managed irrigation systems have been more efficient than those systems controlled by the non-users (Shivakoti, 1992) resulting on the one hand, in poor implication of diverse rules, regulations, responsibilities and roles in carrying out the policies of irrigation systems. On the other hand, the performance of these organizations had been lower than the expectations, which could be due to the fact that persons working in these organizations either have inadequate or no experience and are probably not trained, and such organizations must have been operating under poor conditions and also under financial constraints.

Evans (1996) revealed among others, the importance of power between State and society as the key potentials for the development in several collective action domains. In the Asian countries, positive impacts have been recorded on the good relationships among the State, institutions and local water users leading to better performance of irrigation schemes (Moore, 1989 and Lam, 1996). The roles and responsibilities of the State in irrigation management play very important part in the development of the State's agricultural sector.

In the case of farmers-managed irrigation system (FMIS), institutional aspects are needed for its proper and effective performance (Shivakoti, 1995). Although policy-related problems could occur such as those that aim to increase irrigation effectiveness, proper development of physical components in the infrastructures of FMIS could considerably address such problems that could lead to improved productivity of agricultural crops (Joshi et al. 1998). However, many existing organizations have not exhibited any remarkable improvements in terms of developing their physical capital for the irrigation systems.

People's involvement and participation had been advocated in the irrigation systems of Thailand, where integrated conventional practices and indigenous managerial rules promote the management of irrigation systems with the local resources properly mobilized while operations and maintenance are enhanced. In line with possible changes in the economic development of Thailand, the trends to mobilize the resources are also adjusted accordingly. Moreover, in the irrigation systems of Thailand, users prefer paying cash for availing of the benefits from the systems' operations and maintenance rather than contributing labour and manpower (Shivakoti, 2000).

Some scholars argued that socio-economic and political development in most parts in Asia contributed significantly towards new trends in irrigation management (Moore, 1993). Fast growing economies had not only changed the mode of water delivery but also broadened the vision for sustainable utilization of irrigation water. As of now, focus of irrigation systems is not only in assuring water delivery but also in looking towards water-related conflict resolutions (Lam, 1998; 2001). However, this situation has changed the cost benefit determinants of different stakeholders in the irrigation setup due to the fact that agriculture is becoming less productive. From the farmers' points of view, contributing funds and efforts to improve irrigation systems has been less beneficial and in most parts of Asia, collective action is missing especially in the new urban farm lands. Similarly, with the economic development where governments are putting more investments in other sectors of the economy such as in the industries, the interest of the government in irrigation development investments has diminished.

Irrigation governance and performance of Indus Basin River System

Irrigation system of Pakistan is characterized by poor and unreliable water services, and according to current information, most issues are directed towards the unsatisfactory performance of the irrigation system of Punjab as a major part of the Indus Basin River System. The main causes of such poor performance include inadequate institutional capacity, insufficient database for planning and mechanisms for the development of large irrigation projects, poor quality of construction, mistakes in the design, and intractability of institutional, technical and socioeconomic aspects (David, 2004).

Efficiency of physical water supplies in the Indus Basin Irrigation System has an important concern in the economic development of Pakistan. The irrigation system of Punjab which can only attain 35-40% delivery efficiency from the canal head to the crop root zones because of the age of the facilities and poor maintenance (Tarar, 1995) had been advocated as the main reason for the low water supply at the end users of the canal system. Furthermore, the unavailability of accurate and reliable information on the distribution of irrigation water in the various parts of the canal commands has been considered as the major constraint in the efficient management of the scarce water resources (Ahmad et al., 2004). In fact, almost 20-30% daily fluctuations have been reported in the discharge of the irrigation canals within the irrigation system of Punjab (Sarwar et al. 1997).

In Pakistan, irrigation water supply is distributed to the farmers through a rotational turn system known as “warabandi” which is normally based on fixed seven days rotation, meaning that farmers are allowed to use the entire flow of water from the outlet once in a week, the time allocated by the country’s Irrigation Department based on the size of land holdings. However, under such arrangement, many farmers are confronted with difficulties in irrigating their entire land due to the insufficient allocation of water (Qureshi et al. 2008). In this research study, various parameters have been used to investigate the physical situation of the water supply for irrigation such as water sufficiency, water delivery and its related problems, and agricultural productivity.

In an assessment study of the performance of canal irrigation system of the Indus Basin of Pakistan, Nabi (2009) identified the causes of poor performance of canal irrigation system in Punjab, Pakistan. He constructed a problem-cause diagram with the active participation of various stakeholders such as the farmers, staff of the Irrigation Department, and FOs among others. The first ten problems were then ranked according to their order of importance (No. 1 as the most serious, No. 2 is the next most serious, and so on). The results shown below have been ranked in accordance with their importance.

1. Unequal distribution of water to users
2. Tampering of outlets
3. Poor operation and maintenance of distributaries and minors by FOs
4. Water theft
5. Deposition of silt
6. Poor conditions of banks of main canal/distributaries/minors
7. Illegal outlets
8. Very high losses of water in the conveyance due to seepage
9. Poor operation and maintenance of physical structures
10. Ungated offtake points

The delivery efficiency of the irrigation system of Punjab is only 35-40% from the canal head to the crop root zones due to the age and poor maintenance of the facilities. This is the main reason for the low supply of water at the end users of the canal system. In addition, accurate and reliable information on the distribution of irrigation water are not available within the irrigation systems of Pakistan. These are also the main constraints that impede the effective management of scarce water resources (Mobin-ud-Din, 2004). Moreover, it has also been investigated that 20-30% water fluctuations occur daily in the discharge of the irrigation canal (Sarwar et al. 1997).

2.2 Institutional reforms in irrigation systems of Pakistan

Pakistan has the largest contiguous irrigation network in the world, irrigating nearly 80 percent of its farm lands but the country's water sector is faced with serious challenges. Water institutions in Pakistan are entangled in a complex setting where formal irrigation acts and water organizations operate side-by-side with an intricate set of informal social institutions, considering that "good water governance has the prerequisites of good institutions, good policies and good practices set in place, which need to be inculcated into the water supply system" (Bandaragoda and Firdousi, 1992). Water institutions[1] that define the rules of water development and utilization in terms of policies, laws and administration have to be concurrently reoriented to reflect the changing supply-demand and quantity-quality dynamics of the water resources (Tiwari, 2006). While discussing the institutional and organizational issues for irrigation development in Asia, Coward (1980) emphasized on the governance matters, mobilization of internal resources and role of central bureaucracy to facilitate the water users through locally defined patterns and procedures.

The Government of Pakistan has been making efforts since 1995 to reform its one and half century-aged irrigation system by linking the beneficiaries (water users) in the different units of irrigation management. Among the foremost objectives of institutional reforms are to promote improved operation and maintenance of the irrigation sector, to balance revenues and expenditures, to maintain reasonable drainage system, and to enhance crop production through efficient use of water (Lashari et al. 2003).

Over the last decade, experiences in the restructuring of water institutions seem to suggest an emerging global consensus on the key principles of institutional reforms, which could include:

- Development of an appropriate Public Private Partnership (PPP) in the delivery of water supply services, including the small-scale providers
- Decentralization of service responsibility to the lowest appropriate levels of government to respond to local conditions
- Establishment of autonomous utilities with commercial orientation and financial viability for service delivery

[1] According to Bromley (1989), North (1990) and Ostrom (1990), water institutions can be considered as "rules that together describe action situations, delineate action sets, provide incentives, and determine the outcomes both in individual and collective decisions related to water development, allocation, use, and management". Water institutions also feature the characteristics of being subjective, path dependent, hierarchical and nested both structurally and spatially, and embedded within the cultural, social, economic and political aspects like all other institutions.

While recognizing the problems in canal water management and irrigated agriculture, the Government of Pakistan introduced major institutional reforms in its irrigation sector in 1997 (Shah et al. 2000) through Irrigation Management Transfer (IMT). IMT can be define as transfer of responsibility and authority for management of irrigation systems from government agencies to private-sector organizations that that are meant to represent the interest of users. Later in the early 1980s, the legislation was passed by four provincial governments establishing the WUAs. The reforms undertaken during the 1990s had been very encouraging for long-term institutional development as these were aimed at shifting the decision-making roles from the federal and provincial agencies to decentralized autonomous public utilities and user organizations (Saleth et al. 2005). Specifically, the Government of Punjab decided to adopt further institutional reforms in its irrigation sector since 1997 when the Punjab Provincial Assembly passed the "Punjab Irrigation and Drainage Act". Under this Act, the Punjab Irrigation and Drainage Authority (PIDA) was set up at provincial level with representations from the public sector and farmers. The institutional framework of the reform consists of four entities:

1. Punjab Irrigation and Drainage Authority (PIDA) at provincial level
2. Area Water Board (AWB) at canal command level
3. Farmers' Organizations (FOs) at distributary level
4. Water Users' Associations (WUAs) at tertiary canal level

After institutional reform (IMT), certain functions, operational powers and responsibilities were transferred to FOs which is given in Table 2.2.

Table 2.2. Comparative review of operational functions transferred to FOs after IMT

Functions	Before IMT	After IMT
Fixation of water charges	IPD	IPD
Assessment of water charges	Staff of IPD	FO
Collection of water charges	Staff of Revenue Department	FO through WUAs
Assessment of expenditures for O&M at second canal level and below	IPD	FO
Responsibility of O&M	IPD	FO
Incentive system	No	Yes but not clear
Dispute settlement	IPD	FO and WUA
Penalties on late payment	Complicated	Yet to be implemented

Source: IPD, 2003 and discussion with stakeholders

It is clear from Table 2.2 that FOs are not fully empowered as only limited roles were transferred such as assessment and collection of water charges (ISF), O&M, and settlement of disputes among farmers. FOs are still lacking in terms of powers for penalties to defaulters, water rights, control on the flow of main canal, capacity to deal with nepotism and monitoring etc.

Farmers' Organizations (FOs) are the basic management units responsible to operate and manage the irrigation and drainage infrastructure within its jurisdiction. The process of institutional reforms commences with community development at village level by making the farming communities aware of the concept of Participatory Irrigation Management (PIM) and its initiatives, and organizing themselves into FOs (Raza et al. 2009). Moreover, the Water Users' Association (WUA) which is a participatory organization and farmers-based manages the local irrigation water system, the members of which are supposed to be elected by the local farmers. Nevertheless, WUAs play the important role in the effective management especially in raising the efficiency of the irrigation system along with the improving incomes and serving the deprived farmers (Huang et al. 2008).

Thus, the direction and contents of the reforms could be among the most formidable challenges in recent times with debate focusing on institutional restructuring and enhancing efficiency gains. However, questions had been raised on the access of the poor to irrigation water, affordability of irrigation, and the mechanisms for developing pro-poor regulations. Nonetheless, the inclusion of water access target as part of the Millennium Development Goals of Pakistan underscores the sector's close link to social equity. It is therefore a challenge for policy planners to ensure that future regulations should aim to address both efficiency and social welfare objectives in the water sector balancing the stakeholders' interests. It is equally very important for a developing country to assess and address the challenges in the irrigation systems in order to attain distributive justice to its population (Tiwari, 2006).

In recent years, institutional arrangements governing the water sector have also been undergoing remarkable changes where privatization or public-private partnerships (PPPs) have been increasingly recommended to address the enormous challenges confronting water supply and management services. Such arrangements have gathered momentum in view of the relatively poor performance of the public sector and it had been argued that the role of the State should be that of facilitator rather than as provider. The nature and direction of these institutional changes vary from country to country but in Pakistan, institutional reforms had been carried out through the ratification of its water laws, promotion of integrated water resources management (IWRM), creation of basin and users-based organizations, decentralization to promote stakeholders/users participation, establishment of public-private partnerships (PPPs), creation of water rights system, and reorientation of the prices of water as well as the corresponding services (Tiwari, 2006).

Globally, water institutions are also collectively undergoing unprecedented changes by revisiting the interactive roles of water policies, water laws and water administration (Saleth and Dinar, 2000). These institutional reforms provide better options and management frameworks for the improvement of water resource management at local level by encouraging local water users to take part in the decision making process. Thus, current institutional reforms in irrigation sector promote the collective actions among the stakeholders and encourage the participation of water users in water management and in the decision making process, resulting in empowerment, trust development, and knowledge sharing.

2.3 Socio-economic indicators and their impacts on water management

The issue of water management is complex and is integrated with the social, economic and environmental aspects of water basins for sustainability (Cai et al. 2001).

Social capital and its role towards effective water management

The concept of "social capital" has been defined by a number of scholars in various perspectives. Coleman (1994) stated that "*social capital as defined by its function, is not a single entity but a variety of different entities having characteristics in common: all consisting of some aspects of a social structure, and facilitating certain actions of individuals within the structure"*. However, Isham and Kähkönen (1999) defined social capital in a different way by stressing that *"social capital refers to the institutions, relationships, and norms that shape the quality and quantity of a society's social interactions"*. Therefore, social capital is not just the sum of the institutions that underpins a society but it is the glue that holds the institutions together and improves their collective actions, particularly in water delivery services.

There is no doubt that many researches considered the concept of strong social capital as social trust affiliated in the social networks that correlates with diverse and enviable policy outcomes. Putnam (1995) mentioned that social capital have "forceful, even quantifiable effects on many different aspects of our lives" such as fewer crime rates, less corruption and effective governance. While studying the impact of social capital on the performance of irrigation systems, Lam (1998) argued that high level of mutual trust among water users is closely associated with the efficient performance of the irrigation system. He also emphasized that performance of the irrigation systems could be enhanced by improving the mutual trust among water users in order to counter the irrigators' practice of offering incentives to free-riders and other users who do not act in accordance with the operational rules and regulations of the water sector. He added however that there is no standard rule to measure mutual trust especially in terms of concrete values.

It should be understood that water institutions are not actually formal organizations considering that within such institutions are informal rules with respect to norms, traditions and symbolic meanings associated with water. Although these informal rules are not codified, legitimized and enforced through formal structures (e.g. the State) but these are results of the self-organizing dynamics of social interaction that possesses minimum legitimacy and continuity, and are being observed as structures. Moreover, water laws, water administration, and water policies could also be formal as well as informal rules. In local water management for instance, informal rules are often more powerful than the formal ones, especially that water rights can be effective without being written down as a law but could be referred to in other sources of legitimacy. Furthermore, water could also have spiritual or religious values that define its usage rules. In many cases, the use of water is determined more by awareness patterns of the population rather than by the sanctions imposed. Therefore, it is necessary to systematically include such informal rules, arrangements, and traditions as part in any water analysis studies (Sehring, 2006).

Various local institutions in farm communities have significantly promoted the development of social networks of interactions in favour of their personal as well as collective remunerations. Social networks are engaged in developing some rules, norms and operational frameworks that cater to the institutions' benefits. These institutions could also comprise the water users' organizations capable of developing their rules and regulations, organizing management committees and regular annual meetings, creating levels of associations, and charting the responsibilities of the different actors and water users. Such actions are intended to support the development of an environment of trust towards the ownership of water resources by the communities as well as in the resource mobilization, acquisition, allocation and distribution of water for irrigation purposes. These activities also constitute the cognitive social capital in the management of irrigation systems by the water users (Pradhan, 2002).

Participation and collective action in irrigation management

Arnstein (1969) declared that the seminal text on citizens' participation provides some basic ideas about the involvement of stakeholders in development projects. Later, the trend of involving stakeholders in natural resource planning and management gained significant attention globally (Buchy and Hoverman, 2000; House, 1999). In the current scenario of development and social responsibility, public participation has been considered as cornerstone of an emerging governance paradigm (Hirschman, 1982). ADB (1973) highlighted the importance of participation in the success of an irrigation project as;

"The success of irrigation project depends largely on the active participation of and cooperation of individual farmers. Therefore, a group such as farmers' associations should be organized, preferably at the farmers' initiatives or if necessary, with initial government assistance, to help in attaining the objectives of the irrigation project. Irrigation technologies alone cannot satisfactorily operate and maintain the system".

Many scholars defined such participation as *"the involvement of people in different areas of irrigation management"* considering that farmers' participation in irrigation management is very vital for the sustainability of any irrigation system. In the context of enhancing farmers' participation, many developing countries put more focus on PIM and IMT for the sustainable management of irrigation water and infrastructure development. The role of the farmer as an individual and in the collective efforts (*referred to collective action*[2]) is equally important in enhancing the efficiency and performance of irrigation system which could lead to the sustainability of the system.

Social justice, ethical practice, economic efficiency, equity, decision quality, shared responsibility, extended democracy, environmental concerns and other formal approaches are some of the factors that provide justification to support the involvement of communities in development projects at different levels of planning and governance. The growing institutional interests in governance issues in recent years had promoted accountability in all actions and inclusive processes, ensured quality of decision making processes, enhanced responsibility in information sharing, and facilitated trust enhancement. As a matter of fact, public participation in the development projects of irrigation systems has already been generating better outcomes recently (Pereira et al. 2003).

Direct interests, solidarity, trust, expectations, and awareness are the major components of participation. Thus, increased participation in irrigation system also increases the people's control over the resources. Farmers' participation can be useful especially in identifying problem areas and solutions necessary in decision making. Their participation can also be

[2] Collective action means "action taken by a group (either directly or on its behalf through an organization) in pursuit of members' perceived shared interests" (Marshall, 1998).

effective in monitoring and evaluating the systems' delivery situation especially in the context of demand and supply of irrigation water. Similarly, since physical involvement of farmers is very vital in any irrigation setup, the role of the FOs is necessary to motivate their farmer-members to participate in the irrigation activities, and promote sense of ownership for them to be responsible for whatever actions they take with respect to the utilization of the resources.

Furthermore, participation in irrigation set up is very important as it could ensure the sustainability of plans and policies related to irrigation systems as well as farmers' participation at all stages of the planning and implementation. Moreover, such participation could also make the irrigation systems cost effective on the part of the government as cost could be reduced through active participation and sharing of responsibilities among the stakeholders. In addition, participation not only enhances the performance and service quality in O&M but also promotes self-sufficiency of farmers along with the sustainability of the system. In this regard, Meinzen-Dick (2007) suggested some key factors that could affect the participation of farmers in irrigation management. These could include water scarcity, size of WUAs, social capital, socio-economic heterogeneity of users, leadership, distance to market, and government policies.

At the global level, thousands of irrigation systems that are being managed by local people exist and are working at different levels, but the major problem identified in these systems is lack of ownership (rights to access and use resources and infrastructure). Therefore, there is a strong need to develop a strong sense of ownership among the stakeholders including those who are managing these systems. Once ownership of the systems is acknowledged, those concerned would recognize that they are accountable of all actions being undertaken especially with respect to the management of the systems.

Institutional reforms and its linkages with livelihood of farmers

Institutional reforms in irrigation system had changed the mechanism of water governance at various levels of water management. According to the official website of UNDP, there are four different dimensions of water governance. These are social, economic, political, and environmental sustainability, all of which can impact on rural livelihoods particularly for those who are mostly excluded from access, decision making process, and operation and management aspects of irrigation water management.

In a report on "water governance and poverty", UNDP (2004) stated that effective water governance improves water management and enhances the capacity of the stakeholders. In addition, the degree of empowerment and access to water could be improved, while social mobilization and equity are promoted. Effective governance could also find the ways and means of improving the livelihoods of the poor and vulnerable people by providing them the opportunities to enhance their financial capability and also their capacity to participate in the various levels of water management. As a result, cost recovery is improved while sustainability of water services is ensured. In this regard, the decentralized Water Users Associations (WUAs) could serve as effective forum for helping the small-scale and poor farmers.

2.4 Relationships and coordination mechanisms among institutions

In order to strengthen the governance of natural resources at global and national levels, Ayer and Callway (2005) presented a two-fold requirement among a series of recommendations in their book on "Governance for Sustainable Development". They mentioned that many institutions at local, national and international levels continue to conduct their activities in their respective sectoral silos without considering possible areas of interlinks and the ultimate impacts on other sectors. This kind of silo mentality undermines the sustainable management of resources which actually requires integrated or joint management approach. Meanwhile, in an integrated mechanism of management, the involvement of a range of institutions, stakeholders and the civil society, and other interest groups are necessary for the effective use, protection and necessary improvement of the resources. Moreover, Ayer and Callway (2005) also emphasized on the need to share local experiences in responding to the impacts of global and national policies and efforts. In the same manner, they argued that poor coordination is a major barrier towards good governance of the natural resources while sharing of experiences would establish a feedback mechanism and promote learning at local level.

The overall performance of water institutions depends not only on their individual capabilities but also on their collective strength in terms of structural and functional linkages since institution-performance interaction in the context of water resource occurs within an environment characterized by the interactive role of many factors outside the strict confines of the water institutions and water sector. However, institutional linkages and their performance implications are also subject to exogenous and contextual influences, which could be formally traced by unbundling the water structure from its institutional environment (Saleth and Dinar, 2005). Moreover, it should be understood that not all institutional arrangements are effective especially in the area of water management. While success might be achieved in one case but failure could also occur in other cases, due to diverse social, economic, cultural, and political attributes of any typical case. In fact, all these critical factors may have affected the performance of many irrigation institutions (Meinzen-Dick, 2007).

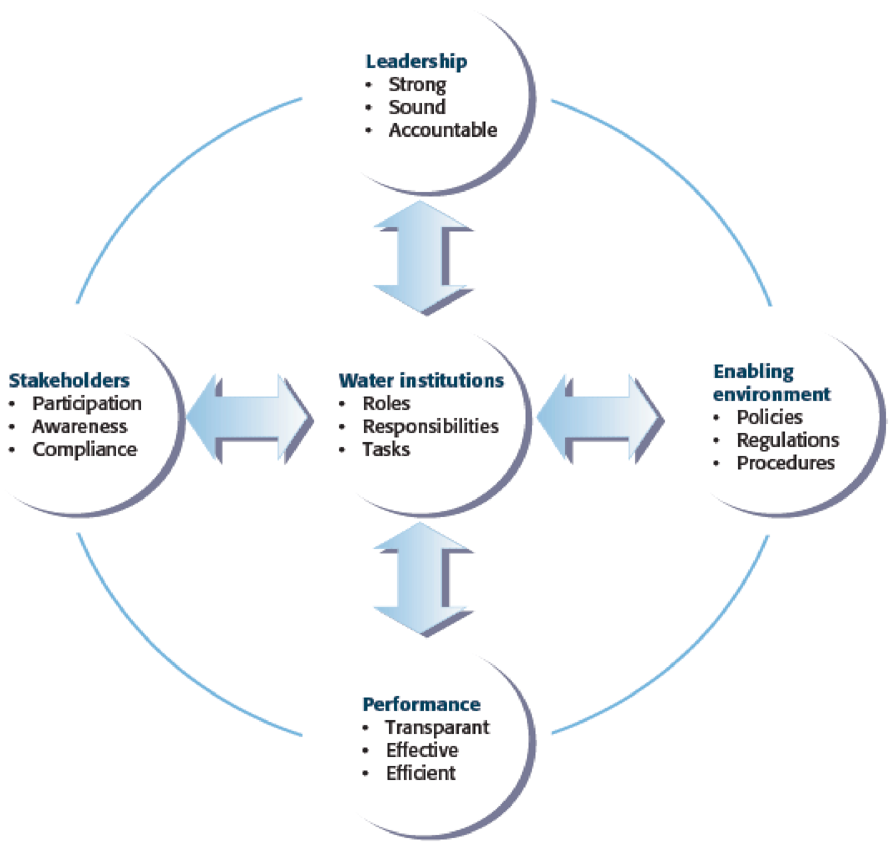
The relationship mechanism among existing institutional arrangements and other concerned parties has been changing which was emphasized in Commission of the European Communities (2002) in its White Paper on European Governance. The introduction of new processes of decision-making and new structures and modes of thinking, interaction among concerned parties and communication had been suggested in this White Paper for consideration in all efforts that aim to improve the governance of institutions.

Furthermore, the changing trends in the institutions of the global water sector had been reviewed by the Saleth and Dinar (2000) who also presented an analysis of the institutions based on three pillars such as water administration, laws and policies. The same argument had also been supported by some other analysts and managers of water resources who stated that laws, policies and administration are the focal points for analyzing the performance of water institutions (Bandaragoda and Firdausi, 1992). In contrast, social patterns of adopting new institutional changes must be considered although this is beyond the practices of international organizations, government bureaucracies and regulatory systems. The institutional framework proposed by Bandaragoda (2000) is comparatively more comprehensive than those from other previous studies in assessing the performance of water institutions. Such framework covers a range of rules and regulations, norms, local practices, and organizations that collectively configure the human actions to manage the water resources effectively.

Saleth and Dinar (2004) also argued that institutional change is economically more profitable in terms of improving the performance of water institutions as transaction cost for institutional change is not expensive. Such cost is only meant to come up with a "welfare theoretic logic" for initiating the process of change in the arrangements of water governing institutions. The rest of the efforts are then focused on the structural unbundling of water institutions in order to evaluate their performance under the changing context of governing bodies. However, they added that such areas of studies are lacking especially in terms of measuring the factors that exogenously influence management and affect the performance of water institutions.

An analytical framework to categorize the different levels of inter-linkages within water institutions was developed by Saleth and Dinar (1999). They also examined the interaction under the performance network of the water sector. In investigating the different institutional layers of linkages of such analytical framework, they used perception-based data and identified the contribution of economic factors in the changing process of water institutions. They also determined how these economic factors build up a political pressure on the bureaucracy to undergo institutional change in national water sector.

Royal-Haskoning (2003) introduced a model for analyzing water institutions in a different perspective by involving different dimensions that have direct influence on the performance of water institutions as shown in Figure 2.1. This comprehensive model is appropriate for improving water governance by enhancing the performance of water institutions. In this framework, four main dimensions of water institutions were identified and categorized, such as leadership, stakeholders, enabling environment, and performance which could have two way effects on the performance of water institutions.



Source: Royal-Haskoning, 2003

Figure 2.1. Different dimensions of water institutions for good water governance

In order that water institutions could achieve effective performance, integrated approaches must be applied at appropriate scales of the management (Bates et al. 2008) under the principles of good governance and public participation (Rehman and Varis, 2005). In the context of development of effective water management institutions, Samad (2003) proposed that water management institutions must refocus their intentions from development of infrastructures towards better utilization and conservation of water resources, and finally should aim for improving over time the allocation of and regulations on water resources. Together with such adjustments, efforts should also be made towards capacity building, revisiting incentives for participation, facilitating the willingness to pay for services, and sustaining social mobilization at community level (UNDP, 2004).

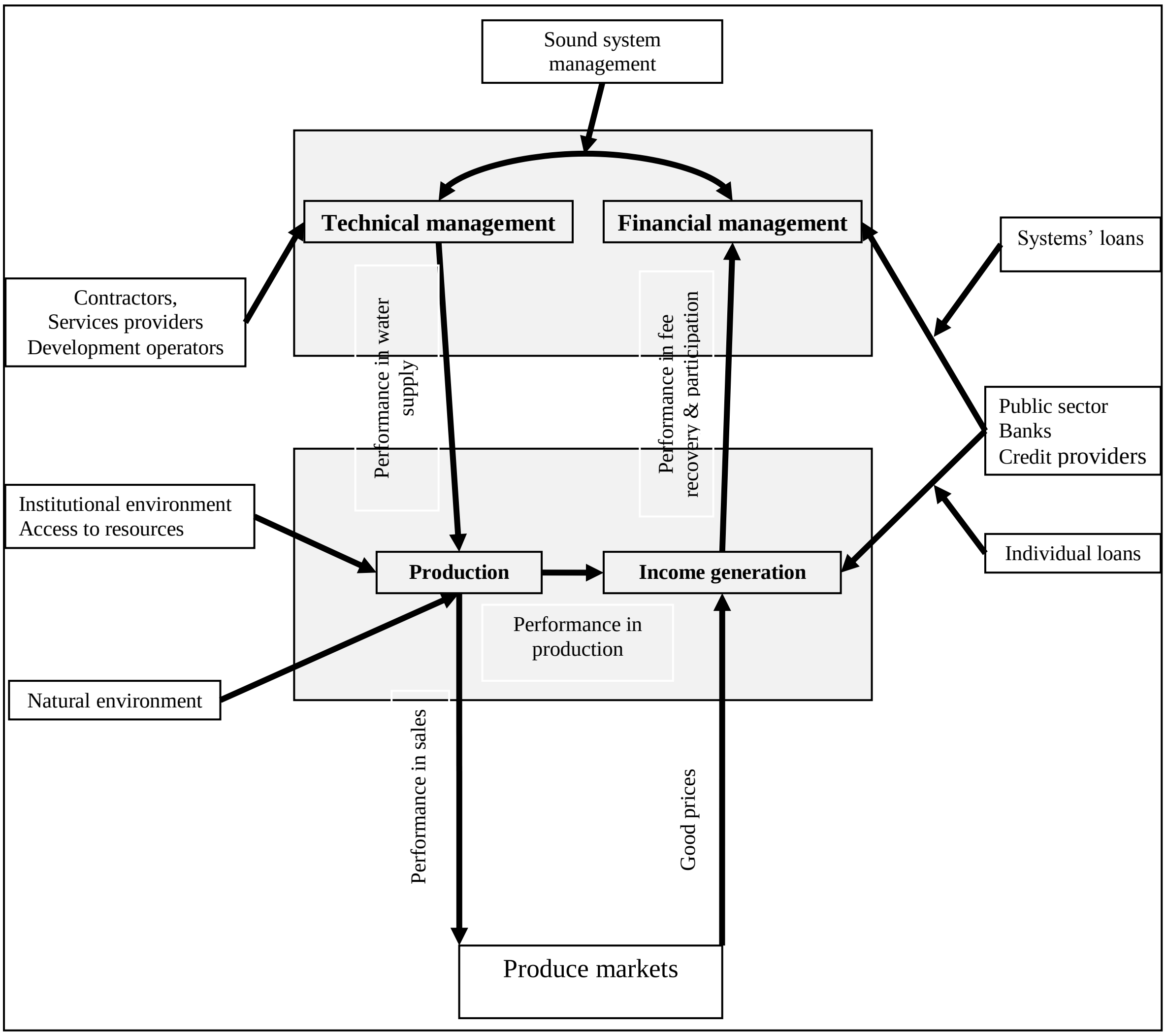
2.5 Performance assessment approaches in irrigation system

Evaluating the performance of irrigation systems has been a pivotal topic of interest that aroused a great deal of attention among researchers, planners and managers of irrigation systems in the last decades. The performance of irrigation systems is an engineering term used in “irrigation science”, where in a broader scale; the term “irrigation system performance” includes efficiencies of various components like storage efficiency, conveyance efficiency of canals, application efficiency, and field efficiency among others. In turn, three main standards could be used to evaluate the performance of irrigation systems, these are: the physical condition of the infrastructure, water delivery services, and agricultural production.

In this study however, the meaning of “irrigation system performance” covers limited areas of the canal levels’ operations, delivery services, organization and management, and the sensitivity of hydraulic structures, internal performance indicators, financial and agricultural productivity as well as the economic indicators at the whole command of any typical canal, as defined in the MASSCOTE approach. Nevertheless, this study also considered the suggestion of Renault (1999) that performance evaluation is necessary in order to improve irrigation management.

Approaches and indicators for performance assessment

Perret and Touchain (2002) proposed a framework (Figure 2.2) to improve the operational efficiency of irrigation systems. Later on, the framework was modified by Le Gal et al. (2003) in their study that dealt with the economic factors that influence the operations of irrigation systems. In the revised framework, more focus had been given to the ways of improving the operational efficiency of a given irrigation system, while also suggesting that the external influencing factors should be incorporated in assessing the performance of irrigation systems.



Source: Perret and Touchain, 2002; Le Gal et al. 2003

Figure 2.2. Operation of an irrigation scheme: conceptual framework

The conceptual framework proposed by Perret and Touchain (2002) provided many suggestions that were very useful in this study. This is considering that technical management and financial management domains of such framework have been considered and analyzed under the MASSCOTE methodology. In addition, the other two domains such as production and income generation were considered in the farm-level analysis of this study.

Molden et al. (1998) identified the various factors that affect the performance of irrigated agriculture, i.e. hardware design, management, prices of inputs and their availability, climatic conditions, among others. In addition, Kloezen and Garces-Restrepo (1998) used comparative indicators (proposed by IWMI) to assess the hydrological, agronomic, economic, financial, and environmental performance of an irrigation system in Alto Rio Lerma Irrigation District (ARLID) in Mexico, where the researchers used comparative indicators to determine the gaps among the irrigation management policies. Such indicators were then used to assess the actual performance of ARLID relative to the system's specific management goals. The findings of the study in ARLID showed that availability of abundant water and the planned irrigation depths were more than what the crops required. As a consequence, operational and maintenance costs were fully recovered while the economic outputs per unit of water were maximized. Such efforts proved that the application of process indicators could provide better insights of the process of system management. Moreover, the results also showed that in all cases, the actual water delivered to the canal and fields was higher than what was planned and reported. Therefore, it was emphasized that that the minimum set of comparative indicators are the most cost effective tools for monitoring the outputs of an irrigation management.

While describing the current challenges in water management, Renault (2000) pointed out that re-engineering the irrigation systems can enhance irrigation system management and canal operation which ultimately leads to improving the performance of the system. He also stated that there is a strong linkage between performance and sensitivity properties of canal structures, and thus, emphasized on the need to improve water efficiency and productivity to meet the future challenges of water and food.

Murray-Rust et al. (2003) assessed the water productivity in the Syr-Darya River Basin of Central Asia, including the performance of its irrigation system in terms of water productivity and crop yield as the major performance indicators. They concluded that there was great variation in terms of performance of the system at different levels. For example, the upper part of the Basin was more efficient than the other parts while the performance of the private units was better than the cooperative units. Meanwhile, Sakthivadivel et al. (1999) used satellite remote sensing and geographic information system (GIS) techniques to assess the performance of Bhakra Irrigation System in India, where wheat productivity was used as a performance indicator. Groundwater depth/quality, distributary level discharge, rainfall, and evaporation were also considered in diagnosing the problem areas and developing the corresponding action plan.

Mapping system and services for canal operation techniques

FAO proposed in 2007 an approach known as the *"Mapping System and Services for Canal Operation Techniques"* (MASSCOTE) for improving the performance of surface canal water. The MASSCOTE approach is especially useful for water engineers and irrigation professionals in their efforts towards modernizing the irrigation management of surface canal systems. In this aspect, the word "mapping" has two meanings, namely: (i) spatial survey, and (ii) planning (Renault et al. 2007). While canal operation is at the heart of the MASSCOTE approach, a step by step methodology has been developed to overcome the complexity in improving irrigation water management.

Through Rapid Appraisal Process (RAP), the constraints and performance of irrigation system had been systematically diagnosed while the problem areas in the system had been identified. Therefore, indicators in the RAP approach could be used as benchmark in comparing the performance of the system before and after the implementation of any modernization plans such as internal and external indicators of irrigation system. Burt and Style (2004) developed the corresponding definition of "benchmarking"[3] which was the basic concept used in the RAP spreadsheet of the MASSCOTE framework.

[3] Benchmarking is a systematic process for achieving continued improvement in the irrigation sector by comparing the relevant and achievable internal or external goals, norms, and standards. The three aspects of benchmarking are: evaluation of technical indicators (both internal and external), appraisal of the system processes, and evaluation of the services to users and their corresponding degree of satisfaction from such services.

Renault and Wahaj (2006) used the MASSCOTE approach to modernize the irrigation management of Sunsari Morang Irrigation System (SMIS) and the Narayani Irrigation System (NIS) in Nepal by specifically adopting ten steps of the MASSCOTE procedure. Results from the RAP which was conducted in 2003 and subsequently those of the MASSCOTE were applied in 2006 to the SMIS although the different steps of the MASSCOTE approach were adjusted. However, RAP was used to identify, locate and prioritize the problems while concerned staff had been mobilized to compile the baseline information of the project area for the modernization effort.

Moreover, Renault et al. (2007) used various financial indicators to assess the performance of irrigation systems. Such financial benchmarking indicators which are shown in Table 2.3 have been defined by the World Bank.

Table 2.3. Financial indicators for assessing the performance of irrigation systems

Indicator	Definition
1. Cost recovery ratio	(Gross revenue collected) / (Total MOM cost)
2. Maintenance cost to revenue ratio.	(Maintenance cost) / (Gross revenue collected)
3. Total MOM cost per unit area (US$/ha)	(Total MOM cost) / (Total command area serviced by the system)
4. Total cost per staff person employed (US$/person)	(Total cost of personnel) / (Total number of personnel)
5. Revenue collection performance	(Gross revenue collected) / (Gross revenue invoiced)
6. Staff persons per unit irrigated area (Persons/ha).	(Total number of personnel engaged in irrigation and drainage service) / (Total irrigated area serviced by the system)
7. Number of turnouts per field operator.	(Total number of turnouts [offtakes]) / (Total number of personnel engaged in field irrigation and drainage service)
8. Average revenue per cubic meter of irrigation water delivered to water users by authorities (US$/m3).	(Gross revenue collected) / (Total annual volume of project irrigation water delivered)
9. Total MOM cost per cubic meter of irrigation water delivered to water users by the project authorities (US$/m3).	(Total MOM cost) / (Total annual volume of irrigation delivered by project authorities)

Source: Renault et al. 2007

Burt and Styles (1999) analyzed 16 irrigation projects in 10 developing countries and recommended the need to promote modern water control and management practices in irrigation systems. Using various tools and indicators, mainly the Rapid Appraisal Process (RAP), and external performance and internal process indicators for the collection of data and evaluation of each irrigation project, they provided some details on the proper and improper design and operation of various physical features such as turnouts, cross regulators, canals, water users' organization, investments, and so on. The positive findings of their study prescribed that: (1) hardware modernization can drastically improve water delivery services and ease all operations; (2) some water users' organizations are able to collect nearly 100 percent operation and maintenance fees were operating in a business style of providing good water delivery services; and (3) in most of the projects, small changes in design and operation had facilitated the improvement of water delivery services. However, Burt and Styles (1999) also came up with negative findings which included: (1) most irrigation projects could only attain about 20 to 30 percent efficiency;

(2) many consultants who have been improperly using the computers were only wasting time and resources; and (3) in projects with poor water delivery systems, the difference between actual and stated value of the water delivery services was wide. After the study, 15 projects had partially modernized their systems in terms of hardware or management while some modernized both their hardware and management.

Internal Indicators of RAP

According to Renault (1999) and Renault et al. (2007), internal indicators could be used to assess the internal mechanisms (input used and outputs obtained) of an irrigation project. These internal indicators could be identified from the hardware, management and services that are available throughout the system. For example, the most common internal indicators could include equity, efficiency, adequacy, timeliness, and reliability of water supplies. These indicators would enable the visualization of the changes that are needed in terms of management, hardware and services as well as their influence on the overall performance of the system. The internal indicators could also determine how effective an operation is to be able to carry out the stated services.

External Indicators of RAP

Renault (1999) and Renault et al. (2007) also cited that external indicators (financial and agricultural productivity) could be used to compare the inputs and outputs, and eventually to assess the overall performance of an irrigation system. Usually expressed in ratios and percentages, the benchmarking indicators used by the International Programme for Technology and Research in Irrigation and Drainage (IPTRID) also lie in this category. These external indicators deal with outputs, i.e. production of agriculture, economic and environmental effects. However, financial indicators as given in Table 2.2 do not actually indicate the internal processes that are going on to produce the outputs. Nevertheless, external indicators could also be used as benchmark to evaluate improvements in the performance of a system before and after the implementation of modernization plans.

Sensitivity of irrigation structures and canal operation

Renault et al. (2001) also assessed the sensitivity of irrigation structures in Sri Lanka and Pakistan. Such sensitivity analysis was useful for the management of unexpected perturbations in a gated system and also helped to improve canal operations. They established that the overall performance of irrigation systems would depend on the sensitivity of the irrigation structures, and that sensitivity indicators change with the type of water flow. Moreover, they also proved that submerged flow conditions reduced the sensitivity of irrigation structures. Among the various methods in determining the sensitivity indicator of irrigation structures, they recommended that full supply depth should be attained in the parent canal with maximum discharge in the dependent canals through the offtake points.

According to Renault et al. (2007), a steady state of flow conditions along the canals should be the management goal but such condition could be seldom achieved in open channel flows because change in water level or discharge is a main feature of irrigation canals. In this regard, FAO recommended that sensitivity analysis should be undertaken to observe the behavior and response of irrigation structures under the varying discharge and water levels.

Renault (2000) described that in most irrigation structures, adjustment of the open surface irrigation system to attain the goals of canal networks may not be necessary. Since the irrigation structures and reaches are interacting with each other, operations of the irrigation structures generate perturbations in these reaches. The findings of Renault (2000) also suggested that any small change in inputs could generate a large variation in outputs especially for those structures which are highly sensitive. Sensitivity analysis is therefore important to reduce the costs of operation. Furthermore, the irrigated areas which are more vulnerable to the changes would require more consistent irrigation water supplies and services than the lesser reaches which are capable of reconciling with the high variations of perturbations.

Moreover, Renault (2000) also developed a mathematical relationship between the internal performance at system level with the sensitivity of offtake points and water depth control. Applying the model to irrigation systems in Sir Lanka and Pakistan, he proved that this was useful in defining the required operational efforts to meet the desired services. Using the established relationship, he was also able to set the tolerance limit of water depth that would enable an irrigation system to provide improved discharge by at least 10% variation from the indicated services. Visser et al. (1998) found inequitable and non-proportional behaviour of most of the outlet structures which transfer changes in inflows at the head of the distributary towards tail, which was different from the equitable and proportional design performance of the distributaries in the irrigation system of Punjab, Pakistan.

Renault and Hemakumara (1999) maintained that the main aim of any irrigation system is to hold, transfer, regulate, and give or share water between the different irrigation areas. Regulation of water along the gravity canal is usually done by the cross regulators while distribution is done by the offtake structures. In order to run the irrigation systems, some kinds of manual or non-manual operations are required. In this regard, they developed a mathematical framework for the operation of the offtake structures by considering with their levels of sensitivity. The inaccurate information especially on the specifications of the settings of the structures had been among the main reasons for the low performance in canal operations, creating considerable impacts on the adjustments made in the irrigation structures and conveyance sensitivity. They also established that results of sensitivity analysis could describe two things, namely: (1) how the propensity of the system changes with perturbations, and (2) how an easy operational procedure could be developed.

Renault (1999) reported that the ability to use new technologies (i.e. new hardware and software solutions) in the management of irrigation systems in developing countries had been rather very low. Although inaccurate operation directly affects water distribution and productivity, very little attention is given to canal operations due to certain difficulties. He therefore emphasized on the need to carry out sensitivity analysis of the irrigation systems in order to examine how the systems react when operated under the influence of various external factors. He also established that sensitivity analysis could help in identifying portions of the canal that require more care during the operations than any other parts. Nonetheless, he cited that the unavailability of updated information to assess the status of an irrigation system is a common flaw in most irrigation management.

In order to improve the operational performance of irrigation structures, Renault (2000) divided the reaches into three categories that require high, medium and less frequent adjustments of the offtake points and cross regulators and still could provide the desired services in the concerned areas. He also conceptualized performance as a function of operations using the following relationship:

$$\text{Performance} = Function\{Sensitivity\ of\ offtake\ structures\ \&\ Water\ depth\ control\}$$

Kouchakzadeh and Montazar (2005) also used sensitivity analysis to estimate the reach time response to perturbations in Vadodara Canal of the Narmada irrigation project in India. Recognizing that the main purpose of any canal operation is to maintain the specified conditions in the canal and attain better distribution of water, they suggested that improvement in irrigation efficiency could be the main challenge for irrigation managers. Moreover, they also established that irrigation efficiency can be enhanced by improving canal operations which depend on accurate information, proper management and accurate setting of the irrigation structures.

Cost of operation

Sagardoy (1986) described that the main reason for the poor performance of irrigation systems could be the insufficiency of the resources for operations and maintenance. He also cited that inadequate services are the results of unavailability of sufficient financial resources but imposing higher irrigation service rates could not guarantee that repair, maintenance and operational activities would be improved. In this regard and before increasing water fees, he suggested that O&M costs should be reduced first, where the O&M cost must be equal or less than the water charges to be imposed. He assessed this concept using four irrigation agencies in Jamaica and arrived at the conclusion that in all cases, water charges had been considerably less than the O&M costs. Among the major components of O&M costs, personnel salary was found in one case while in other three cases, energy use was extremely high. He also conducted studies analyzing the costs of four irrigation schemes in the USA and found that in two schemes, personnel cost and in the other two schemes miscellaneous expenditures were the major components of the schemes' annual expenditures.

Renault et al. (2007) reported that irrigation managers usually mobilize different resources in order to provide the desired services to the water users, i.e. staff, transportation, energy, and so on, and all these services incur certain costs. As one of the fundamental elements of the modernization process, conducting a cost analysis can provide a clear picture of the cost effectiveness of current irrigation operations. The main objectives of conducting cost analysis could include the need to: (1) specify the service levels against the different costs, (2) set up appropriate water prices so that the costs for providing the services could be fully recovered, and (3) improve the performance through automation in order to promote better utilization of the resources in a cost effective manner. Furthermore, an analysis of the irrigation management budget could also provide good picture about the costs related to management and operational activities. For instance, personnel salaries and wages are the most important components of management budget, and in the case of Canal St. Julien in France, these components accounted for about 60% of its budget. The second major component of the Canal's budget was related to canal maintenance contracts which accounted for 18% of the total budget. Nevertheless, about EUR 250 per hectare per year had been collected from the users the Canal's water services in 2006.

Cornish et al. (2004) reiterated that the main objectives of collecting irrigation water fees are to: (1) fully recover the costs of irrigation services without considering any forms of subsidies, (2) provide sufficient funds for the maintenance of physical infrastructures, (3) render better services to water users, (4) lessen excess demand, and (5) improve equity. They also mentioned that the rates of water fees computed based on area holdings are most commonly practiced in many parts of the globe. Such practice had also been considered as the easiest method of imposing charges for services for which most administration in developing countries could easily implement compared with the volume-based charges. Nevertheless, after assessing the water charges in different parts of the globe, Cornish et al. (2004) noted that in Pakistan, India and Nepal, irrigation water fees could be less than 10 US$ per hectare. Specifically in Pakistan, the cost of operation and maintenance of irrigation system is about 10 US$ per hectare while water fees ranged from 2 to 8 US$ per hectare, implying that water fees could be much lower than the O&M costs. Therefore, the main objective of charging water fees which is to recover the costs of relevant O&M activities is usually not fulfilled. This is one issue that was also reviewed in this study. Moreover, out of the eight previous case studies, it was only in three that such objective has been fulfilled, and only in one case that capital cost was recovered. This implies that the benefits gained by the farmers from irrigation are generally very high compared to the corresponding delivery costs. Nonetheless, the unwillingness attitude of farmers to pay for water services charges which still prevails at present comprises the major constraint in recovering the O&M expenditures.

2.6 Performance assessment of irrigation farms

Crop production and efficient water use are the major goals in developing the most appropriate design and management of irrigation systems. Increasing the productivity of water is particularly important in areas where water is a scarce resource. Physical scarcity is common in an increasing number of either dry or intensively developed basins even if additional water could be made available in a river basin that could be developed for further use (IWMI, 2000). Since it is likely that water will be increasingly less available for agriculture to sustain production, efforts to increase water productivity are deemed necessary. Malano and Van Hofwegen (2006) argued that in irrigated agriculture *"the management of an irrigation system should aim for the delivery of water to agriculture lands at such times and such quantities that will enable the irrigator to produce the largest and best crops"*. In a study conducted by Hayat (2007), lower crop productivity has been reported in Pakistan than in neighboring country India, as shown in Table 2.3.

Table 2.4. Country-wise crop productivity in 2003-2004

Crop	Pakistan Punjab (Ton/ha)	Indian Punjab (Ton/ha)
Rice	1.70	3.69
Wheat	2.49	4.20
Maize	1.78	2.98
Cotton	3.22 Bales/Hectare	3.26 Bales/Hectare

Source: Hayat, 2007

Water productivity which means *"production per unit of irrigation water delivered"* depends on several factors that include water management practices, agronomic practices, crop genetic materials, and economic and policy incentives to produce the desired crops. When water is distributed in an irrigation system, important processes are involved that include allocation, distribution, conflict resolution, and water drainage system. An explicit goal of water management should therefore be to increase productivity of the available supply of water. In this regard, quantification of water productivity in relation with the impacts of institutional reforms would be an important concern which should be addressed in order to improve the economic outputs of irrigation systems.

The irrigated agricultural area of Pakistan is mainly limited to the Indus plains where efficiency in water use is low especially within the command area of the irrigation system due to losses from seepage in the canal systems. Specifically, losses from seepage in the upstream area of the system could have severe consequences to the farmers located at the tail end of the irrigation system resulting in the overall inefficient delivery of surface water supply (Qureshi et al. 2008).

Water productivity can be expressed as physical productivity or in economic terms as partial factor productivity, where physical productivity is defined as *"the quantity of product divided by the quantity of input used"*. Physical productivity is expressed in terms of mass (kg) or sometimes in monetary terms ($) especially in comparing the productivity of different crops (Molden et al. 1998). Moreover, the economic productivity of water uses can be determined using valuation techniques to derive the value of water used, and can be expressed as *"income derived from water use or benefits derived from water resource"*.

According to Molden et al. (2003), improved water management should be concerned with water productivity which should also aim to provide improved timing of water supplies in order to reduce stress particularly at the critical crop-growth stages and subsequently increase yields. Since better water management could help in improving the reliability of water supplies, this would eventually encourage the farmers to invest more in terms of good farm practices and agricultural inputs, which would ultimately lead to high productivity per unit of water consumed. In another study conducted by Molden et al. (1998), they illustrated that water productivity is a measure of the system's performance and can be calculated as the *"ratio of agricultural benefit (output) to water use (input)"*.

$$\mathrm{WP} = \frac{\text{Agricultural Benefit}}{\text{Water Use}}$$

While economic productivity of water can be calculated using the equation given below however, in this study local market prices were used to calculate the costs of farm inputs and the corresponding farm incomes.

$$\mathrm{SGVP} = \sum_{Each\,crop} \left(\mathrm{Area} \times \mathrm{Yield} \times \left(\frac{local\ price}{base\ price} \right) World\ market\ price \right)$$

In a study conducted by Molden (1997) which accounted for water use and its productivity in an irrigation system, the following mathematical expression was used:

$$\text{Output per cropped area} \left(\frac{S}{ha} \right) = \frac{\text{Production}}{\text{Irrigated cropped area} \left(\mathrm{A_{Cropped}} \right)}$$

$$\text{Output per unit command} \left(\frac{S}{ha} \right) = \frac{\text{Production}}{\text{Command area} \left(\mathrm{A_{div}} \right)}$$

$$\text{Output per unit irrigation supply} \left(\frac{S}{m^3} \right) = \frac{\text{Production}}{\text{Diverted irrigation supply} \left(\mathrm{V_{div}} \right)}$$

$$\text{Output per unit water consumed}\left(\frac{S}{m^3}\right) = \frac{\text{Production}}{\text{Volume of water consumed by ET}\left(V_{\text{consumed}}\right)}$$

Where,
Production is the output of the irrigated area in terms of gross or net value of production measured at local or world prices
Irrigated cropped area is the sum of the areas under crops during the time or period of the analysis
Command area is the area designed to be irrigated
Diverted irrigation supply is the volume of surface irrigation water diverted to the command area, plus the net removals from groundwater, and
Volume of water consumed by ET is the actual rate of evapotranspiration of crops

Molden et al. (1998) stated that the performance of irrigated agriculture could be assessed for various purposes, i.e. to determine the general conditions of the irrigation systems, to improve the systems' operations, to diagnose the constraints and problems, to assess the progress against the strategic goal, to better understand the determinants of performance, and to compare the performance with other systems or with the same system over time. Eighteen systems were selected from 11 countries, i.e. Burkina Faso, Colombia, Egypt, India, Malaysia, Mexico, Morocco, Niger, Pakistan, Sri Lanka, and Turkey, where the researchers assessed the relative performance of the different systems using external and comparative performance indicators and compared the irrigation performance across the various irrigation systems. In their study, the indicators used were related to the output of irrigated agriculture and to the inputs such as water, land and finance. In order to compare the performance of the irrigation systems, nine indicators were selected, which were easily available as well as those that need less amounts of data. During the estimation of the indicators, the researchers found two main types of uncertainties, i.e. uncertainties in the source of data and uncertainties in the estimates. Furthermore, the indicators used were related to the outputs and gave limited information about the internal processes. Nonetheless, the results of the study showed large difference in the levels of performance of the different systems where the least performing system was found in Pakistan while the most efficient system was in Mexico.

Renault et al. (2007) also used same indicators to assess the water productivity in economic terms but adopted a different expression of the agricultural productivity and irrigation supplies. Nabi (2009) applied MASSCOTE approach to assess the irrigation performance of BC Irrigation Scheme in Pakistan. His findings are given in Table 2.5.

Table 2.5. Agricultural outputs in Burala canal irrigation scheme in Pakistan

Agricultural productivity and economic indicators	Outputs
Output per unit command area (US$/ha)	1,285
Output per unit irrigated area, including multiple cropping (US$/ha)	807
Output per unit irrigation supply (US$/$m^3$)	0.28
Output per unit water supply (US$/$m^3$)	0.16
Output per unit of field ET (US$/$m^3$)	0.11

Source: Nabi, 2009

Recently, Uçar (2011) assessed such comparative indicators for the performance of 10 irrigation schemes in Turkey from 2004 to 2008. He reported that the highest output per unit command area in Boğazova irrigation scheme was at US$38,724 per ha and US$34,907 per ha in 2007 and 2008, respectively. The main findings of Uçar (2011) are shown in Table 2.6.

Table 2.6. Output of irrigation performance indicators in Turkey

Indicator	Minimum value (US$/ha)	Maximum value (US$/ha)
Output per unit command area	397	38,724
Output per unit irrigated area	4,289	41,060
Output per unit water supply (m^3)	0.22	4.62
Output per unit water consumed (m^3)	0.97	8.28
Water supply ratio	0.60	7.32
Irrigation ratio	7	100

Source: Uçar, 2011

The indicators of the abovementioned agricultural productivity have also been considered as part of the MASSCOTE methodology in this study in order to assess the performance of external indicators which usually indicate the farm level outputs (a primarily objective of an irrigation scheme) as per unit of irrigation application from per unit of cultivated area in a given irrigation scheme.

Typology of farms

In the midst of the diverse nature of farming systems, landholdings, and production factors, it would be a challenging feat to develop sustainable economic strategies for adaptation of new technologies and institutional services particularly in Punjab Province, Pakistan. A farm typology[4] approach had been used to classify the groups of farms in the study area which have similar characteristics such as socio-economics, among others. Typology constitutes an essential step in any realistic evaluation of the constraints and opportunities that exist within farm households. Typological studies can therefore be of great importance for exploring the factors that explain the main characteristics of each type of farms.

Bidogeza et al. (2007) used the farm typology approach to classify the farm households in Rwanda, where farm households were typified by taking into consideration the factors that explain the adoption of new technologies. For this purpose, multivariate statistical techniques such as the principle component analysis (PCA) in combination with cluster analysis were used. Since multivariate statistical techniques offer the means of creating such typologies, particularly when an in-depth database is available, therefore PCA and cluster analysis had been correspondingly applied by Köbrich et al. (2003), Usai et al. (2006), and Bidogeza et al. (2007) before identifying the farm household types.

In contrast, this study developed the farm typology manually as the multivariate statistical tools were unable to configure the well-defined and clear types of farms. In developing the said typology for this study, the criteria for the baseline characteristics were designed for

[4] Farm typology can be defined as "the classification of agricultural farms into number of groups based on similar characteristics".

each farm type, which was actually a very challenging task. Nevertheless, farm typology was finally developed for this study although it was based only on landholding size owned by the farmers.

Assessment of the techno-economic efficiency of irrigated farms

The concept of relative technical efficiency[5] based on a number of inputs and outputs was first introduced by Farell (1957). The basic stand point of efficiency as applied in DEA is to individually compare a set of Decision Making Units (DMUs)[6]. The Data Envelopment Analysis (DEA) approach defines an empirical production function from a sample of similar cropping systems in DMUs. This function is actually the efficiency frontier that defines the full but relatively technical efficiency. The extended definition of efficiency[7] was given by Pareto-Koopmans in the handbook on DEA by (Cooper et al., 2004), where the difference in the distance to the frontier provides a score for each farm from 0 (for worst performance) to 1 (for best practice performance). DEA simultaneously constructs efficiency frontier and calculates the distance to that frontier for each individual observation. The frontier is a piecewise linear equation which is formed by enveloping the data points of the observed 'best practice' activities in the most efficient firms. DEA produces efficiency scores for individual farms as well as generates information about the benchmark farms for each individual production unit in the sample, the result of which provides the normative guidance for management (De Koeijer et al. 2002).

Data Envelopment Analysis (DEA) has been used increasingly in recent times by both researchers and management practitioners in determining the relative efficiencies of cropping systems. DEA is a non-parametric analytic tool (Sarrico and Dyson, 2004; Asmild et al. 2007; Amado and Dyson, 2008; Chen and van Dalen, 2010; Khalili et al. 2010; Ntantos and Karpouzos, 2010) which is commonly applied in the research and user communities to determine the relative efficiencies of the Decision Making Units (DMUs). This method has long been widely applied to evaluate the productivity and performance in industry as well as in marketing and services sectors. Moreover, this method has been applied to evaluate the productivity and performance of products and services (Doyle and Green, 1991), regulations (Piot-Lepetit et al. 2001), and strategic decision making (Demirbag et al., 2010). DEA-based research is much more recent in the agricultural sectors where researches on agricultural and environmental efficiency for sustainable development were pioneered by Callens and Tyteca (1999); De Koeijer, Wossink et al. (2002). However, very recent research studies were conducted applying DEA for wheat farming efficiency (Hadi Vencheh and Matin 2011) and irrigation systems performance assessment in Greece (Ntantos and Karpouzos, 2010).

Two types of orientation for inputs and outputs data can be used in the DEA method. The input-oriented model aims to produce the same output while minimizing the inputs whereas the output-oriented model aims to maximize outputs using the minimum amount of inputs (Ntantos and Karpouzos, 2010). DEA input-oriented model was selected in this

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[5] Technical efficiency means the ability of a firm (or agricultural farm) to produce a given level of output with minimum quantity of inputs and with the available technology or getting the maximum production from the available resources.

[6] Any entity that mobilizes a set of inputs in order to produce a set of outputs could be designated as a Decision Making Unit (DMU), thus, any set of such entities could be subjected to DEA. Irrigation cropping systems are typical DMUs.

[7] Full (100%) efficiency is attained by any DMU (cropping system) if and only if none of its inputs or outputs can be improved without worsening some of its inputs or outputs.

research study since production costs proved to be the key factor of farm differentiation (as shown in the results of the PCA). A BCC model that considers variable return to scale (VRS) was also used in this study since it provides more possible solutions for efficiency (Banker et al. 1984). Furthermore, each individual farm has been treated as a DMU to process the relative technical efficiency.

Return to scale is another classification of the DEA models such as the CCR and BCC. The CCR model (Charnes et al. 1978) assumes a constant return to scale (CRS) and as a result all DMUs operate on an optimal linear scale but its frontier considers only one DMU as efficient. Meanwhile, the BCC model (Banker et al., 1984) considers the variable return to scale (VRS) with more possible solutions for efficient DMUs. In performing the relative technical efficiency analysis, DEA compares a set of decision-making units (DMUs). Since irrigation cropping systems are typical DMUs, each farm can be treated as a DMU. Furthermore, the DEA input-oriented model focuses on minimizing the inputs (Ntantos and Karpouzos, 2010) since production costs proved to be a key factor for farm differentiation.

Assessment of irrigation water requirement

Water demand management is being prioritized in the evaluation of the performance of irrigation systems (Lecina et al. 2011). Projection of water demand both at farm and at whole command level is important to assess the irrigation system performance in terms of water balance. Doria and Madramootoo (2009) used the CROPWAT model was used to estimate the irrigation water requirement in three different local climatic scenarios (dry, normal and wet) in Canada. For the same purpose, Kazbekov et al. (2009) also employed the CROPWAT model to calculate the IWR for the evaluation of the planning and delivery performance of WUAs in Kyrgyzstan. Similarly, Stancalie et al. (2010) explained the methodology used in CROPWAT model for assessing crop water requirement, crop evapotranspiration and irrigation requirement with the help of earth observation data. However, the input and output indictors in the CROPWAT model depend on the research needs, and for this study the only output indicator is irrigation water requirement in order to compare with the supplies from canal and groundwater in arid to semi-arid areas.

Chapter 3

Research Methodology

This chapter on Research Methodology provides the reader with an overview of the methods used to conduct this research study. Thus, this chapter includes description of the study area, reasons behind its selection, sample size, data collection methods, and the data analysis techniques used for the analysis of the data.

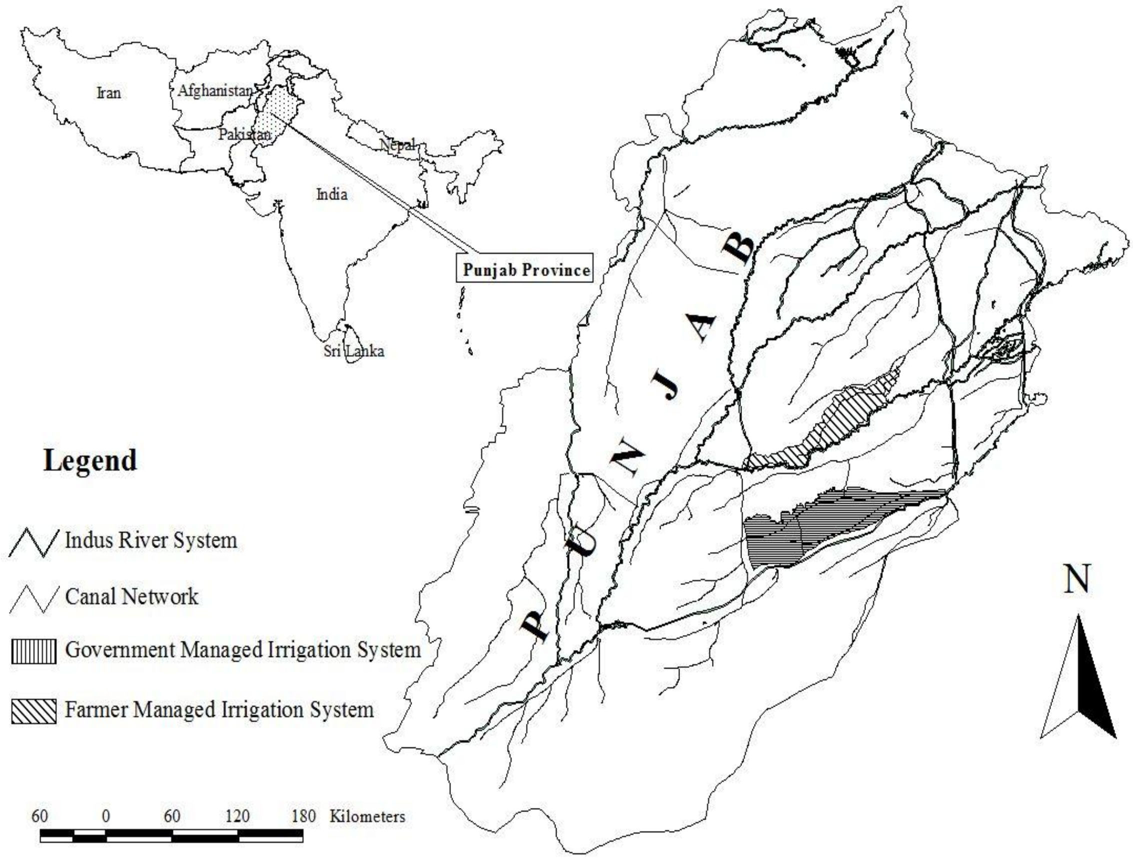
3.1 Selection of the study area

This section explains the choices made about the case studies to be investigated. Two irrigation schemes were selected, each under different governance system as per the requirement of the study. The Upper Pakpattan Canal (UPC) Irrigation Scheme was selected to represent the non-transferred irrigation schemes (IMT is not yet implemented) and thus is dubbed as Government-Managed Irrigation Scheme (GMIS). Meanwhile, the Burala Canal (BC) Irrigation Scheme was selected to represent the transferred irrigation schemes (IMT has been implemented) and is called the Farmers-Managed Irrigation Scheme (FMIS). The PIDA Act of 1997 was an initial step that initiated institutional changes in irrigation systems in Pakistan. The main criterion used to select the two different irrigation schemes was based on two conditions, firstly the institutional reform that has taken place and secondly the bio-physical and climatic conditions surrounding the systems.

At the start, institutional reform was implemented in the Faisalabad irrigation zone only, out of the six main irrigation zones (administrative structures) in the irrigation system of Punjab. The institutional changes were adopted under a pilot project funded by the Government of Japan under a Mega Project of the Japan International Cooperation Agency (JICA) and the World Bank. As a result, the irrigation system of Faisalabad zone was transferred to the farmer-users for them to operate and manage the irrigation water through their own capacities. For this reason, the “BC Irrigation Scheme” was selected as a study area from the Faisalabad zone, where irrigation management transfer (IMT) has been implemented. In this case, the irrigation system is managed and operated by farmers through different institutional structures like the Farmers’ Organizations (FOs) and Water Users Associations (WUAs).

The BC Irrigation Scheme forms part of the Lower Chenab Canal (LCC East) circle in the Faisalabad Zone. It is situated about 40 km from Faisalabad City and takes its discharge from the Upper Gogera canal. Having been constructed in 1898 during Britain’s colonial rule in the Subcontinent, therefore it has a very long history of development. The total discharge of Burala Canal is 66 $m^3.s^{-1}$ while the gross command area of the Burala Canal is 244,583 hectares, and the total length of the irrigation system is 156 kilometers. Irrigation Management Transfer (IMT) was implemented in Burala Irrigation Scheme in 2003-2004, while the rehabilitation and modernization projects on this canal were funding by external donors such as JICA and the World Bank. Under this project, FOs and WUAs were established after which the managerial and operational responsibilities were transferred to the farmer-users.

Meanwhile, the Upper Pakpattan Canal Irrigation Scheme was selected from the neighboring Multan irrigation zone (where IMT was not yet implemented). The biophysical and climatic conditions of the Upper Pakpattan Canal Irrigation Scheme are relatively different to those of the Burala Canal Irrigation Scheme. The Upper Pakpattan Irrigation Scheme is a Government-Managed Irrigation Scheme (GMIS) which takes discharge from the Sulemanki Headworks at Sutlej River near the Indian Border (eastern Punjab). It is also one and half century old irrigation system which was constructed during the British regime in the Subcontinent. The total discharge or flow rate capacity of the Pakpattan Canal is 186 $m^3.s^{-1}$ (including the discharges of seasonal canals), while the gross command area is 289,181 hectares and with total length of 174 kilometers. GMIS is operated under the Colonial Law and Irrigation Act of 1873. Both irrigation schemes are part of the Indus Basin Irrigation System (IBIS) and located within Punjab Province in Pakistan, as shown in Figure 3.1.



Source: Author

Figure 3.1. Location map of study areas

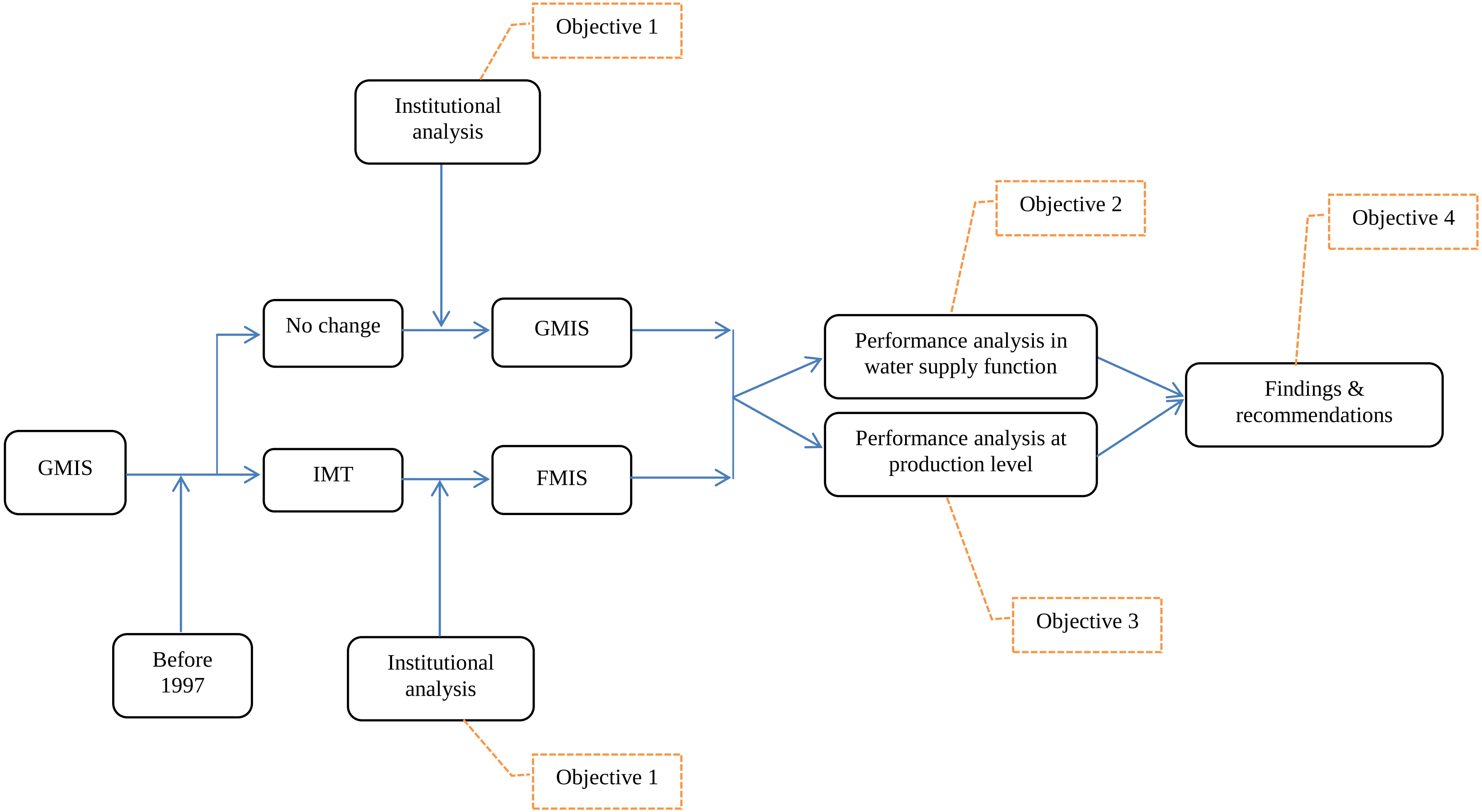


Figure 3.2. Research framework

3.2 Conceptual framework

In order to conceptualize the study, a framework (Figure 3.2) was drawn to reflect the philosophy of the research study. The conceptual framework reflects the four objectives of the research. As mentioned in the background of this study, the performance of the irrigation system was very low under the government's management and the system was confronted with a series of operational, managerial, technical, economic, and governance related issues. Under such circumstances, institutional reforms were implemented in 1997 where two pathways were considered, i.e. one with institutional reforms (FMIS) and the other without institutional reforms (GMIS). After the implementation of PIDA Act 1997 (IMT), the governance structure has been changed taking into consideration some basic features such as laws, institutions, management, participation, and conflict resolution mechanism. Thus, Objective 1 relates to the description of the governance situations and institutional environments in both irrigation schemes under different governance systems. Objective 2 focuses on the performances of both irrigation systems in terms of water supply functions at scheme-level, while Objective 3 emphasizes on the farm-level production performances. Objective 4 reveals and concludes the results of the analyses and further focuses on the recommendations of the research. Figure 3.3 interlinks the functions of an irrigation system and performances to be analyzed in the research study.

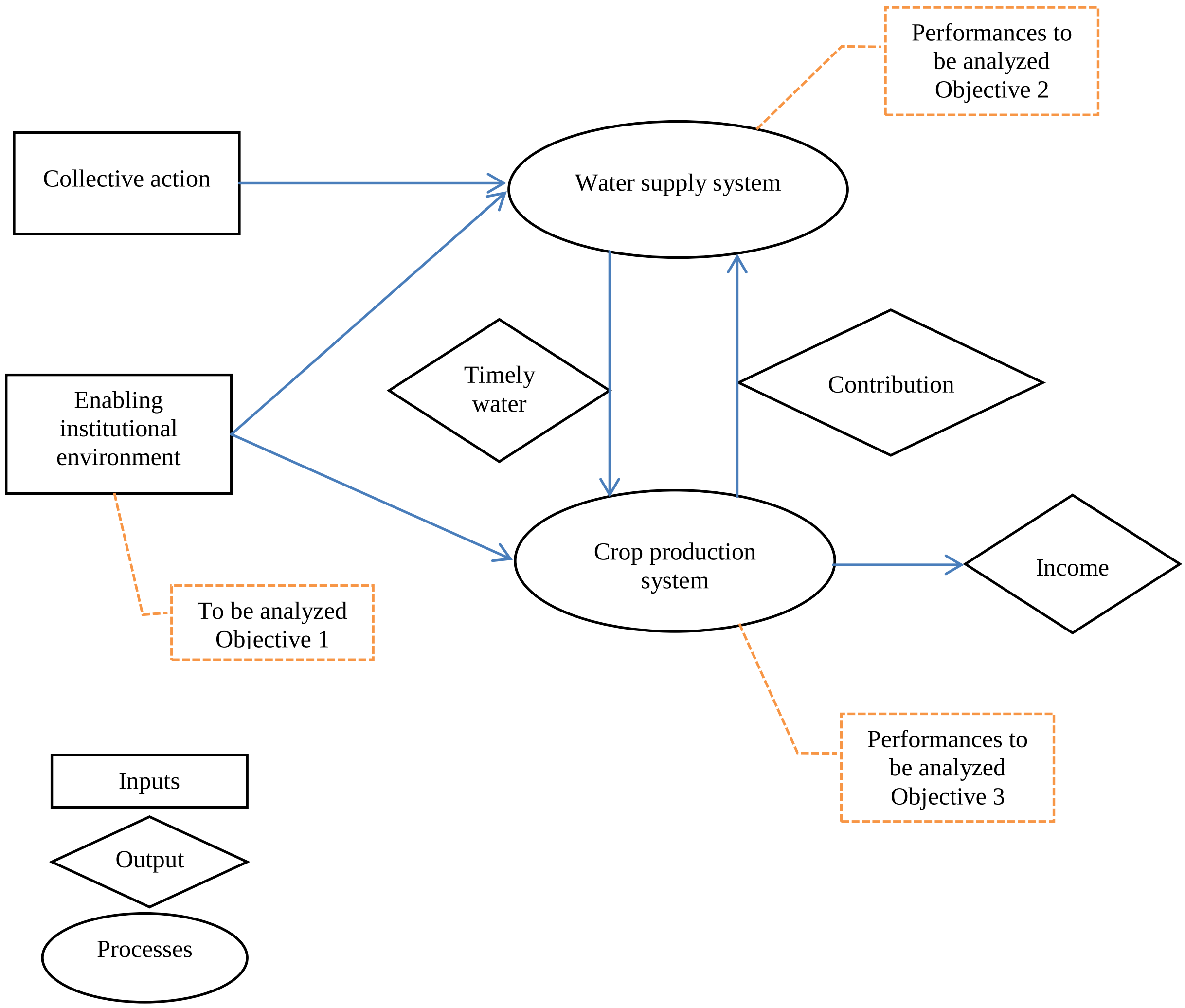


Figure 3.3. Conceptual framework of the research

Collective action at water supply level accounts for maintenance and repair of canals, and decisions for better operation of water supply system. Enabling institutional environment effects simultaneously on canal level water supply system and on farm level crop production system. Institutional environment accounts for laws, rules and regulations under which FOs and WUAs perform their prescribed functions for canal operation through accountable, responsive, and equitable delivery services. However, institutional environment at crop production level accounts for extension services, marketing services for farm inputs and outputs, access to groundwater, and financial services. Timely service refers to water delivery services in terms of reliability (availability of water at the time when it is demanded to irrigate crops). Access to groundwater and its usage for irrigation purposes provides a true picture of timely water in Pakistan where canal supplies are mostly unreliable. Contribution refers to money and in-kind services to improve water supply system which are directly depend on crop production system. It explains that farmers will contribute more if they will get better water delivery services to irrigate their crops which will ultimately improve farming income.

3.3 Overall research design

This research is an analytical evaluation type and thus, the research design is based on primary and secondary, as well as qualitative and quantitative data. The research design (Table, 3.1) relies on the two case studies from IBIS, one of which is the Burala Canal (BC) Irrigation Scheme (known as FMIS) and the other is the Upper Pakpattan Canal (UPC) Irrigation Scheme (known as GMIS).

Table 3.1. Research design of the study

Objective	Sub. objective activities	Methodologies used	Data needed and sources
1) To describe the institutional settings at play in the two contrasted governance systems of the selected case study schemes, and more generally, the ongoing irrigation management reforms in Pakistan.	Organizational structure of irrigation system, Institutions, Legal frameworks, Governance situation	Analysis of policy documents Key informant interviews Descriptive statistic	Secondary data (see table 3.4), Primary data
2) To assess and analyze the performances of the selected irrigation schemes in terms of water supply system and delivery service.	Sensitivity of hydraulic structures, Water delivery services, Irrigation operation Water balance	RAP sheet Observations MASSCOTE approach	Primary data, Secondary data (see table 3.5)
3) To assess and analyze the performances and efficiency of irrigation farms in the selected irrigation schemes.	Farm differentiation, Farm efficiency, Crop water requirement	Farm Typology, Principle component analysis, Descriptive statistic (frequency, percentage, average), Parametric statistic (t-test), Data Envelopment Analysis, CROPWAT	Primary data, Secondary data
4) To develop recommendations regarding management of both types of systems and regarding future transfer programs.	Conclusion, Implications, Recommendations	Key findings from objective 1, 2 and 3 Key informant interviews Group discussions	Primary data

3.4 Sample design for questionnaire survey

In order to achieve Objective 3, the number of farms to be studied was established. The respondents were selected randomly from the command areas of both irrigation schemes based on the list provided by the agricultural support services. A systemic random sampling technique was adopted in both study areas mainly because the study area is large and deficient in terms of resources. The following formula given by Arkin and Colten (1963) was therefore used to calculate the sample size in both irrigation schemes.

$$n = \frac{NZ^2 * p * (1-p)}{Nd^2 + Z^2 * p\,(1-p)}$$

n=sample size
N=total number of households
Z= confidence level (at 95% level Z = 1.96)
P= estimated population proportion (0.85)
d= error limit of 5% (0.05)

A set of 126 households in FMIS and another set of 82 households from GMIS were surveyed. A questionnaire survey was conducted at household level (January to April 2010) to collect the detailed quantitative information on technical and socio-economic features, including demography, livelihood system, farming system, and performances. However, the information collected were mainly based on farmers' recollection and records of seasons' events, and farming performances of the previous three years (2008-2010).

3.5 Data collection methods

The research is based on primary survey using questionnaire to collect a combination of qualitative and quantitative data, while secondary data were collected from various concerned offices.

Primary data collection

The primary data for this research study was collected through the use of different techniques such as household surveys, interview of key informants, observations, farmers' groups discussions, and some discussions with the officials from both irrigation systems during the field survey. The specific primary data collected with the corresponding approaches adopted are shown in Table 3.2.

Table 3.2. Primary data collection methods

Data collection approach	Information seeking
Household interviews (questionnaire)	Socio-economic and technical information at irrigation system and farm level
Key informant interviews	Legal, policy, institutional environment. See also Table 3.3
Observations	Apparent canal conditions, irrigation methods, cropping systems, O&M of water channels, conditions of outlets, among others etc.
Group discussions	Role and performance of WUAs and FOs, resource mobilization and underground water issues at farms, market related concerns, and opportunities and suggestions for improvements
RAP survey	Canal operation, performance indicators, water quality.

i. Household questionnaire survey

Most socio-economic data were collected from households through a questionnaire survey. The questionnaire was used to interview the farmers. The sets of questions were mostly related to crop yields, costs of major inputs, farm resources, cropping calendar, governance-related questions and problems of farmers, institutional problems, farmers' participation, and benefits of the new system. The sample Questionnaire is shown in the Appendix-A.

ii. Key informant interviews

Interviews of key informants are usually carried out to draw information from politicians, lawyers, government department officials, NGO officials, and village heads. For this research, scheduled and semi-structured interviews were conducted for key informants in the study area. Specifically, old farmers with knowledge of the old and new systems, members of WUAs or FOs were chosen as key informants and they were asked to give their views regarding efficiency issue, local farmers' participation, problems and benefits of the new system, and the changing trends in selected irrigation systems. A total of 36 key informants were interviewed as shown in Table 3.3. The Checklist of questions for the interviews is shown in Appendix-B.

Table 3.3. Key informants' interviews

Interviewees	Description	Number	Nature of information
Government and NGO officials	PIDA officials (2) AWB officials (1) FO president (2) WUA chairmen (4) IWMI officials (1) PIPD officials (4)	14	Policy interpretation Problems Suggestions
Politicians	Local MNAs (1+1) Locals MPAs (2+2)	6	Policy interpretation, future planning, and party response
Lawyers	Local Bar Councils (1+1) District Bar councils (1+1)	4	Legal rights Conflicts cases, Suggestions
Village heads	Lumberdaar (4+4)	8	Problems and suggestions
Intellectuals	Academicians (2+2)	4	Policy interpretation and suggestions

iii. Observation

Direct field observations would provide an overview of the existing situation of the canals, head, tails, and any discrepancy in the system. During the series of visits in both case study schemes, observations were also made on the farm situations, cropping systems, irrigation methods applied by farmers, and physical condition of the canal infrastructure and supplies. Photographs were taken especially with regards to the issue of O&M of the canals and water theft through *mogha* (outlet) damaging and farm activities (Appendix–F). Observations also helped to compare the results obtained after a series of data analyses in this study.

iv. Farmers' group discussion

Focal group discussions were carried out with groups of farmers at the canal, where the discussions mainly focused on their opinions about the performances of WUAs and FOs, corruption in the system, problems faced and their participation in the system. Problems of farmers with respect to resource mobilization at their farms, underground water, cost of farm inputs, and product market related issues were also taken into consideration during group discussions. Open-ended questions were discussed with the groups of farmers which highlighted only on the main concerns, while some opportunities and suggestions to solve their problems were also raised. All points discussed were recorded and incorporated in the research study.

v. Rapid Appraisal Process (RAP)

RAP sheet is a data collection tool and a part of MASSCOTE approach and is designed by FAO. In fact, RAP sheet is a template which constitutes further 13 sheets. A major part of RAP sheet required primary information through observation of hydraulic conditions and infrastructures of canals, offtakes etc. However, a bulk of secondary data was also required to enter in the RAP sheet such as water flow, daily discharges, technical information of canal design, underground water pumping etc.

Secondary data collection

The research made use of information from previous scholarly works by reviewing the literatures in journal articles and web sources especially on the performance of the irrigation system and its measuring indicators. Furthermore, secondary data were also collected from different organizations working in the area of irrigation. Moreover, farmers' data, technical data about canal irrigation system, and policy documents and procedures were collected from different sources. Details of the main sets of data gathered are shown in Table 3.4 which also indicates the corresponding sources.

Table 3.4. Specific sources of secondary data with data information

Source	Information
Provincial Irrigation and Drainage Authority, Punjab (PIDA)	Maps, technical information, performance data of FOs.
Program Monitoring & Implementation Unit (PMIU)	Water flows, technical information
Irrigation & Power Department, Punjab (IPD)	Budget, expenditures, salaries, vacancy status, maps
Area Water Board (AWB), LCC, East	Budget, expenditures, salaries, vacancy status, maps
Department of Agriculture	Extension services, farm machinery status, tube wells statistics.
Department of Revenue	ISF assessment and recovery situation
Meteorological Department	Climatic data
International Water Management Institute (IWMI)	Maps, reports on IMT in Pakistan
Water and Power Development Authority (WAPDA)	National water policy

3.6 Data processing and analysis: general statistics

All the data from the questionnaires and other sources were compiled and then analyzed using Microsoft Excel, Statistical Package for Social Science (SPSS) software, and Data Envelopment Analysis (DEA) software.

Quantitative data analysis

i. *Descriptive statistics*

Different types of descriptive statistical methods were used, e.g. percentage, frequency, average, mean, median, cross tabulation, diagrams, and bar charts.

ii. *Analytical statistics*

Considering the diversity in farm performances and the multiple factors that explain them, the Principle Component Analysis (PCA) was used to identify the variables that are most involved in the differentiation between farms through much smaller number of variables or dimensions called factors (Haan, 2002). PCA contributes to achieving a linear combination of representative variables that represent a maximum variance for a multidimensional phenomenon which are also uncorrelated. The initial number of variables is reduced in a smaller number of principle factors that explain most of the variance. Thus, PCA makes it possible to determine which indicators most explain the variability in farms (Corcoles, 2010). It also provides a correlation matrix of all input variables which could help in understanding the variable relationships within samples. The PCA was carried out using the SPSS software. However, prior to conducting the PCA, the data were checked for appropriateness through Bartlett's sphericity (Bidogeza et al. 2008), where all factors with eigenvalues greater than 1 were ultimately retained based on the Kaiser's criteria.

iii. Parametric statistics

In order to compare the difference of the means between the two sets of data, T-test was used to highlight the significant differences among farm types in terms of production factors and farm income in both irrigation schemes. Furthermore, 2-tailed Pearson test was applied to observe the association of the various farm variables with each other. The significance of the pair-wise correlation was checked at P value of 0.01.

Qualitative data analysis

Qualitative analysis was also employed in this study using qualitative statements as these could help in identifying the problems and concerns of the farmers.

The information for the qualitative analysis was collected from the sample households during the group discussions, from the responses of the open-ended questions, from the friendly and formal discussions, and field observations. Some aspects regarding the socio-economic conditions in the systems were described taking into consideration the compiled qualitative data. For instance, since it was essential to know how the water users participate in collective decision, agreements, farmers' perceptions, users' level of satisfaction in different activities related to their implementation, it was therefore necessary to collect the qualitative data. However, field observations also transparently provide some details about various phenomena with respect to the research goal. All the relevant factors which were closely linked were therefore used to come up with the detailed conclusion.

3.7 MASSCOTE approach

MASSCOTE is an approach for carrying out sound and complete diagnosis of canal irrigation systems to unravel the complexity in the systems and ultimately to improve water management. The MASSCOTE spreadsheet also known as RAP sheet which was developed by FAO was used in this study to determine the external and internal performance indicators used for the analysis. The advantages of this spreadsheet include its being systematic, clear, well planned, and proceeds in a step by step manner. Efforts were therefore made to gather information to be fed into the MASSCOTE spreadsheet. These included the identification of the problems, their location and nature, and in order to obtain information about the general characteristics of the Burala Canal Irrigation Scheme and Upper Pakpattan Canal Irrigation Scheme which was done through actual field inspections. During the said inspections, information related to the operations of the irrigation systems and their physical conditions were evaluated. Moreover, relevant Information for the Rapid Appraisal (RAP) spreadsheet was obtained through interviews with the systems managers and operators especially with regards to the management aspects. The primary and secondary data were also analyzed to determine various indicators and physical features of the selected schemes. For the evaluation of water delivery services at different levels of the canal, the discharge/water delivered at each level was analyzed. In order to determine the internal indicators, i.e. indicators related to cross regulator, turnout, regulating reservoirs, communication, general condition and operation at different level of canals, three types of information were used, i.e. those collected during field inspections, interviews and secondary data. These internal indicators are part of RAP spreadsheet. For the external indicators, the World Bank benchmarking indicators were adapted (Appendix-D). Financial indicators were evaluated using budget data, number of employed personnel in irrigation department and farmers' organizations, and water fees collection data. For further analysis, the budgets of the irrigation department and farmers organizations were broken down into various components. Crop yields, area under particular crops, prices of crops and flow data were used for estimating the economic indicators and agricultural productivity. Details of the data sets required for the RAP sheet in the MASSCOTE approach is shown in Appendix-E.

The RAP systematically diagnoses the constraints and performance of the irrigation system and identifies the problem areas in the system. The indicators for the RAP were therefore used as benchmark in order to compare the performance of the systems before and after the implementation of modernization plans. There are 10 steps in MASSCOTE framework as given in Table 3.5.

Table 3.5. MASSCOTE framework

Phase A	**Phase B**
Baseline information	Vision of SOM & modernization of canal operation
1. Rapid diagnosis	6. Service of users
2. System capacity and sensitivity	7. Management units
3. Perturbations	8. Demand for operation
4. Water networks and water balances	9. Canal operation improvements
5. Cost of O&M	10. Integration of options

Sensitivity of irrigation structures

Two types of irrigation structures are present in the Burala Canal, i.e. cross regulators and offtake structures. The functions of cross regulators are to maintain constant water level along the canal whereas offtake structures provide the desired discharge to sub-command areas. Perturbations in the main canal generate variations in water level and discharge on the cross regulators and offtake structures, respectively. The level of variations that occur on these structures with perturbations was assessed by determining the sensitivity of the offtake structures only as the required data was not available for the calculation of the sensitivity of cross regulators.

The offtake sensitivity was determined by following expression:

$$S_O = \frac{\Delta q / q}{\Delta h}$$

S_o = Sensitivity (offtake structure) (m^{-1})
q = Offtake discharge (m^3/s)
Δh = Change in water level at regulator's upstream side (m)

Variation in water depth in main canal generates changes in the discharge from the offtakes which in turn produces an equal opposite variation in the main canal discharge. Based on the proportional distribution of water in IBIS, sensitivity varies as calculated by Visser et al. (1998). Therefore, in order to find out the effect in the main canal downstream of such particular offtake point, the conveyance sensitivity was determined using the following expression:

$$S_{conveyance} = S_o \frac{q}{Q}$$

S_{con} = Conveyance Sensitivity (m^{-1})
S_o = Sensitivity (offtake structure) (m^{-1})
q = Offtake discharge (m^3/s)
Q = Main canal discharge (m^3/s)

Perturbation

For the perturbation analysis, discharge and water level data were collected for the year 2007. Then, the causes of perturbations were identified by analyzing the flow data and irrigation structures sensitivity by investigating the physical canal infrastructures. Moreover, the average water level (WL) change on a daily basis in the upstream cross regulator (major changes not included) was determined by using the standard deviation formula. Therefore, the discharge variation at distributaries, $\pm$ target in % was calculated using the following expression.

Discharge variation at distributary, $\pm$ target (%) = Average WL change x S of distributary

Service to users

The status of the water delivery services was determined using the RAP spreadsheet, and the equity, flexibility and reliability indicators were calculated at different levels of the canal. The number of outlets receiving less or more water was identified using the existing and designed discharge data of those outlets. The amount of irrigation water supplied per unit area at different levels of canal was calculated by determining the total water supplied per year divided by total irrigated command area of that particular or minor distributary.

Cost of operation

Financial indicators identified by the World Bank were used as guide to obtain the information on the current operational costs. Furthermore, budget data from the irrigation department and farmers organizations were compiled, and broken down into budget elements in order to find out where improvements are necessary to minimize the repair, maintenance and operational costs. Thus, the maintenance and repair expenditures of Burala Canal from 2004-09 were collected and drawn against time to look at the trend of the maintenance and repair expenditures. Moreover, the performance of water fee collection after the formation of farmers organizations in the project area were also evaluated using the following expression:

Water charges collection performance = water fees collected / water fees assessed

Therefore, by using the above expression, the collection performance of each farmers' organization in the project area could be calculated for the period from 2004-2009.

Demand for operation

The objective of this step was to determine the kind of operation necessary for the different irrigation structures to enable them to provide water delivery services within $\pm$ 10% and $\pm$ 20% variation from the target values. Since the demand for operation depends on (1) service required, (2) perturbation, and (3) sensitivity of irrigation structures, therefore the demand for operation for each structure was calculated using the following expression:

$$Tolerance = \Delta h = \frac{\Delta q / q}{S_{offtake}}$$

Where

Δh = allowable variation in water level upstream side of the structure to provide the desired water delivery service (m)

$S_{offtake}$ = Sensitivity (offtake structure) (m^{-1})

$\Delta q/q$ = allowable variation in discharge from the target value in the secondary canal in %

Finally, following criteria was used to set the demand for operation for each offtake structure.

(1) If $\Delta h < 5$ cm then demanding target is high
(2) If $5 < \Delta h < 10$ cm then demanding target is medium
(3) If $\Delta h > 10$ cm then demanding target is low

3.8 Farm typology

Given the fact that farm operations and characteristics vary in terms of strategy, diversity, resources, and potential towards farm income, a typology of farms was developed based on farm size. This could be justified considering that most agricultural statistics and irrigation policy documents of Pakistan have categorized irrigation farming systems into farm land size. In addition, farm size is considered a key factor for agricultural performance in Asia as cited by Fan and Chan-Kang (2005). The distribution of farms according to size in both schemes is shown in Figure 7.1.

Therefore, farms in both irrigation schemes were categorized into three farm types, namely: “small farms” when the size is less than 2.5 hectares, “medium farms” for 5 to less than 12.5 hectares, and “large farms” when the size is greater than 12.5 hectares.

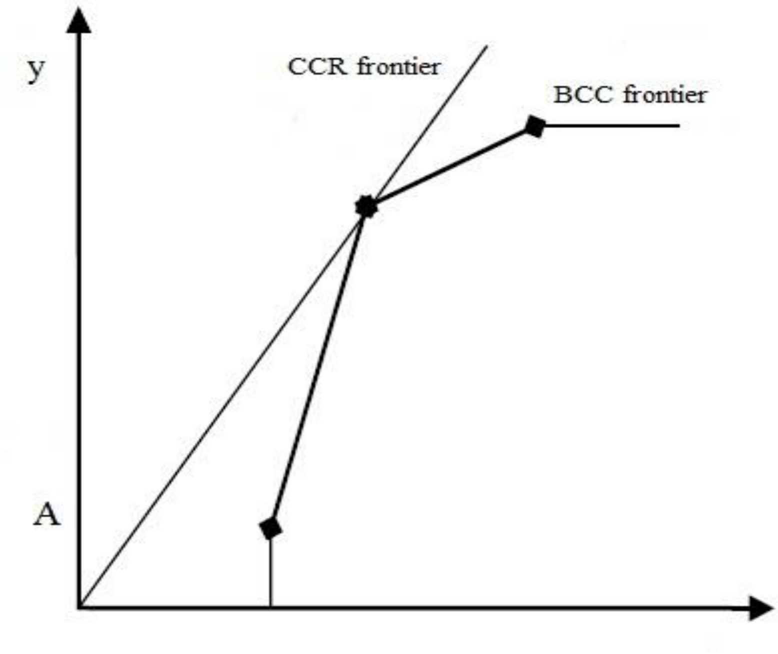
3.9 Farming performances

In order to analyze the technical performance of farms from the point of view of factors’ efficiency, a techno-economic efficiency analysis model was used for the investigation using the Data Envelopment Analysis (DEA).

DEA is a non-parametric linear programming approach that defines an empirical production function from a sample of similar Decision Making Units (DMUs), where cropping systems are considered as typical DMUs. This function is actually the efficiency frontier that defines the full but relative technical efficiency. It forms a best-practice function, constructed empirically from observed inputs and outputs (Norman and Stoker 1991). When DEA performs the relative technical efficiency analysis, it compares a set of decision-making units (cropping systems). The difference in the distance to the efficiency frontier is given a score for each farm from 0 (worst performance) to 1 (best-practice performance). The DEA simultaneously constructs an efficiency frontier and calculates the distance to such frontier for each individual observation. The frontier is piecewise linear and is formed by enveloping the data points of the observed ‘best practice’ activities for most efficient farms, then the DEA produces the efficiency scores for the individual farms.

A DEA input-oriented model focuses on minimizing the inputs (Ntantos and Karpouzos, 2010). This model was selected in this research study since production costs proved to be a key factor for the farm differentiation (as shown by PCA in the Section on Results). A BCC model that considers variable return to scale (VRS) was then used, as it provides more possible solutions for efficiency (Banker et al. 1984). In this connection, each individual farm has been treated as a DMU to be able to process the relative technical efficiency.

Return to scale is another classification of the DEA models such as CCR and BCC. The CCR model (Charnes et al. 1978) assumes constant return to scale (CRS) and as a result all DMUs operate in an optimal linear scale but its frontier considers only one DMU as efficient. While in the BCC model (Banker et al. 1984), the variable return to scale (VRS) was considered with more possible solutions for efficient DMUs. Major difference in the CCR and BCC frontier is given in Figure 3.4.



Source: Ntantos and Karpouzos, 2010

Figure 3.4. Model differences between BCC and CCR

When the DEA performs relative technical efficiency analysis, it compares a set of decision-making units (DMUs). Any entity that mobilizes a set of inputs in order to produce a set of outputs could be designated as a decision making unit, thus, any set of such entities could be subjected to DEA. Irrigation cropping systems are typical DMUs, so that each farm can be treated as a DMU while the DEA input-oriented model could be used to minimize the inputs (Ntantos and Karpouzos, 2010) since production costs are key factors in farm differentiation. Then, maximization fraction is calculated as the ratio that represents the sum of output per sum of inputs.

$$\max \frac{\sum_{r=1}^{s} u_r y_{r0}}{\sum_{i=1}^{m} v_i x_{i0}}$$

Subject to:

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1,\ j = 1, \ldots\ldots., n$$

$$u_r, v_i > 0, i = 1, \ldots., m \ \kappa\alpha\iota \ r = 1, \ldots. s.$$

Where, u_r is the weight given to output y_r, υ_i the weight given to input x_i, and y_{rj} and x_{ij} represent the values of the produced outputs and inputs y_r and x_i by DMU_j, respectively.

A BCC model with variable return to scale (VRS) was used in the analysis as it provides more possible solutions for efficiency (Banker, Charnes et al. 1984). In case of an input oriented BCC approach, the final solution is derived from the dual linear programming problem, as follows (in vector form):

Minimize θ

Subject to:

$$\begin{aligned} &-y_0 + \mathrm{Y}\lambda \geq 0 \\ &\theta x_0 - \mathrm{X}\lambda \geq 0 \\ &\mathrm{N1}\lambda = 1 \\ &\lambda \geq 0 \end{aligned}$$

Where, θ is a scalar that corresponds to the efficiency and consequently the percentage of radial reduction to which each of the inputs is subjected; $\lambda \geq 0$ is a vector of n elements, representing the influence of each DMU in determining the efficiency of DMU_0, Y and X are the vectors of outputs and inputs of all DMUs under study, y_0 and x_0 are the vectors of outputs and inputs of DMU_0, and N1 a nx1 vector of ones.

The variables used in the DEA model are listed in Table 3.6 where the inputs used include selected production, harvest and post-harvest costs (related to land, machinery and equipment, biological and chemical inputs, labour), while annual farm income (monetized yields) was used as the only output variable. Land rental cost was used only in GMIS as land renting is hardly practiced in FMIS. All costs were calculated on a per hectare basis. Local market prices were used to monetize the costs and income. Transportation per unit of weight or bag, renting farm machinery per activity per hectare, tube well pumping cost per hour basis, and wages for labour on daily or fixed basis for particular farm activities (such as broadcasting granular fertilizers and application of chemicals by hand sprayers) were calculated based on the real expenditures by each farmer. Fertilizers include urea, Di-Ammonium Phosphate (DAP) and farm yard manure for each crop, and zinc application for selected crops like rice and potato. Pesticides include herbicides, fungicides, and insecticides.

Table 3.6. Variables used in efficiency (DEA) analyses.

Category	Variables	Application domain
Farming inputs	1. Land preparation cost (PKR/ha)	FMIS / GMIS
	2. Land renting cost (PKR/ha)	GMIS
	3. Seed cost (PKR/ha)	FMIS / GMIS
	4. Fertilizer cost (PKR/ha)	FMIS / GMIS
	5. Pesticide cost (PKR/ha)	FMIS / GMIS
	6. Tube well irrigation cost (PKR/ha)	FMIS / GMIS
	7. Labor cost (PKR/ha)	FMIS / GMIS
	8. Harvesting cost (PKR/ha)	FMIS / GMIS
	9. Post-harvesting cost (PKR/ha)	FMIS / GMIS
Farming output	10. Annual farm income (PKR/ha)	FMIS / GMIS

In the case of private ownership of equipment, tube well irrigation costs refer to the energy (fuel) required for pumping which is estimated considering the number of hours in use, while in the case of tube well renting, costs refer to the charges on a per-hour basis. Specifically, since sugarcane is replanted only every three years, the costs for seeds are spread accordingly.

3.10 Estimation of irrigation water requirement in canal command

Irrigation water requirement was estimated using a tool known as CROPWAT which was introduced by FAO. Thus, this tool was applied on each crop in both case study irrigation schemes to assess the irrigation requirement during the whole crop season. Climatic data including ET_o, rainfall, effective precipitation were obtained from the climate database of FAO in CLIMWAT.

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}$$

where

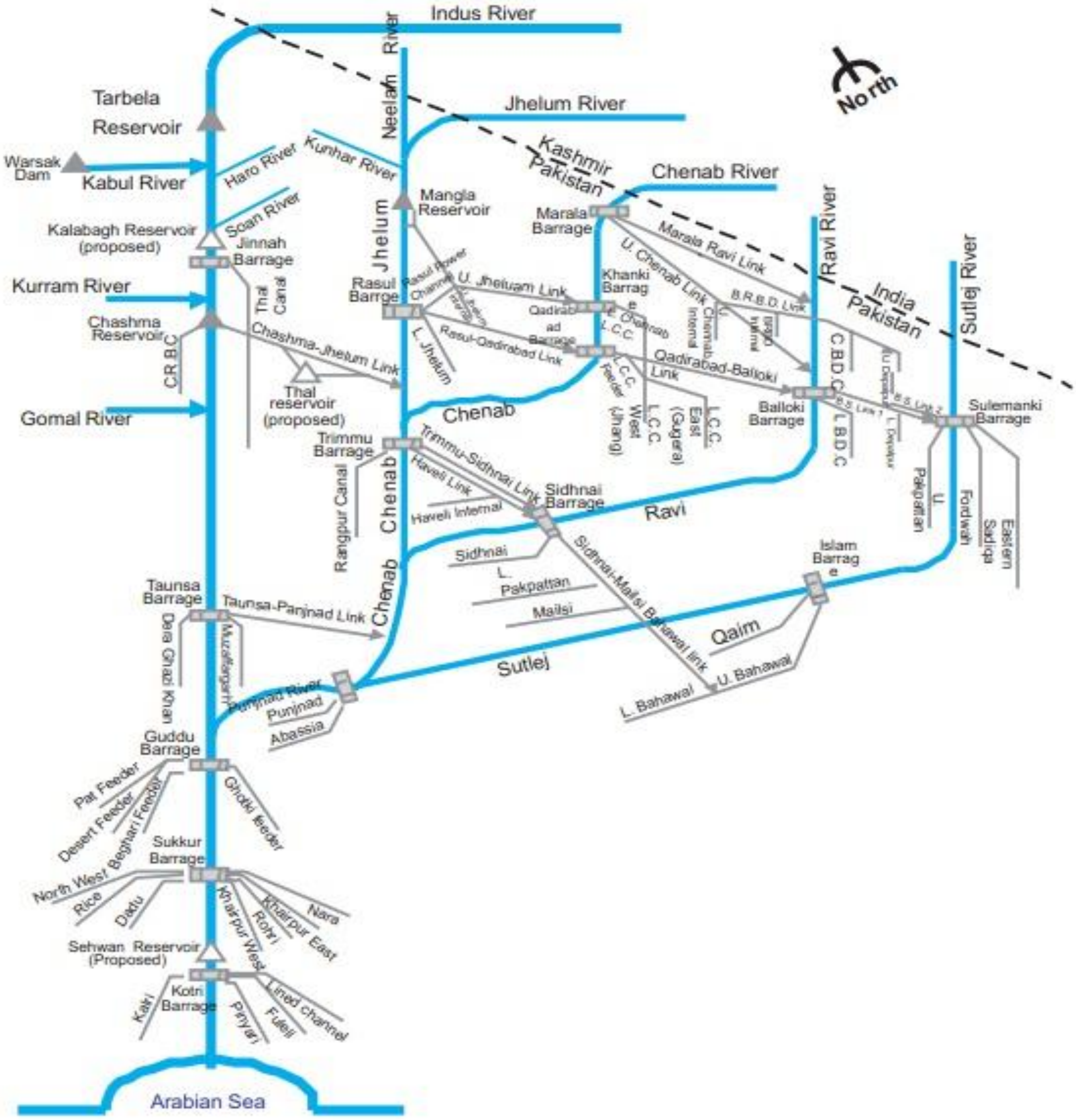
ET_o reference evapotranspiration [mm day^{-1}]
R_n net radiation at the crop surface [MJ m^{-2} day^{-1}]
G soil heat flux density [MJ m^{-2} day^{-1}]
T mean daily air temperature at 2 m height [°C]
u_2 wind speed at 2 m height [m s^{-1}]
e_s saturation vapour pressure [kPa]
e_a actual vapour pressure [kPa]
e_s - e_a saturation vapour pressure deficit [kPa]
D slope vapour pressure curve [kPa °C^{-1}]
g psychrometric constant [kPa °C^{-1}]

Loamy soil texture (medium soil type) common in both irrigation schemes was also considered during the analysis of the water demand-supply. The results were configured on an annual basis based on crops grown in different seasons at whole scheme-level.

Moreover, the monthly requirement of irrigation water was calculated and compared with the monthly canal supplies in order to investigate the monthly water demand-supply status.

3.11 Case study description: historical and current situation

This research study was carried out in the Indus Basin Irrigation System (IBIS) of Pakistan which embraces as a major part, the irrigation system of Punjab. IBIS is the most extensive irrigation system in the world which had been developed over the last 140 years. The schematic network map of the Indus basin irrigation system is shown in Figure 3.5.



Source: Briscoe and Qamar, 2005

Figure 3.5. Schematic network map of Indus Basin Irrigation System

It stretches from the Himalayan Mountains in the north of the Pakistan to the alluvial plains of Sindh Province in the south passing through Punjab Province. The total estimated command area of the Indus basin is 944,574 km^2. Most of the Indus plains have deep alluvial characteristics which could have developed through the continuous deposition by the Indus River and its side tributaries (rivers) such as Sutlej, Ravi, Chenab and Jhelum. These alluvial plains cover an area of 207,200 km^2 of the entire Indus plains. The total length of Indus River system is 3,180 kilometers, and thus on the overall, it irrigates 60% of the total cultivable agricultural land of 20 million hectares in the arid- to semi-arid region. The Indus River system comprises three western rivers (Indus, Jhelum and Chenab) and three eastern rivers e.g. Sutlej, Beas and Ravi. The Indus basin irrigation system embraces 3 dams, 19 headworks and barrages, and 12 link canals between the rivers. In addition, IBIS system includes main canals, branch canals, distributaries, and minors with length of 4230, 6835, 25,874 and 19,189 kilometers, respectively. Moreover, at field level, the system has 135,000 watercourses.

Source: Ahmad, 2009

Figure 3.6. Indus Basin Irrigation system of Pakistan with Punjab province

Irrigation water is delivered to the field through a network of barrages, main canals, branch canals, distributaries, minors, sub minors, and outlets. The irrigation system of Punjab consists of about 23,184 miles long canals, which command the Culturable Commanded Area (CCA) of about 21 million acres. The 24 canal systems draw their allocated discharges from 14 barrages of the Punjab irrigation system. The barrages also control the diversion of supplies to the inter-river link canals which transfer the water of the western rivers to the eastern rivers to cater for other irrigation systems off taking from these rivers. The water from the rivers is diverted to main canals/link canals from barrages and head regulators, and distributed to the farmer's fields through 58,000 outlets after flowing through the lengthy irrigation net-work. Figure 3.6 highlights the part of Indus Basin irrigation network in the Punjab Province in Pakistan.

Water resources in the Indus plains could have also emanated from glacier melting in the upper part of the Indus basin and precipitation in the form of rainfall and snow. In spite of all this, ground water economy in the Indus basin has been emerged up to a considerable extent particularly during and after the Green Revolution period. Even, it is called as Tube Well Revolution which has accompanied with serious governance issues not only at farm level but at bureaucracy level as well (Shah, 2009). According to Irrigation and Power Department (IPD) of Punjab, its irrigation agriculture is 22% deficit of irrigation water which is fulfilled by groundwater to meet the total crop water requirements. However, at global irrigated agriculture, share of ground water has been increased up to 30-50% of the total irrigation water demands. As a result in Punjab, water table is being depleted due to excessive pumping of groundwater which is causing serious economic and environmental effects. If water table is allowed to drop as such, availability of groundwater for the next generation will become difficult. For the sustainability of irrigated agriculture, canal supplies are to be increased (Bhutta, et al. (2007).

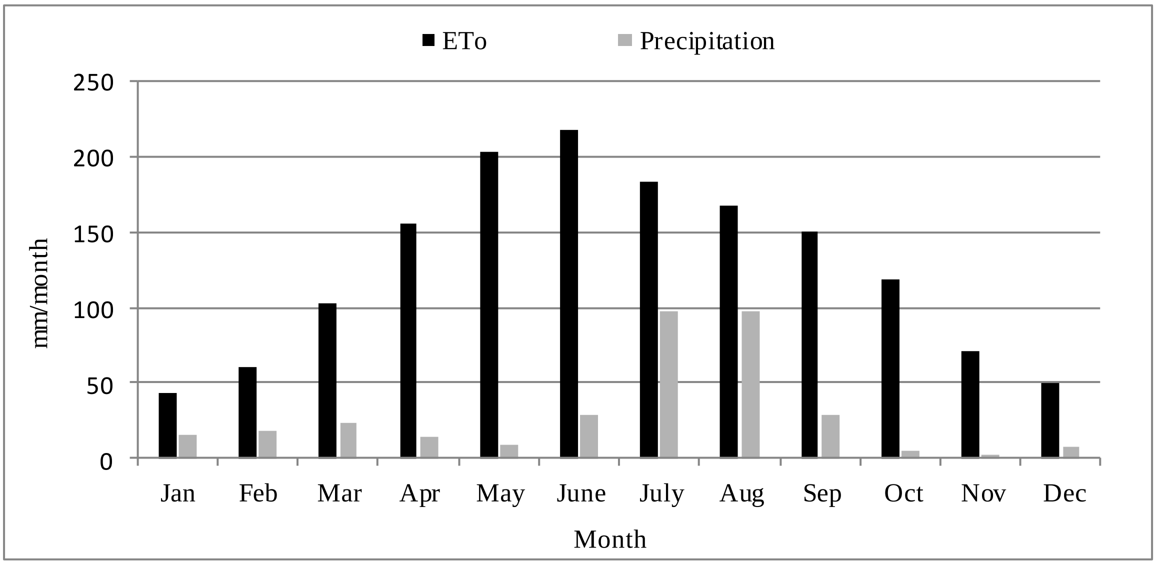
IBIS is situated in arid to semi-arid region of Pakistan. Irrigated agriculture is the main source of commodities to boost the economy in the Indus plains of Pakistan. Thus, the potentials for full irrigation would be the main contributor to the sustainable agricultural development of the country. The population of Pakistan is gradually increasing at 2.7 percent annually, and according to the Federal Statistics of Pakistan, the population of the country in 2010 was more than 180.8 million, of which labour employed in agriculture accounted for 44%.

3.12 Biophysical profiles of the case studies

Profile information of two case studies under this research study includes climate, soil and topography, land use patterns and agriculture, and cropping calendar. A brief overview of each profile is given below.

Climate

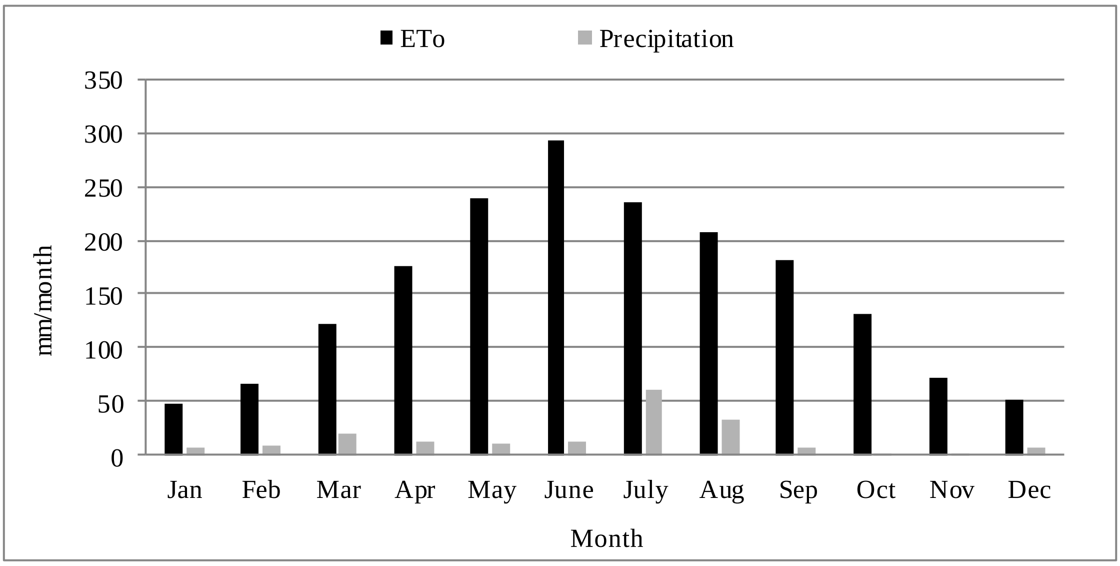
The climate conditions of the study area follow high seasonal fluctuations throughout the year, where there are four well-defined seasons: winter, summer, spring and autumn. For both case study schemes (FMIS and GMIS), data on climatic parameters such as temperature, rainfall, and evapotranspiration were acquired from CLIMWAT, the climate database of FAO. This climate database was developed by FAO based on average values of thirty years (1971-2000). Meanwhile, the reference evapotranspiration was calculated using the Penman-Monteith method.



Source: CLIMWAT

Figure 3.7. Monthly variation in ET_o and precipitation in BC Irrigation Scheme

In the Burala Canal (BC) Irrigation Scheme, the total annual rainfall is 348 mm mostly occurring during monsoon in May, June and July. The monthly variation in evapotranspiration (ET_o) and precipitation are shown in Figure 3.8. Evapotranspiration is the combined process of evaporation from soil and wet plant surfaces and transpiration from plants. Evapotranspiration rate is also very high compared to the rate of precipitation due to arid and hot climate in the Indus plains. The monthly precipitation is much less than the monthly evapotranspiration as shown in the Figure 3.7. The total annual evapotranspiration in the BC Irrigation Scheme is 1,527 mm, and the highest ET_o rate usually takes place in July and August.

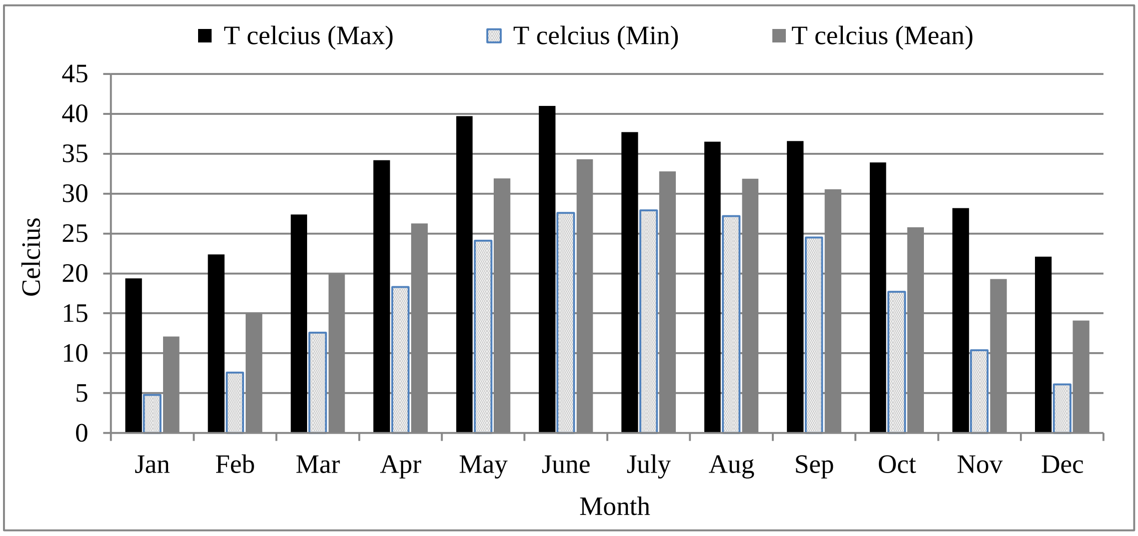


Source: CLIMWAT

Figure 3.8. Monthly variation in ET_o and precipitation in UPC Irrigation Scheme

Figure 3.8 shows the ET_o and precipitation situation in Upper Pakpattan Canal (UPC) Irrigation Scheme. The total annual rainfall in the area is 180 mm which is much less than the total annual ET_o of 1,822 mm. ET_o rate peaks in June at 76.5 mm which is higher than in Burala scheme in the same month. July and August have more rainfall compared to all other months during the entire year but the amount of rainfall is lower than that in the Burala scheme.

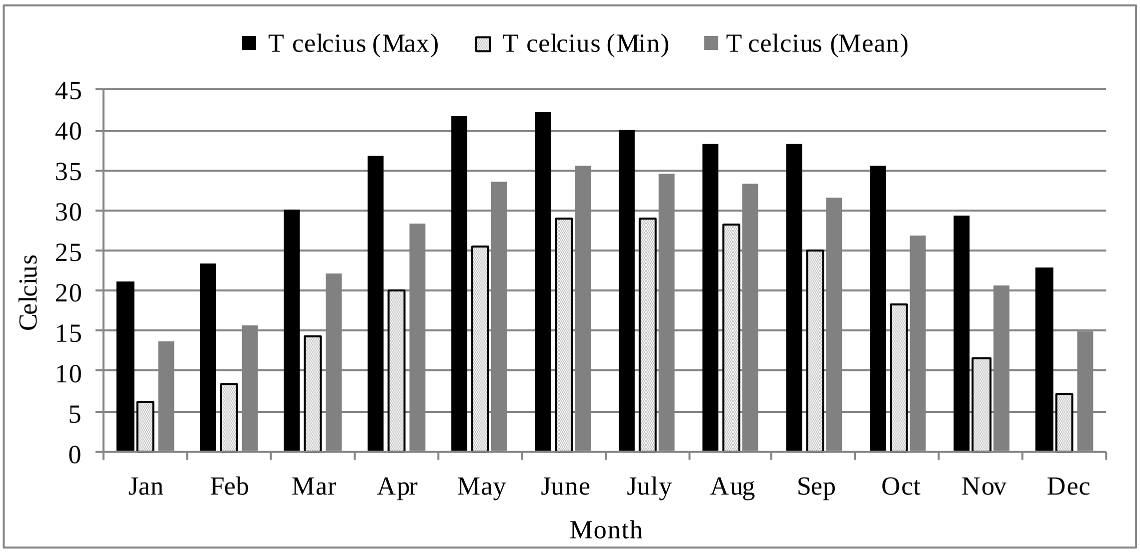
The mean day temperature during winter varies from 15 to 27 degrees Celsius (°C) while during winter nights the temperature could decrease to near freezing point. However, during dry winter nights, fog usually occurs while occasionally frost also occurs that could cause damages in crops. The summer temperature ranges between 34°C and 41°C, where the monthly averages in BC Irrigation Scheme are shown in Figure 3.9. The minimum summer temperature could be about 18°C while the minimum winter temperature of about 5°C usually manifests in the month of January.



Source: CLIMWAT

Figure 3.9. Monthly variation in temperature in the command of BC

Figure 3.10 shows the temperature range in UPC Irrigation Scheme where May and June are the warmest months when the temperature could go beyond 42°C, but is also the most appropriate time for rice cultivation and harvest of maize, and when farmers would need higher amounts of water irrigation for their crops. There is much variability in the monthly temperatures during summer and winter, when the temperature could go higher than 40°C in summer and could go down to 6.5°C in winter with dry and fogy nights, even sometimes coming with frost. The occurrence of frost mostly during the months of December and January is however harmful for the potato crop, and it is during this time when crops demand more reliable and frequent water irrigation to protect their crops from the harmful effects of frost particularly in case of potato and other vegetables.



Source: CLIMWAT

Figure 3.10. Monthly variation in temperature in the command of UPC

There could be drastic arid conditions in both irrigation schemes but with little difference in terms of T_o. While arid conditions manifest more in the UPC Irrigation Scheme than in BC Irrigation Scheme, the average monthly T_o in the former is slightly higher while ET_o is also higher but its precipitation rate is usually lower than in the latter.

Soils and topography

The soils in the BC Irrigation Scheme are characterized by predominately medium to moderate texture (clayey-loam) with little organic matter contents, and can be classified into two major groups such as normal and saline sodic soils. Normally, there is accumulation of lime below 1 meter, which is the main reason for the salty groundwater in some patches (mostly in the head and middle reaches of main canal) of the study area limiting the choice of crops to cultivate. As a remedy, farmers apply gypsum and some other forms of treatments to the groundwater prior to its use for irrigation. Meanwhile, soils in the UPC Irrigation Scheme are known to be silty and clayey-loam and thus, have predominately high productive potentials.

BC Irrigation Scheme is situated in the command area of Chenab and Ravi rivers also known as “Rachna Doab” while the UPC Irrigation Scheme is situated in the command area of Sutlej and Ravi rivers which is generally known as “Bari Doab”. Topographically, most part of the study area is flat with alluvial deposits from the Indus river system. On the average, the topographic gradient of this area is 0.20 meter per kilometer with a general direction towards southwest. Surface drainage of the study area is therefore slow due to its flat topography.

Land use patterns and agriculture

The major use of land in both case study schemes is for agriculture. Rural settlements are scattered in different organized villages while some other small houses located away from villages seem to lack of basic facilities. Agriculture is the major occupation with sugarcane, maize, wheat and rice as the main cash crops of the area in FMIS (Burala Canal Irrigation Scheme) while cotton, potato, wheat, maize and vegetables are the main cash crops in GMIS (Upper Pakpattan Canal Irrigation Scheme). Citrus and guava orchards are also found in some parts of the study area as additional sources of income in both irrigation schemes. In order to feed their livestock, fodder is also grown in the study area which includes sorghum, millet, berseem, and oat.

In both irrigation schemes, change in type of cropping system is associated directly or indirectly with the performance of the water delivery system (both from canal and groundwater). Such performance of the irrigation system determines the quantity of water available at farm gate largely affecting the decision of the farmers on what crops to grow in their farms. Thus, irrigation sensitive crops such as maize, rice, and potato are grown in areas with favorable condition of the available canal water or where access to groundwater is possible. Furrow[8] irrigation method is commonly under practice for crops such as cotton, maize, and vegetables in GMIS. However, furrow irrigation method is not commonly used in FMIS except sugarcane. In FMIS, flood[9] irrigation method is commonly under practice.

Cropping calendar

In general, cropping calendar can be categorized into three main cropping seasons, e.g. Kharif, Rabi and spring. While sugarcane is grown mostly in FMIS as a perennial crop, rice, cotton, fodder (sorghum, millet) and maize are the major crops in summer (Kharif) from May to October in both irrigation schemes (FMIS and GMIS). Wheat is the major crop for winter (Rabi season) from November to April in both irrigation schemes. In GMIS, cotton and maize are typically the main crops for spring (February to June), while potato is grown as an early Rabi crop in October.

Table 3.7. Cropping calendar of major crops

Crop	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Rice[1]							■	■	■	■		
Rice[3]				■	■	■	■					
Wheat[2]	■	■	■	■							■	■
Cotton[1]					■	■	■	■	■	■		
Cotton[3]		■	■	■	■	■	■	■	■	■	■	
Corn[1]							■	■	■	■		
Corn[3]		■	■	■	■	■						
Sugarcane	■	■	■	■	■	■	■	■	■	■	■	■
Vegetables[1]				■	■	■	■	■				
Vegetables[2]								■	■	■	■	
Potato[2]	■									■	■	■
Foddar[1]				■	■	■	■					
Foddar[2]	■	■								■	■	■

[1]means Kharif season, [2]means Rabi season, [3]means spring

[8] Furrow irrigation is a method of surface irrigation where the water is supplied to small ditches or furrows for guiding across the field.

[9] Flood irrigation is a method of irrigation where water is applied to the soil surface without flow controls, such as furrows, borders or corrugations.

The cropping calendar for both case study schemes is given in Table 3.7. Although there is not much difference in the timing of cropping systems between FMIS and GMIS, but one to two differences could be very prominent. Sugarcane which is a major crop in BC Irrigation Scheme is not commonly grown in the UPC Irrigation Scheme. Meanwhile, cotton is usually grown in FMIS during Kharif season while farmers in GMIS prefer early sowing of cotton seeds in February and March.

The information in Table 3.7 was obtained from various sources such as from the interview with farmers and secondary data from Punjab Agricultural Department. This cropping calendar can be matched with the official timing for cultivation and harvesting proposed by Punjab Agriculture Department. However, it was gathered during the group discussions and field observations that farmers do not strictly follow this calendar since they use their local knowledge to determine the appropriate timing for growing their crops.

Chapter 4

Institutional Environment in the Study Area

This chapter opens the section on the results of the dissertation, and mainly discusses the ways to achieve Objective 1. The beginning of this chapter briefly discusses the main institutions at federal level in Pakistan, specifically elaborating on the current institutional environment in the overall irrigation system of Punjab and then on the concerned local institutions in the case study schemes. The later part of the chapter discusses the changing governance features in the overall governance system of Punjab irrigation system, particularly after the institutional reforms, i.e. policy, participation of farmers, collection of water charges, budgeting, and conflict resolution mechanisms.

4.1 Institutional setting for irrigation in Pakistan

This research study was carried out in the Indus Basin Irrigation System (IBIS), in Punjab Province in Pakistan. The main institutions and organizations involved in the management and regulation of water resources at national level of Pakistan are presented in the succeeding sections.

Indus Water Treaty, 1960

The Indus River system comprising the River Indus and its five tributaries, two western rivers (Jhelum and Chenab) and three eastern rivers (Sutlej, Beas and Ravi), is very crucial for the people in Pakistan and western India. It should be recalled however, that the division of Indian subcontinent in 1947 created a mounting tension between Pakistan and India because of the uneven international boundary drawn cutting across the Indus River System. After the World Bank (a broker and signatory of Indus Water Treaty) interfered, Pakistan and India signed the Indus Water Treaty on 19 September 1960 which stipulated that the World Bank assigns the rights to India to take control of the flow of the eastern rivers while Pakistan has the rights to control the flows of western rivers of the Indus basin (Abbasi, 2012).

Water Apportionment Accord (WAA) of 1991

For the resolution of conflicts on water distribution among the concerned provinces, the Water Apportionment Accord which was unanimously signed by the provinces on 16 March 1991 could be used as a mechanism. Subsequently, the '10 daily allocations' regulation was made part of the Accord by the Council of Common Interest (CCI) on 16 September 1991, which specifically provides that water apportioned for Punjab is 55.94 million acre foot (MAF), where 37.07 MAF is for Kharif and 18.87 MAF is for Rabi cropping seasons.

The main organizational structures to manage and regulate the water resource at various administrative scales in Pakistan are given in Table 4.1.

Table 4.1. Multi-scale organizational structure of the water resource of Pakistan

Geographic scale of jurisdiction	Name of organization	Main functions
National		
	Ministry of Water and Power	To review policy matters related with water and power development. To carry out strategic and financial planning for long term master plans. To monitor the operation of Indus Water Treaty of 1960.
	Water and Power Development Authority (WAPDA)	To undertake investigations, planning and executing schemes for irrigation, drainage, prevention of water logging and reclamation of saline land as an autonomous body responsible for integrated development of water and power resources in Pakistan
	Indus River System Authority (IRSA)	To regulate and monitor the distribution of water sources of Indus River amongst the provinces in accordance with Water Apportionment Accord of 1991
Provincial (before IMT)		
	Provincial Irrigation and Power Department (PID)	To regulate, plan, manage and monitor the surface and ground water supplies and to develop related infrastructure, To develop and implement projects
Irrigation Zone	Irrigation Zonal Office	
Irrigation Circle	Irrigation Circle Office	
Irrigation Division	Irrigation Divisional Office	
Irrigation Sub-division	Irrigation Sub-divisional Office	
Provincial (after IMT)		
	Provincial Irrigation and Drainage Authority (PIDA)	To deliver water supplies in the canal commands To formulate, implement and review policies and procedures
Irrigation Circle	Area Water Board	To manage, distribute and cost of supplying bulk water to FOs
Secondary Canal	Farmers' Organization	To supply irrigation water to irrigators Responsible for O&M To collect water charges
Tertiary Canal	Water Users' Association	

Ministry of Water and Power, Pakistan

The Ministry of Water and Power primarily deals with policy matters relating to development of water and power resources in Pakistan. In addition, the Ministry also performs certain specific functions that include the development of strategic and financial long-term master plans for the sustainable utilization of the country's water resources. For example, proposals for long-term projects are submitted by WAPDA and its allied corporations. These proposals are scrutinized in the Ministry through its attached departments to ensure the technical and financial viability of such projects. The implementation of five-year plans and annual development program in water and power sector are also overseen by the Ministry, which also monitors the activities related to power generation, transmission and distribution, as well as performs supervisory and advisory role for smooth operation of the power sector. Moreover, the Ministry also coordinates inter-provincial water sharing activities related to irrigation, drainage and water logging, and monitors the operation of the Indus Water Treaty of 1960 between Pakistan and India. The structure of the Ministry also includes the Water and Power Wing and the Federal Flood Commission of Pakistan.

Water and Power Development Authority (WAPDA)

Created in 1959, WAPDA is an autonomous body which undertakes investigation, planning and executing schemes for irrigation, drainage, prevention of water logging, and reclamation of saline land, and is responsible for the integrated development of water and power resources in Pakistan. WAPDA also supervises the implementation of the Indus Basin Settlement Plan signed between India and Pakistan in 1960, more particularly developing replacement works for the sustainable management of river water and irrigation system in Pakistan. Thus, it is also tasked to develop water development projects which include extensive research and investigation to augment the capacity of the country's water resources.

Established to control the water sector in the entire country which is divided into north, central, south zones generally covering the North Western Frontier Provinces (now Khyber Pakhtunkhwa) and the provinces of Punjab and Sindh, WAPDA also implements SCARPs and surface water development projects in Pakistan. WAPDA has Chief Engineers (CE) and Project Directors to take charge of the implementation of projects falling under the regions within the zone. In addition, the Chief Engineer (Coordination and Monitoring) of the Water Wing of WAPDA takes charge of the construction and operation of dams and other projects under Water Wing services while two General Managers are designated for the Ghazi Barotha Hydropower and the National Drainage Projects. Headed by a General Manager (GM), the Planning Division of Water Wing looks after all the planning activities on the water side. Implementation of activities on water resources and hydropower development as well as the related vision-2025 are supervised by three General Managers, i.e. GM (Technical, South, North), GM (P&D), and GM for Hydro Development. The three water reservoirs in Mangla, Tarbela and Chashma which play a key role in the distribution and regulation of the surface water resources in the Indus Basin are also being operated and regulated by WAPDA.

Indus River System Authority (IRSA)

IRSA was established on 10 December 1992 to take charge in regulating and monitoring the distribution of water resource of the Indus River among the provinces in accordance with Water Apportionment Accord (WAA) 1991. It also takes care of the interests of the provinces as per allocations of the WAA especially in operating their respective irrigation system networks through the Provincial Irrigation Departments (PIDs). Irrigation demands of relevant canal command areas are addressed by PIDs on the basis of canal capacities, crop water requirements, historical rights, and local hydrological conditions. Taking into account the provincial irrigation demands, IRSA then discharges water from its three reservoirs. The early *Kharif* period (April-June) is the most vital period when irrigation water demands could be high for sowing *Kharif* crops. After this period, the reservoirs are nearly empty after providing for the water demand of the winter crops although water could be available when the spring freshet starts to flow (Khan, 2000).

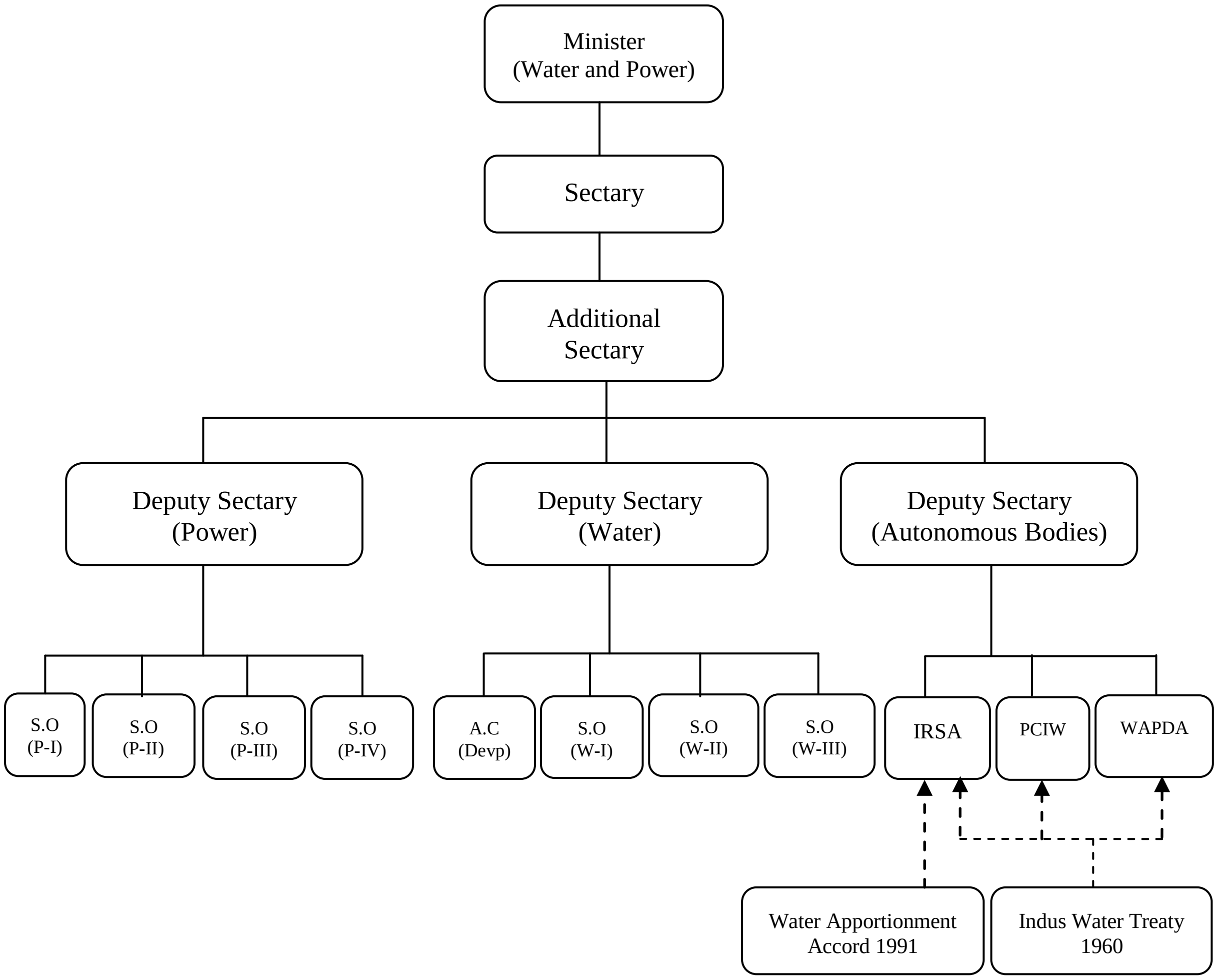


Figure 4.1. Organizational setup for irrigation at national level of Pakistan

4.2 Institutional settings for irrigation in Punjab

The main institutions involved in the management and regulation of water resources of Punjab Province in Pakistan are discussed in the following section. The organizational structure of Water and Power Department, Punjab is given in Figure 4.2.

The Canal and Drainage Act, 1873

The Canal and Drainage Act (1873) is the principle legislation for irrigation in Punjab. Under this Act, the entire irrigation network in Punjab province has been entrusted to the provincial government through the officers of Irrigation and Revenue Departments, and Judicial Officers. Figure 4.2 explains the hierarchy of the process of the Canal and Drainage Act and its implementation at various levels canal water networks in the irrigation system of Punjab.

Irrigation and Power Department of Punjab

As promulgated in the Punjab Government Rules of Business, the official functions of the Irrigation and Power Department (IPD) with regards to irrigation and drainage related aspects include:

- Surveys of rivers and riverines
- Construction work and all matters connected with barrages
- Construction and maintenance of canals
- Research and development on tubewells and other water utilization schemes
- R&D on flood control and flood protection schemes
- R&D on drainage schemes.
- Storage of water and construction of reservoirs
- Conduct basic and applied research in irrigation, hydraulics, groundwater and land reclamation
- Administration of the Canal and Drainage Act, 1873
- Administration of the Soil Reclamation Act, 1952
- Administration of the Land Improvement Tax Act, 1975
- Assessment of water rates
- Distribution of canal waters

Moreover, some other core functions of the IPD of Punjab include:

- Operation and upkeep of the irrigation system of the province
- Planning, prioritization and implementation of maintenance works through approved O&M Work Plans, and under third party top supervision
- Optimizing the use of water resources in the province through the equitable distribution of irrigation water supplies (about 54 MAF) to 58,000 canal outlets
- Assessing water rates based on actual field inspections by the revenue staff of the department
- Implementing the development program portfolio and foreign-aided projects
- Providing for and executing a plan for the management of river floods in the province, and to construct and maintain flood protection programs/works
- Promoting the participation of beneficiaries in the management of the Irrigation and Drainage Systems of the province, in line with requirements of the Punjab Irrigation and Drainage Authority (PIDA) Act of 1997
- Administering the Electricity Act and Village Electrification matters as well as Acting as the Personnel Department for over 52,000 employees of the Provincial Irrigation Department with functions that also include addressing issues related to career development, posting and transfer, promotion and in-service training.

Through the aforementioned roles and responsibilities of the PID, the status of the systems could be distinguished whether the system is controlled and managed by local user organizations and whether it is owned and to varying degrees, controlled by government agencies. While the former includes both indigenous systems which often have long histories, the latter system had turned over by the government to users' groups for management after institutional reforms.

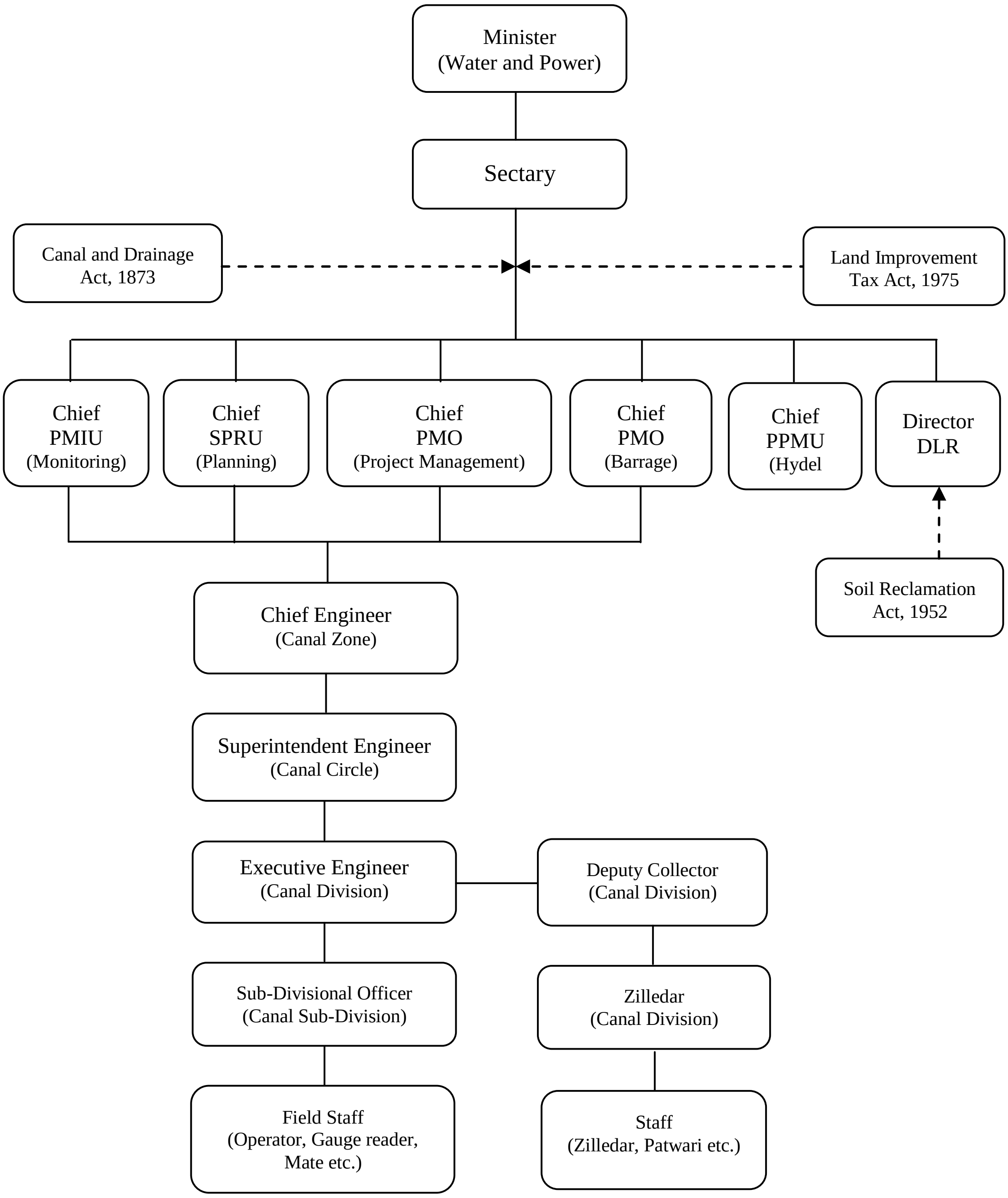


Figure 4.2. Organizational setup of Water and Power Department, Punjab

Program Monitoring and Implementation Unit (PMIU)

The Program Monitoring and Implementation Unit (PMIU) had been established within the IPD for carrying out the efficient and optimal canal operations oriented towards equity and transparency. Headed by a Chief Monitoring (Team Leader), PMIU comprises experts and other professionals who are appointed on contract basis, and had been strengthened with 12 Mobile Teams (two for each Irrigation Zone) and capacitated with the necessary equipment and technical support staff. PMIU keeps a database of the daily water discharge and exercises proper check for water feeding of the tails ensuring the equitable distribution of water in the channels/outlets based on authorized shares and approved plans. This digitized data (available at: http://irrigation.punjab.gov.pk/Search.aspx) had been used as a tool for the proper management of the canal system as well as equitable distribution of water to shareholders/Farmers Organizations.

In addition to the abovementioned rules and mechanisms for monitoring, PMIU is also responsible to carry out the following duties:

- Independent periodic inspections of canals/drains, barrages, large hydraulic structures, flood control facilities, and small dams to assess the special needs of M&R with respect to these structures other than routine M&R, and preparation of special report based on the expected outputs of its periodic inspections
- Monitoring and evaluating the impacts of the overall program as well as implementation of certain key components of the reform program itself, and consolidating and analyzing all monitoring data and issues for publication in quarterly and annual reports.

Conception of Irrigation Management Transfer (IMT) in Punjab

Vermillion and Sagardoy (1999) in their global analysis of IMTs have reported objectives that drived IMTs in various countries. The irrigation and drainage sector of Pakistan has gone through profound changes in recent decades, and was found to be trapped into the vicious cycle of "poor funding, poor maintenance, poor infrastructure condition, poor supply, poor productivity, poor recovery and poor funding" (World Bank, 1994). The water management and use habits resulted into lack of trust, anarchy, inequity, and lack of transparency, which evolved over time and have fitted the particular prevalent economic, social, and environmental circumstances. The Bank's analysis identified these as the symptoms of deep-rooted problems of poor accountability (Dinar, et al. 2004).

The formal irrigation and water supply services in Pakistan have been managed as exclusive monopolies of government agencies, which did not provide services to many – especially the poor and tail-enders – and provided poor quality services to those who had access. Merry (1996) associates the lack of accountability to the scale of irrigation systems and management by bureaucracies. The overall situation in Pakistan has been that the public irrigation supplying monopolies faced no competition, and the accountability was only upwards (Dinar, et al. 2004). The status quo of unclear entitlements, discretion, and lack of transparency suited important groups in society. The essence of the reforms would be to reduce monopoly power, and introduce transparency, thus greatly reducing the space for discretion and corruption. The reforms had to be introduced with the explicit objectives of re-designing irrigation management institutions from a government monopoly to a public utility that would be responsible for sustainability of its assets, provision of quality irrigation and drainage services to its clients, and that would discharge its responsibilities in a business-like fashion, and would be accountable to the clients.

Implementation of reforms and establishment of institutions in Punjab irrigation system

In the 1990s, on the advice of the World Bank, Pakistan's government embarked on major institutional reforms in irrigation management. The original reform proposal by the World Bank, devised through a detailed analysis of the situation (World Bank, 1994) was too revolutionary. It proposed: a) to treat water as a tradable commodity rather than a public good; b) to create private water markets by giving farmers water property rights disconnected from land; c) to divide the four Provincial Irrigation Departments into 43 autonomous Public Utilities (PUs, one each for 43 canal commands) and to create Farmers Organizations (one for each distributary); and d) PUs should have company style management and be registered under the Companies Act.

The Pakistani government sought comments from provincial governments on the proposal, who dismissed the analysis, and provided highly critical comments. All the provincial governments reacted that the Banks' proposals were too much divorced from reality, and the ideas did not match the prevalent socio-economic conditions. The federal government initiated discussions with the Bank for improving the reform model. The discussions and debates continued for another three years, when finally the World Bank and the federal government agreed on a revised reform model. The Bank rigorously pursued the reform through an 800 Million Dollar loan to the government under its National Drainage Program

(NDP). The federal government pushed the provincial governments to accept the reform through attaching the further disbursement of NDP funds with the progress with the passage of legislation. Consequently, all the four Provincial Assemblies passed Provincial Irrigation and Drainage Authority (PIDA) Acts in 1997.

Later on, as part of National Water Policy (still in draft form), the Government of Pakistan launched a medium-term Reforms Program for achieving its vision, in accordance with the national water vision viz: *"By 2025, Pakistan should have adequate water available, through proper conservation and development. Water supplies should be of good quality, equitably distributed and meet the needs of all users through an efficient management, institutional and legal system that would ensure the sustainable utilization of the water resources and support economic and social development with due consideration to the environment, quality of life, economic value of resources, ability to pay and participation of all stakeholders"*.

Cognizant of the multi-faceted and multi-dimensional concerns in the province's irrigation management system, the Punjab Government developed a vision and strategy for its irrigation sector. Its long-term vision is to provide adequate, equitable and reliable irrigation supplies to the cultivable lands of Punjab with the aim of enhancing agricultural productivity, and promote sustainable development focusing on holistic management and broad-based institutional reforms through Irrigation Management Transfer (IMT). In addition, its strategic vision is to advocate institutional and policy reforms as well as critical investments in rehabilitation and systems improvement.

Moreover, in order to improve the managerial and technical performances of the irrigation and drainage sub-sectors, the Government of Punjab introduced four types of reforms as part of its IMT process as follows:

- Institutional and Policy Reform to improve the management and maintenance of the irrigation system for ensuring its long term physical and financial sustainability
- Water Resource Management Reform to emphasize the critical importance of water entitlements, measurements and transparency
- Irrigation Service Delivery Reform to improve the quality, efficiency and accountability of irrigation services, through greater participation of farmers, institutional reforms, and the use of contractual arrangements among water supply agencies and users

- Reform to encourage adaptation of new technology for the improvement of water use efficiency and on farm productivity through a system of incentives

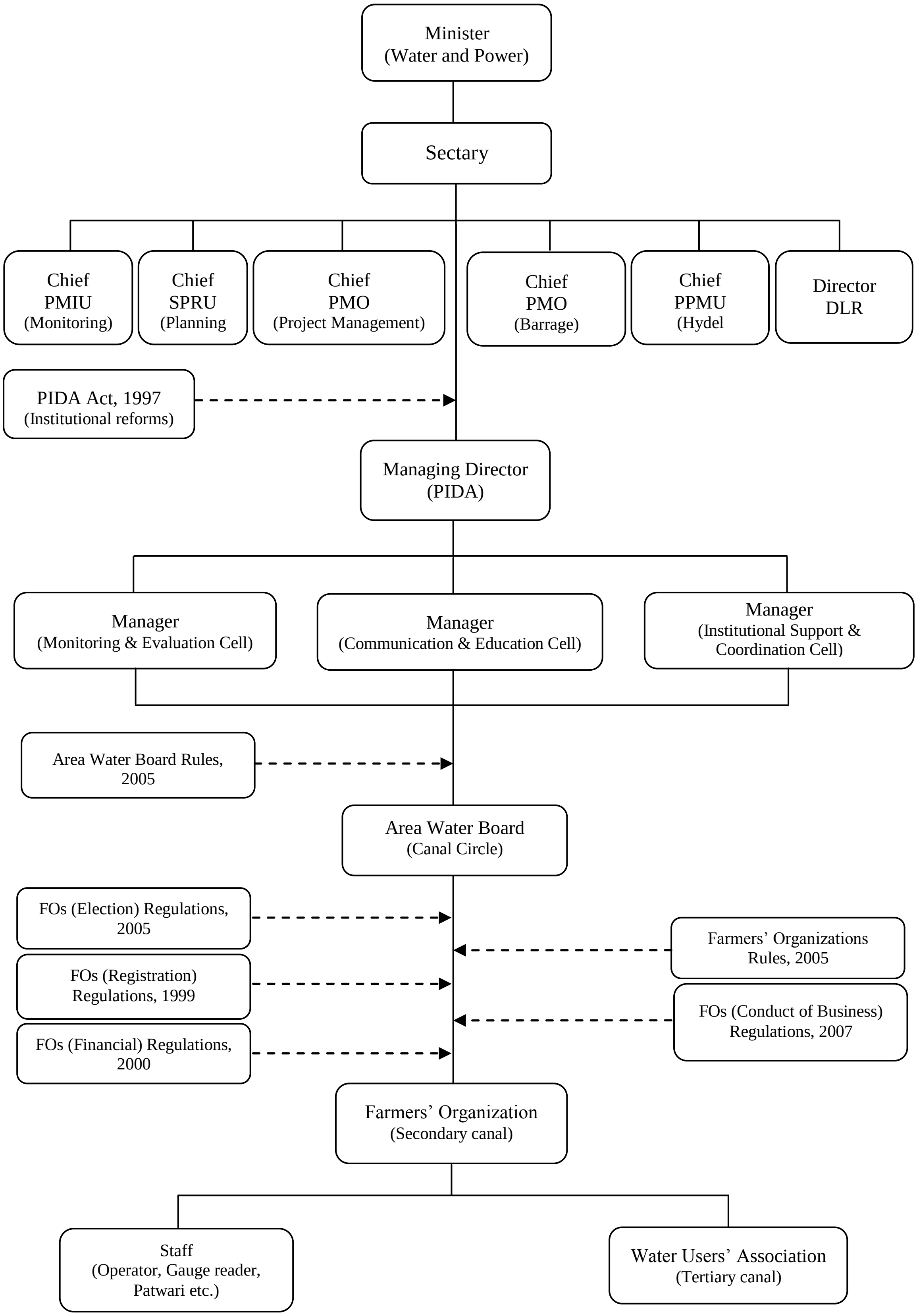


Figure 4.3. Schematic organizational chart of irrigation system of Punjab after reforms

The schematic organizational chart of newly-established institutions of PIDA and its subsequent institutions are shown in Figure 4.3.

In order to effectively implement the Irrigation Management Transfer (IMT), new institutions were established with the Provincial Irrigation and Drainage Authority (PIDA) at provincial level to be responsible for province-wide water delivery, system maintenance, and development and sales of water beyond amounts contracted with AWBs, Area Water Boards (AWBs) at main canal levels to operate, manage and distribute public utility (irrigation water) within command area through formal volume-based contracts with FOs, and trade water with other utilities, Farmers' Organizations (FOs) at the secondary or branch canal levels to supply water to irrigators and responsible for operation and maintenance of secondary irrigation canals, to levy and collect water charges, and to make payments to canal level AWB for cost of supplying bulk water to FOs. At grassroots level is the Water User Associations WUAs at the tertiary canal levels or farmers outlets for providing water to the agricultural fields. Under this shift of governance, a package of certain rights, policies, rules and regulations, conflict resolution systems, water charges collection mechanism, monitoring and accountability measures has been handed over to the farmers. However, for the Government-Managed Irrigation System which is being implemented in accordance with the Act of 1873, no major changes are taking place in its institutional and governance structures.

The reform, however, remained quite controversial throughout the implementation of the National Drainage Program (NDP) during 1994 to 2003, and both the donors and the governmental staff were uncertain whether its progress would be realized smoothly or not (Dinar, et Al. 2004).

Lack of political will and resistance from stakeholders

The media picked up the proposed reform and various stakeholders engaged themselves in a hot debate, questioning the rationale, modalities, as well as the perceived outcomes. For example, it was reported in the newspapers that the government was going to sell the irrigation canals to the World Bank (Nakashima, 2005), and the farmers had the perception that the World Bank would charge much higher rates for irrigation water, and in advance (Bandaragoda, et al. 1997).

People did not like, above all, the idea of a utility company, which would disconnect a water supply just because water charges were not paid properly (Nakashima, 2005). There was strong resistance to the proposed reform program by all the key stakeholders. The Provincial Irrigation Department feared to lose authority to distribute water and maintain irrigation systems. Big landlords and influential farmers feared to lose extra water than authorized and poor farmers feared water rates would go up and influential farmers would exploit them.

While the federal government agreed to the need for reform by signing the loan agreement with the bank after some degree of resistance, the provincial governments did not share the same feeling equally. The federal government also gave mixed signals initially, for example by delaying the acceptance of offer from Asian Development Banks for formulating water sector strategy, which offered support to develop comprehensive national and provincial institutional and policy reforms and infrastructure development plans for all water sub-sectors. "The Government's perceived lack of interest" led to a delay in its execution by almost 3 years and "only after a drought raised awareness of water issues, only then "the follow-up missions of ADB could convince the Government of the need for the program and then the Government supported it (ADB, 2005).

The staff of provincial irrigation departments (PIDs) not only opposed the reform, but resisted and felt as if the reform were being pushed onto them and feared that they would entail dissolution of their service, and a breakdown in existing rent relationships (Shafique, et al. 2004). Another disincentive for the PID staff was that of leaving the relative security of service with the government, for more novel contractual work with more transparent and accountable institutions (World Bank, 2005). The PID staff obstructed the reform initially by delaying the passage of legislation till the donors threatened to withdraw the loan (van der Velde and Tirmizi, 2001). Once the legislation was in place, there was no option to not test the reform. PID happened to choose one of the most challenging irrigation systems in Punjab to pilot the reform.

Equally, those segments of the farmers who were benefiting from the status quo had opposed the reform (Nakashima, 2005). Larger landowners were the most opposed to change, since they had been gaming the system for decades. Clearly, they exercised political influence, and benefited most from the deinstitutionalized politics that were in vogue. Many accounts of reform in earlier years (for example by Nakashima, 2005; Shafique et al. 2001; van der Velde and Tirmizi, 2001) indicated that the reforms were felt to be failing because of inadequate top level support, technical support to the farmers and vested interests of bureaucracy and big farmers. However, such opposition to reform was not unique to Pakistan, as Mollinga, et al. (2001) reported similar experiences in India's Andhra Pradesh.

Involvement of farmers in the implementation of IMT

In the General Body of PIDA at provincial level, there are 6 permanent representations of farmers as given in Table 4.2. These farmers are nominated by government. There is no any election process for these farmers' representatives. However, at scheme level, involvement of farmers is limited to water delivery, revenue collection, M&R, and monitoring. General Bodies of FOs and WUAs are elected by farmers. Farmers are responsible to operate and manage secondary and tertiary canals only.

General body of Punjab Irrigation and Drainage Authority (PIDA)

After the institutional reforms in the irrigation system of Punjab, PIDA was established as an autonomous institution under PIDA Act of 1997. The general body of PIDA is shown in Table 4.2.

Table 4.2. Punjab Irrigation and Drainage Authority (PIDA) at province level

General Body	Number	Remarks
Chairman	1	Minister for Irrigation, Punjab
Farmer Members	6	Nominated by the Government
Non-Farmer Members	5	Chairman P&D Board, Punjab Secretary, Irrigation & Power Department, Punjab Secretary, Agriculture Department, Punjab Secretary, Finance Department, Punjab Managing Director PIDA

Specifically, the main functions of PIDA are:

- To deliver water in the canals of the entire province
- To prepare policy and strategies for construction and development
- To formulate the rules and regulations

4.3 Institutional setting at irrigation system level

Institutional reforms in the province started with promulgation of PIDA Act 1997 by the Provincial Assembly of Punjab. For the implementation of the reforms initiatives, PIDA established a legal framework taking into consideration the participation of farmers at all levels of the irrigation management, i.e. at provincial, canal command and at distributary levels. Such framework legitimizes the reforms processes and sets out the conditions for establishment of Farmers Organizations and Area Water Boards through the Rules and Regulations and legal framework stipulated in PIDA Act 1997.

Under this legal framework, the existing irrigation system management (Figure 4.4) has been converted into multi-tier system for management of the irrigation infrastructure (Figure 4.5). A model sketch showing management units in BC Irrigation Scheme (FMIS) is shown in Figure 4.5.

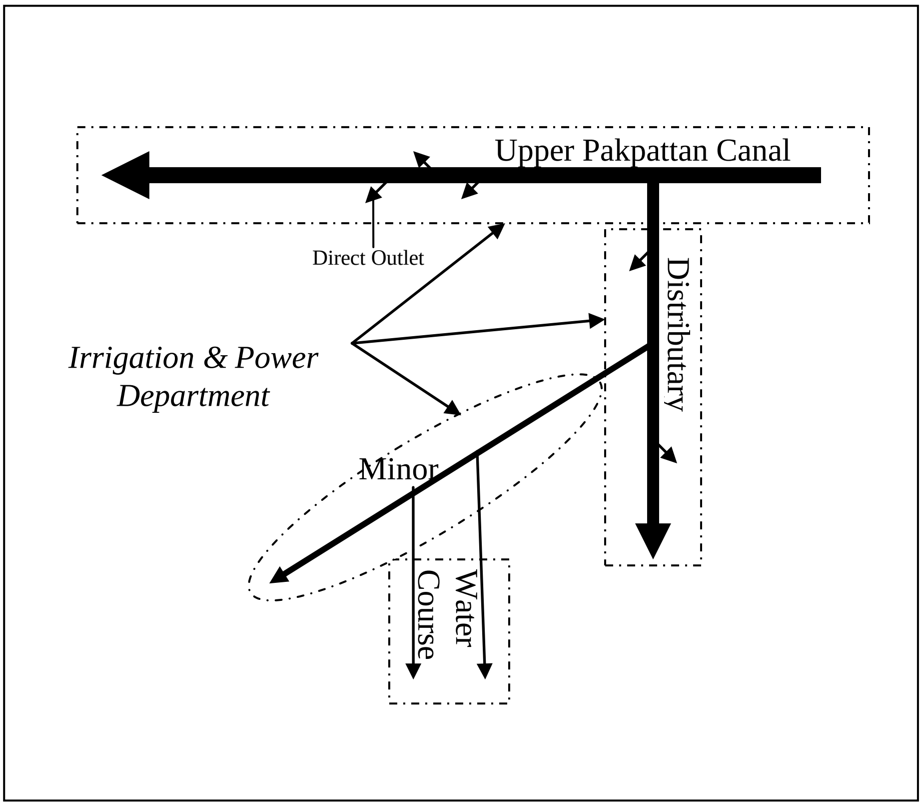


Figure 4.4. A model sketch showing management units at UPC Irrigation Scheme (GMIS)

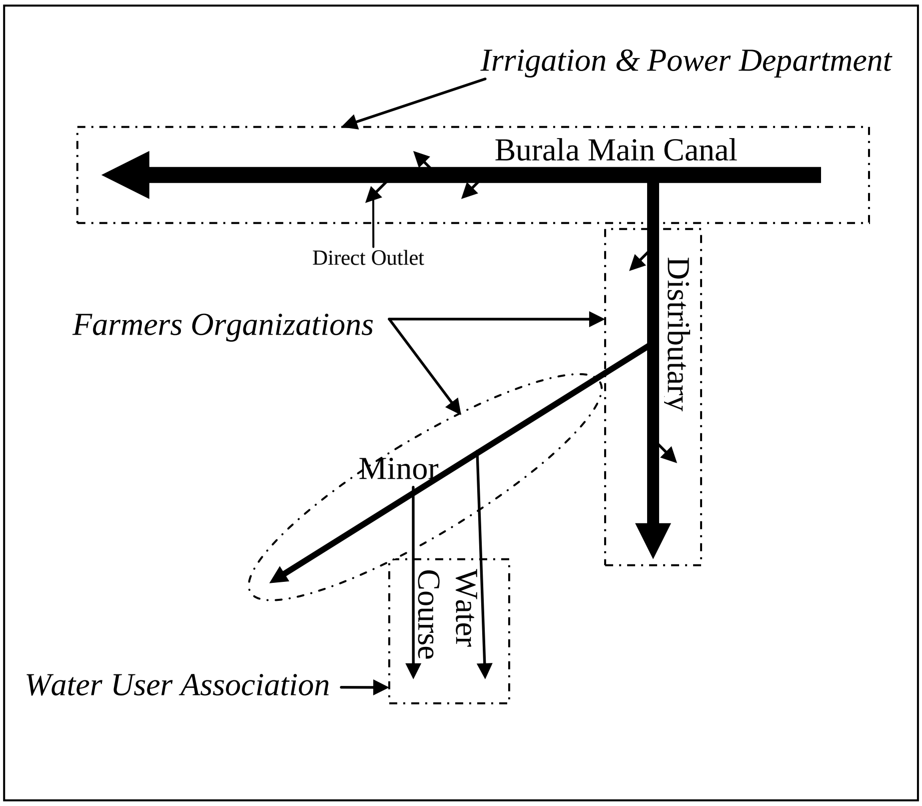


Figure 4.5. A model sketch showing management units at BC Irrigation Scheme (FMIS)

General Body of Area Water Board (AWB)

Area Water Board (AWB) had been established at canal circle level under PIDA Act of 1997, and its rules were defined under "The Area Water Board (Rules) 2005". The General Body of the AWB is given in Table 4.3 while the Pilot Area Water Board of Lower Chenab Canal (East) Circle is shown in Figure 4.6. The BC Irrigation Scheme comes under the jurisdiction of this particular AWB.

Table 4.3. Area Water Board at Canal Command level

General Body	Number	Remarks
Chairman	1	Elected from the Farmer Members
Farmer members	10	Elected from Farmers Organizations
Non farmer members	9	Representatives from allied Government Departments and technical experts

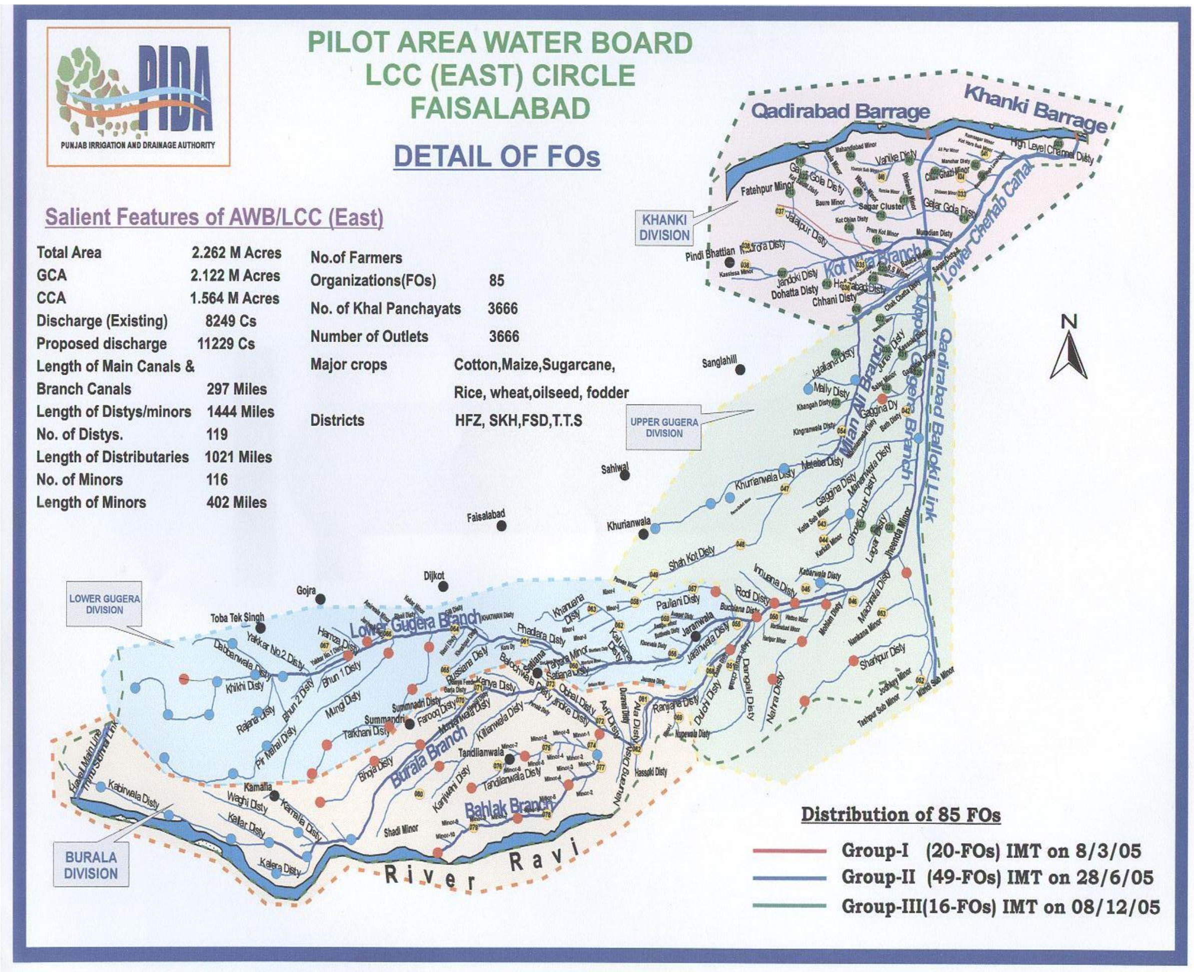


Figure 4.6. Command area of Area Water Board (LCC East)

Functions of Area Water Board (AWB)

The main functions of AWB include the following:

- To monitor/review the implementation of relevant work plans
- To suggest/review the annual development programs
- To prepare and implement the rotational plan for distribution of water under its command canals
- To monitor the main canals, secondary canals, and tertiary canals under its command
- To suggest/explain strategies and their implementation to stop water theft and canal related discriminations under the law of irrigation to ensure equitable water deliveries and address water shortages at tail reach
- To monitor and review the collection of water charges
- To monitor and review the expenditures in accordance with annual granted budget
- To appreciate the participation of water users in the management of canal water
- To establish Farmers' Organizations, and help the Government and the Authority in the process of their development
- To monitor the performance of Farmers' Organizations, and suggest strategies to the Authority for improving the performance of Farmers' Organizations

- To obtain aid/budget/grant or cash from Government/Authority or any person with the permission of the Authority
- To utilize the funds within the defined limits and in accordance the defined rules by the Authority
- To perform additional works assigned by the Authority

In addition to all abovementioned functions, AWBs are also responsible for the management of the irrigation, drainage and flood control systems from barrages to the head of secondary canals in their respective commands.

Establishment of Farmers' Organizations and procedures

Farmers Organizations (FOs) are established according to the "Farmers' Organizations Rules, 2005", and supported by the following legal frameworks to enable them to smoothly carry out their duties and responsibilities.

- FOs (Elections) Regulations, 1999
- FOs (Registration) Regulations, 1999
- FOs (Financial) Regulations, 2000
- FOs (Conduct of Business) Regulations, 2007.

Based on the abovementioned legal frameworks, the procedures for the establishment of FOs are defined as follows:

- Farmers' Organizations will comprise the representatives of all tertiary canals or minors. All Chairmen of Water Users Associations (locally known as Khal Panchayat) will be members of the FOs, where an FO will be responsible to regulate, and conduct repairs and maintenance of its respective secondary canal (locally known as Rajba). An FO will also serve as canal officer under their defined authority to perform their functions and in accordance with the Irrigation & Drainage Act of 1873.
- All Chairmen of WUAs will establish their respective Farmers' Organizations (locally known as Nehri Panchayat), while FOs can be established on minor levels or part of secondary canals.
- Farmer-members of WUA will elect 4 members and one chairman from among themselves where the chairman will be a member of the General Body of FO. Election is held based on the rules and regulations of Farmers' Organizations.
- FO can have its own name, but its circle of authority will be defined according to the rules and regulations set by the Government of Punjab and PIDA, and should emphasize on secondary canals.
- Each FO will establish a registered office within the boundary of its command area, although such office could be located in the building given by the Irrigation Department or any other nominated building or if possible in the building of PIDA.
- Each FO will consist of a General Body and an Executive Committee which can be organized based on conditions given below.

(a) The number of members of the General Body will be equal to the number of tertiary canals or minors, while one member from each minor or tertiary canal could be the chairman of WUA.
(b) The General Body of FO will elect its Executive Committee which will consist of 9 members with corresponding positions as shown in Table 4.4.

Table 4.4. Management Committee of Farmers’ Organization

Management Committee	Number	Remarks
President	1	Management Committee (elected by General Body[1])
Vice President	1	
Sectary	1	
Treasurer	1	
Executive Members	5	Three from tail reaches

[1] General Body consists of Chairmen of Khal Panchayats (WUAs)

- The Executive Committee will discharge all authorities except those which come under the authority of the General Body, while management and financial matters of various institutions/individuals involved are in accordance with the prescribed rules and regulations of FOs.
- The Executive Committee elected by the General Body of FOs will serve for a period of three years starting from the time when the authority is handed down to FOs.
- One person to serve as an assistant, whether full time or part time will be recruited from the Authority or AWB or can be recruited by FO to do office works.
- It will be compulsory for FO to work and to run the irrigation system in accordance with the limits indicated in the rules and regulations of the agreement with AWB/PIDA and according to the related prescribed principles and responsibilities.

Rules and Regulations of FOs

The functions of the Farmers’ Organizations were first defined in 1999 but replaced in 2005 with new rules under “Farmers’ Organizations (Rules) 2005” requiring each FO to perform its functions accordingly. Under the rules defined in 2005, FOs are liable for the repair and maintenance of their command irrigation system, management of water flows, equitable water distribution, repair and maintenance of bridges/falls/outlets, assessment and collection of water charges including those from non-irrigation water usage by industries, and providing solutions for water distribution related conflicts among farmers in accordance with its rules and regulations. Moreover, FOs will recruit its employees and keep accounts of its expenses which should be opened for audit.

These rules which fall under 18 (2) IMT “Farmers’ Organizations (Rules) 2005” are given in detail as follows:

- To regulate, maintain, and look after all basic infrastructures including hydraulic structures according to designed level
- To take canal water supplies from the head regulator of main canal or branch canal
- To ensure equitable and timely distribution of water to farmers and other users of water in the command
- To protect the environment including the quality of water in channels
- To investigate the recovery of water charges and other irrigation related charges from water users
- To collect water charges and other charges from liable persons
- To submit remaining amount of water charges to the account of Authority after deducting the FO share based on the agreement with the Authority
- To charge additional services from FOs and their collection
- To recover fines from the water users in case of delayed payment of water charges

- To solve water related conflicts among farmers or other water users
- To use proper authority and measures in performing all the above mentioned rules

General Body of Water Users' Associations

WUAs (Khal Panchayat) have been established under the rules defined in "Farmers' Organizations Rules, 2005" and the General Body consists of five members, one chairman and 4 members (elected from among the farmers of the watercourse).

Irrigation Management Transfer Agreement

The most important provisions from the agreement of Irrigation Management Transfer and Farmers' Organizations include the following:

- The agreement is made between PIDA (through its Chief Executive, AWB/Superintending Engineer of the Canal Circle) and Farmers' Organizations of concerned distributary.
- The agreement is valid for a period of three years from the date when distributary system is handed over to concerned Farmers' Organizations.
- The Authority/AWB would continuously monitor and evaluate the activities of Farmers Organizations through inspections, field visits and progress reports.
- The FO is entitled to have its share as approved by PIDA and the Authority from the collected water charges which should be spent for the administration and operation of the distributary as well as for repair and maintenance of the channels and structures.
- The Chief Executive (CE), Area Water Board (AWB)/Superintendent Engineer (SE) of the Circle are liable to provide water to distributary as per authorized discharge and based on availability of water.

The criteria for sharing water charges with FOs are given in Table 4.5. In accordance with the rules, FOs are responsible for submitting the funds to the account of the Authority or Area Water Board after deducting their share based on the aforementioned criteria.

Table 4.5. Criteria of water charges sharing by Farmers' Organizations

Water Charges Collection	FO Share	PIDA Share
Below 60%	40%	60%
Up to 80%	40%	60%
80% and above	40%	60%
Above 90%	43%	57%

Source: Provincial Irrigation and Drainage Authority (PIDA)

Moreover, it should be noted that institutional environment which constitutes such factors as access to labour, access to credit, and access to extension services and technical advices, have been incorporated and discussed in the Chapter on performance assessment of farms.

4.4 Monitoring and evaluation (M&E) system of PIDA

Monitoring and evaluation is an important tool for assessing the performance of projects and programs to ensure their smooth and effective implementation towards achieving the objectives. PIDA has developed a very comprehensive and effective mechanism of monitoring its new entities (e.g. Farmers Organizations) against their entrusted functions vis-à-vis impacts and outcomes. In this regard, PIDA has established its M&E Unit with the main objective of carrying out internal on-going evaluation especially with respect to the performance of FOs as well as managing other monitoring and evaluation activities. For benchmarking the performance of Farmers Organizations, the M&E Unit is involved in securing certain improvements through the comparison of relevant and achievable internal or external norms and standards. Nevertheless, the M&E Unit in PIDA has different functions from the PMIU in IPD in view of their different mechanisms of operations and respective core functions of PIDA and IPD.

Main objective of M&E system

The following are the major objectives set in M&E system:

- To carry out continuous monitoring of the reforms components especially the performance of FOs.
- To suggest appropriate remedial measures/actions to smoothen the progress and performance in achieving the desired objectives in accordance with the timeframe.
- To establish benchmarking system taking into consideration the performance key indicators that could be utilized for subsequent monitoring and evaluations.
- To identify the constraints in the implementation of various activities and accordingly suggest different managerial steps/remedial measures to overcome the limiting factors.
- To prepare periodic progress/monitoring reports reflecting the status of the performance key indicators.
- To conduct internal monitoring of pre- and post-project situation in the operation and management of irrigation system.
- To prepare Terms of Reference for third party evaluation for the components where such review would be required.

Implementation process

The M&E Unit of PIDA has prepared and instituted a system of monitoring and benchmarking of performance of Farmers Organizations. The following specific key indicators are incorporated and considered under the monitoring and benchmarking of the performance of FOs:

- Organizational development
- Management of physical condition of distributary - O&M of channels & works
- Irrigation service delivery - operation and regulation of channels, monitoring and recording of water delivery of channels and outlets to maintain equity
- Disputes resolutions and disposal of revenue cases
- Water rate (abiana) assessment and collection

For the implementation of such system, M&E teams have been designated to carry out internal/ongoing monitoring of performance of FOs against their entrusted functions. The template for FOs monthly progress report and M&E field inspection sheets have been introduced to properly assess the functioning of the FOs and standardize the FOs performance, as well as carry out sub-sequent monitoring and evaluations.

Inspections

In-depth monitoring of operational and managerial functions of FOs and verifying the implementation of its irrigation management system as well as investigating the physical conditions of channels including outlets parameters and the delivery performance of outlets, are being periodically carried out by M&E Unit teams through regular inspections of channels and outlets. The M&E Teams inspects the channels jointly with FOs, where copies of physical inspection reports are provided to FOs with the identified weak areas conveyed to particular FOs for them to execute the necessary follow up improvements and to take actions especially towards improving water regulations and delivery, and ensuring equity.

Evaluation

Monthly progress reports submitted by the FOs based on defined templates and field inspection reports of M&E Teams on concerned FO and channels are documented and compiled. These reports are then analyzed with respect to the entrusted functions to FOs especially regarding irrigation service delivery to farmers, repair and maintenance of channels, disputes resolution, and collection of water charges (abiana). The weak areas of a particular FO where its performance is unsatisfactory are communicated directly to the concerned FO through writing. Furthermore, in-house meetings are also convened to formulate strategies for the improvement of the performance of FOs and enhancement of weak areas including capacity building and training of staff and officers of the FOs.

Based on the aforementioned roles and responsibilities of various entities at different tiers, i.e. PIDA, AWB and FOs, the following are the broader areas being considered during the monitoring and evaluation of the performance of FOs:

- Organizational Development – Constitution of Standing Committees, conduct of meetings (General Body & Management Committee), training & capacity building, inter-community visits, preparation of annual business plan/budget, water scheduling, record keeping, understanding & commitment regarding roles and responsibilities, cohesion amongst the FOs members, AWB & PIDA as well as other stakeholders
- Management of Physical Conditions – walking through the channels, identification and execution of physical/O&M works, maintaining of hydraulic structures (bridges, falls, head regulators) and the inner sections of the channels to design parameters
- Efficient Service Delivery – responsiveness to emergency calls relating to breaches, cuts, water theft, water related disputes as well as maintenance of outlet structures to design parameters, serving as watch and ward of the channels, reduction in canal breaches/cuts as well as water theft cases, suggesting methods of improving irrigation system, efficient use of water, water measurements, increase in delivery efficiency/conveyance losses at watercourse level
- Regulation and water accounting – ensuring effective delivery performance of outlets at different reaches, observation of gauges at various reaches of the channel including water delivery, accounting among others
- Equity in Water Delivery – carrying out water measurements at various reaches of the channel, actual discharge against the sanction, checking of gauges, checking of outlets, and control over water theft

- Revenue Management – assessment and collection of water rates (abiana), utilization of funds for the operation & management of the distributary sub-system
- Dispute Resolution & Disposal of Revenue Cases – resolution of conflicts related to water allocation, distribution, and revenue & unauthorized irrigation/water theft cases (initiation, action & finalization)
- Farmers Community Participation – promoting self-help regarding repair of breaches/cuts, desilting of channel, repair & maintenance works as well as several others
- Accounts Management – management of accounts (procurement of goods & services, execution of works, assessment, collection & utilization of funds) as per the procedures laid out in the financial management guidelines of PIDA
- Coordination amongst the Stakeholders – facilitating interaction/cohesiveness between PIDA, AWB, FOs, IPD, Agriculture Department, NGOs as well as other stakeholder in collaboration/or with the assistance of stakeholders relating to the irrigation/water management, agriculture, marketing and other activities
- Self-Monitoring & Progress Reporting to PIDA/AWB – monitoring FOs to improve their performance with reference to agreed parameters and monthly & periodically progress reports submission on prescribed formats/forms

Criterion for Ranking the Performance of Farmers' Organizations

The appropriate types of indicators are included in the criterion for examining the success and sustainability of the Farmer Organizations (FOs), where each indicator is assigned a specific weight. Based on the collective values of the performance indicators, the performance evaluation of particular FO is given the corresponding performance rating based on the standardized four broader rating categories shown in Table 4.6.

Table 4.6. Categories of rating the performance of Farmers' Organizations

Rating/Standard	Score %age	FO performance as per rating
Poor	Less than 55%	FO is not performing adequately in this aspect and requires support and guidance. The PIDA/AWB should intervene, investigate and boost the performance of FOs
Adequate	55-70 %	FO has reached the minimum acceptable standard in this aspect, but remains vulnerable, and progress should be monitored
Satisfactory	70-85%	FO is performing well, and the FO is considered to be sustainable, but monitoring and support should be continued
Good	More than 85%	FO performance is very good, mature, fully sustainable and model for other FOs. FO is able to develop further or accept additional responsibilities

Source: Provincial Irrigation and Drainage Authority (PIDA)

Rating of Farmers' Organization functioning against performance indicators

The performances of Farmers' Organizations (FOs) are also evaluated based on the criteria for ranking shown in Table 4.7. Each FO is assigned value/score (in percentage) for each major indicator as also given in Table 4.7.

Table 4.7. Performance indicators and criteria for ranking Farmers' Organizations

	Indicators	Standard	Assigned Value/Score
1	Organizational development	Poor Adequate Satisfactory Good	Less than 50% out of wt.(weightage) score 15 50-70 % out of wt. score 15 70-90% out of wt. score 15 Greater than 90% out of wt. score 15
2	Management of physical condition of distributary sub-system – O&M of channels & works	Poor Adequate Satisfactory Good	Less than 60% out of wt. score 20 60-70 % out of wt. score 20 70-80% out of wt. score 20 Greater than 80% out of wt. score 20
3	Irrigation Service Delivery: a) Operation & regulation of channels; b) Monitoring & recording of water delivery of channels and outlets to maintain equity	Poor Adequate Satisfactory Good	Less than 70% out of wt. score 45 70-80 % out of wt. score 45 80-90% out of wt. score 45 Greater than 90% out of wt. score 45
4	Disputes resolution and disposal of revenue cases	Poor Adequate Satisfactory Good	Less than 40% out of wt. score 5 40-60 % out of wt. score 5 60-80% out of wt. score 5 Greater than 80% out of wt. score 5
5	Water charges assessment and collection	Poor Adequate Satisfactory Good	Less than 60% out of wt. score 15 60-80 % out of wt. score 15 80-90% out of wt. score 15 Greater than 90% out of wt. score 15

Source: Provincial Irrigation and Drainage Authority (PIDA)

Summary of Irrigation management Transfer (IMT) in Punjab

In Punjab, irrigation management transfer (IMT) has been a fully bureaucratic decision since it was a prerequisite to heavy investments on rehabilitation by the World Bank (Hassan, 2008). Although, IMT in Burala Canal Irrigation Scheme can be justified by technical concerns but cannot justified by farmers' demands or requests. The adoption of IMT policies in Pakistan represents a case of a "coercive policy adoption" as opposed to a "voluntary policy adoption" (Dolowitz and Marsh, 1996; Hassan, 2008) at all levels. Later on, Dolowitz (2000) identified three main reasons for policy failure in "policy transfer cases" such as; a) uninformed transfer, b) incomplete transfer; and c) inappropriate transfer. In case of Pakistan, it appears that all the three reasons were quite evident when the debate started. According to irrigation engineers from the Department of Irrigation (IPD) of Pakistan, IMT has been imposed with some sense of haste in 1997 through PIDA Act 1997 and implemented in 2004-2005. In spite of such situation, IPD is now expanding the reform to other schemes in Punjab near the case study area. Observers admit that farmers, although they may have not yet been fully autonomous, skilled and capacitated, are actually quite enthusiastic and motivated about the IMT. Until now, in terms of transferred schemes, the WUA and FOs only deal with water delivery and service fee collection with no effort exerted for instance in product marketing, credit, machinery pooling, and input supply. Thus, with such limited role, the government falls short of the actual needs of the farmers for irrigation water. As aforementioned, the recent warning from Ostrom (2007) and Molle (2008) against "panaceas" should be considered so that IMT is not fraught with haste, leapfrogging, and disregard of the local situation and human dimensions. Lankford (2009) further ascertained that irrigation development is not only about infrastructure and technology, and thus, should not put the individual farmer at the center but the community of smallholders instead. "*This subtle shift moves us away from* *an excessive emphasis on 'atomised' […] solutions and technologies, and towards the notion that the institutional and organizational challenges of managing water as a common property are paramount*" (Lankford, 2009: 479).

4.5 Main findings

Institutional and organizational settings underlying the FMIS and GMIS have been investigated, the results of which are discussed in this chapter. Based on the analysis of policy documents, it could be gleaned that all the legal frameworks as well as rules and regulations are well-documented in both irrigation schemes. Farmers in FMIS have more awareness about functions, rules and regulations of FOs and WUAs. Moreover, PIDA has a well-defined mechanism for performance evaluation, monitoring and inspection especially with respect to the operations of the Farmers' Organizations. However, some key elements were ignored during implementing institutional reform such as; a) assignment of clear water rights for FOs, b) making AWBs accountable to FOs, and c) putting in place strategies for capacity building of FOs, AWBs, and PIDA to undertake their jobs in the new fashion (Hassan, 2008).

Chapter 5

Assessment of Governance Features at Scheme Level

As part of the performance assessment at scheme level, it is important to include some governance performance indicators that are not included in the application of the MASSCOTE approach. It should be considered that these governance indicators could also reveal the performance of institutions in terms of delivering services, since these are mostly based on the opinions and stock knowledge of farmers. In this regard, this chapter starts with the perceptions of farmers on the governance of the irrigation systems, which they indicated as part of the questionnaire survey. The results of the performance of FOs specifically for resolving water theft cases and in compiling statistics of water theft cases by each FO are also reported in this chapter based on secondary data from the Area Water Board of the Lower Chenab Canal (LCC East) in Faisalabad.

5.1 Farmers' perception on local governance features

This section provides the picture of the governance features in the Burala Canal (BC) Irrigation Scheme (FMIS) as well as that of Upper Pakpattan Canal (UPC) Irrigation Scheme (GMIS).

Level of transparency

Figure 5.1 shows the level of transparency regarding financial and organizational aspects in the study areas, such as Burala Canal (FMIS) and Upper Pakpattan (GMIS) irrigation schemes. During the survey, the farmers were asked whether they are aware of the budget allocated to the schemes, ISF recovery situation, corruption (to secure water deliveries of legal water share and illegally) budget expenditures on O&M, and the organizational procedures adopted by WUAs, FOs, and by IPD.

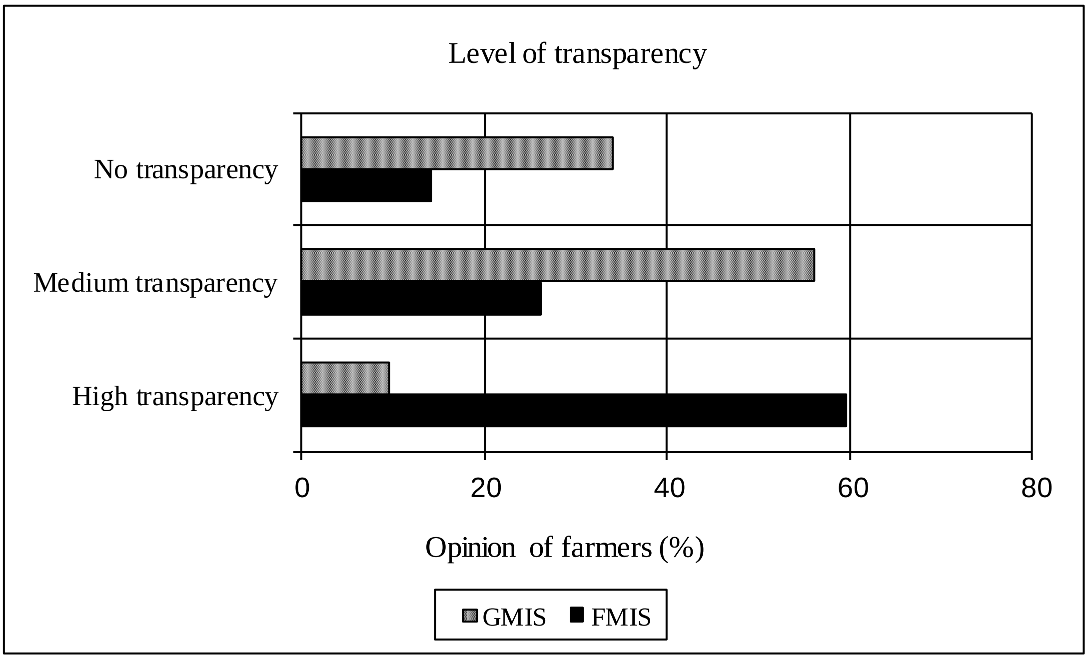


Figure 5.1. Level of transparency regarding financial and organizational matters

The results indicated that farmers in FMIS have been very motivated and nearly 60% are much aware about the financial and organizational matters of WUAs and FOs. Meanwhile, in the same category of "high transparency" only 10% of the farmers in GMIS know about the financial and organizational operations of such institutions. Specifically, more than 30% of farmers in GMIS have no idea about the financial and organizational aspects of the IPD. Moreover, in terms of corruption and rent seeking behavior by the officials and staff of public agencies (IPD) has been reported by Rinaudo (2002), Easter and Liu (2005). However, farmers are also involved in this kind of bid to get better water deliveries particularly under water scarce situations.

Level of fines and penalties imposed and recovery

Figure 5.2 shows the level of fines and penalties imposed by authorities against persons found to be involved in illegal actions that could affect or suspend water delivery services to other farmers. Based on the farmers' opinion, it could be perceived that GMIS has more strict policies against such illegal actions than FMIS. Specifically in GMIS, punishment is meted by requiring offenders to deposit cash after which long procedure of hearings are conducted either by responsible officers of IPD or by legal courts. Although, the process could be time consuming and expensive, very high amount of fines and penalties had been collected from an individual offender or groups of offenders. In one instance, even tampering the information prepared by field staff was subjected to punishment such as the case in Patwari, Ziledar as the action had obviously misguided the authorities in taking the most appropriate action. Nevertheless, the influence from local but politically influenced persons could also affect the decisions to punish offenders.

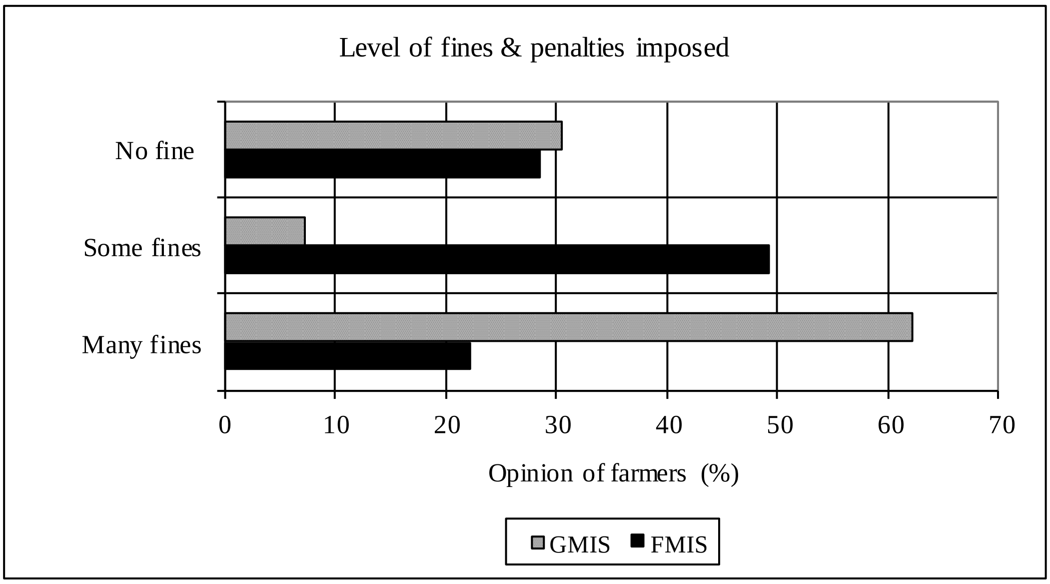


Figure 5.2. Level of fines & penalties imposed on farmers against illegal actions

In Burala Canal Irrigation Scheme (FMIS), the practice of imposing big fines and penalties is not common as indicated by only about 23% of the farmers surveyed who agreed with the option "many fines". Although about 50% of the farmers agreed with imposing "some fines" which could be in terms of cash deposit to WUA or FO or to some extent closure or suspension of the water delivery during certain period of time, nearly 30% of the farmers believed that there is no need to impose fines and penalties against offenders.

Even after the institutional reforms in Burala Canal Irrigation Scheme, there was still no specific nor pre-defined fines and penalties imposed by FOs and WUAs against persons involved in illegal actions such as outlet tampering, water theft, canal breaching, and so on. It is also significant to mention that even a simple guideline of punishment such as the kind of punishment corresponding to which action, the terms and conditions and the like, was lacking. However, in cases where farmers are not satisfied with the decisions taken by the FOs, they have to undergo the usual government court litigations which could involve very lengthy procedures. In fact, such situation could have been a result of the absence of well-defined punishment guidelines and on the mechanism of imposing fines, and the type and degree of fines to be meted per illegal actions, in the rules and regulations of FOs given by PIDA.

Figure 5.3 shows the level of restoration of fines and penalties imposed by concerned authorities. In view of its more effective mechanism, GMIS shows better results of recovering fines and penalties from offenders than FMIS. Although the procedures of imposing fines and recovery mechanism could be lengthy, but there is no respite granted to offending farmers. In GMIS for instance, once a case had been filed, fines are immediately imposed and recovered in any way possible. However, the main weak side of this whole procedure is the difficulty in accessing the appropriate offices of IPD especially during hearings and investigations, while the process could be time consuming and costly.

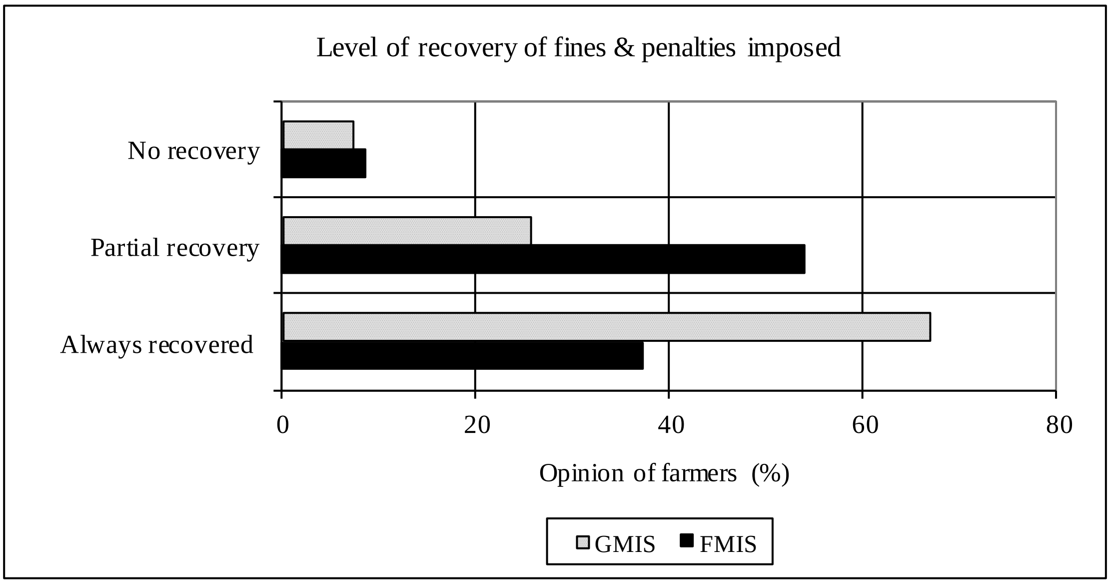


Figure 5.3. Level of recovery of fines and penalties

As mentioned earlier, the mechanisms for imposing fines in FMIS are weak. As confirmed during the survey, 50% of the farmers believed that only partial recoveries had been accomplished in the FMIS as regards collecting fines. In fact, even if WUAs and FOs are fully autonomous in their decisions, some kind of respite and flexibility had been granted to offenders (nepotism and political affiliations) which tend to decrease and slow down the rate of recovery. Easter and Liu (2005) also reported that there is penalty system for the defaulters and late payers of water charges (ISF). This situation violates the governing principle no. 5 when (Ostrom, 1990) calls for graduated sanctions on those who violate the operational rules. However, FOs are not yet fully institutionally capable to take necessary action and to implement sanctions.

Level of responsiveness by authorities

Figure 5.4 presents the picture of the opinion of farmers on level of responsiveness by authorities in attending to their complaints and suggestions for water delivery services. During the survey, more than 50% of the farmers in FMIS agreed that WUAs and FOs were quick to respond and take immediate actions in short period of time. For such efforts, the farmers could easily access to the offices of FO and WUA which means savings on transportation costs and precious time on the part of the farmers.

In the case of GMIS, almost 65% farmers believed that IPD seemed to delay its response on their complaints as well as in taking the appropriate actions. The farmers reported that they have to visit offices of IPD many times even for registering their simple complaints. Moreover, they also cited that the procedures to get the final actions by IPD are much too lengthy.

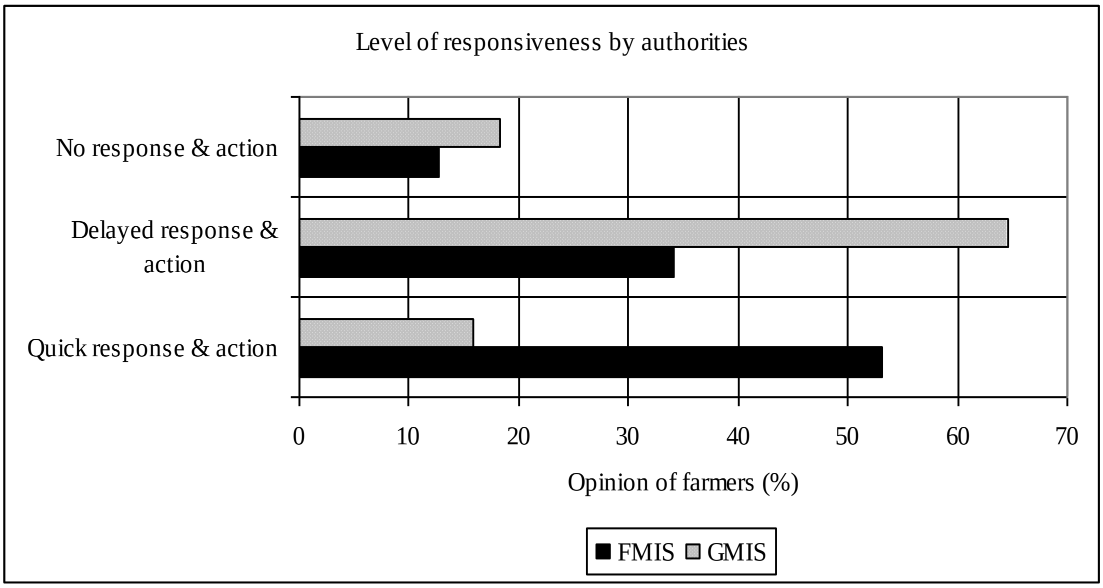


Figure 5.4. Level of responsiveness by institutions regarding complaints and actions

Level of satisfaction on decisions taken by authorities and institutions

Figure 5.5 shows the satisfaction level expressed by the farmers on decisions taken by authorities and institutions with regards to conflict resolution and irrigation management. More than 52% of the farmers in FMIS are satisfied with the decisions taken by WUAs and FOs, while only 16% of the farmers in GMIS agreed. Farmers in FMIS have been more satisfied because most of their conflicts are resolved locally with mutual understanding and decisions at WUAs and FOs level. It don't mean here that farmers are fully satisfied in all aspects of irrigation management under FOs and WUAs such as water delivery, monitoring, revenue collection, and equity, reliability of water flows etc. Most farmers also recognized that conflict resolution mechanism is very important tool to improve their satisfaction level and enhance their contribution towards effective operation and maintenance of irrigation system. However, level of farmers' satisfaction is comparatively higher in FMIS mainly because of their motivation to participate and their involvement in the management of irrigation system. Farmers were observed satisfied as they don't have to go to IPD offices for their complaints and conflict resolutions. Results given in Figure 5.5 are limited to satisfaction on O&M and ease of conflict resolution.

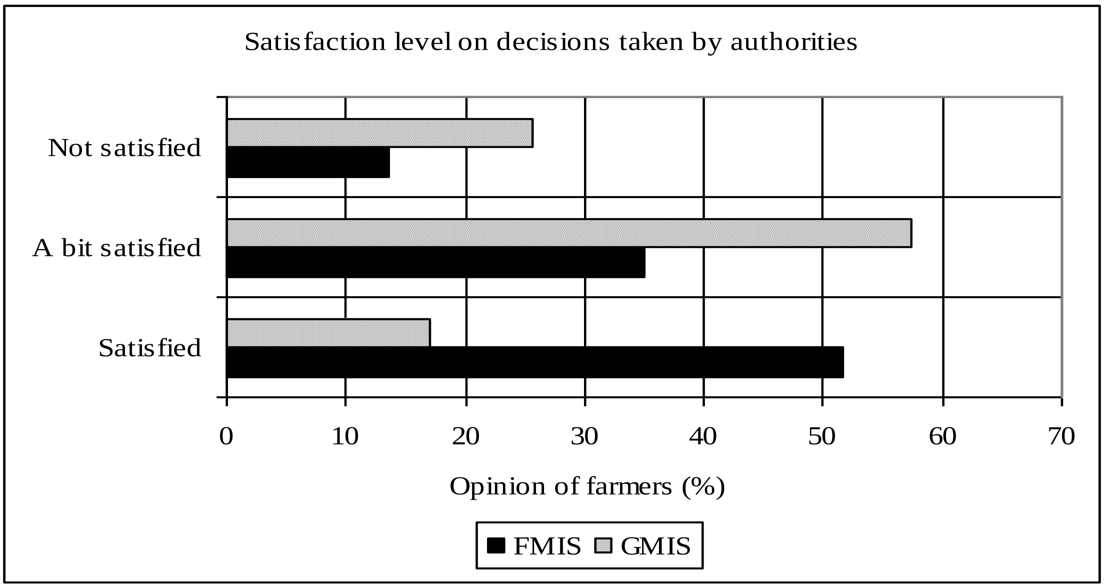


Figure 5.5. Level of satisfaction on decisions for conflict resolution

Provision of respect and moral support

Figure 5.6 shows that 70% farmers agreed and were obliged to recognize the role of authorities of WUAs and FOs in promoting respectful consideration and moral support, in which case they felt feel well treated. It was also noted that all types of farmers (regardless of their farm sizes) have been treated and respected well in FMIS.

However, the situation in GMIS had not been so favorable, as could be noted from only about 12% of the farmers who agreed with the promotion of respectful considerations and moral support extended by the IPD. Consequently, nearly 60% of the farmers agreed that authorities have shown less respect and moral support. More strikingly, 32% of the farmers gave full negative response and showed no respect with the IPD. Many farmers reported instances that clearly manifested the insulting attitude and behavior of clerical and office staff of IPD, and more particularly, small and poor farmers had been humiliated in the offices of IPD. The inattentive behavior of authorities by neglecting the concerns of farmers (by any means) in public offices is therefore challenged as such attitude could affect the trust and cooperation of farmers in the smooth operation and maintenance of irrigation systems. Efforts to buoy up respect and provide moral support on the part of the authorities and institutions could build the confidence of farmers and their motivation towards enhancing their contribution for the effective operation and maintenance of irrigation systems, and promote collective action among them.

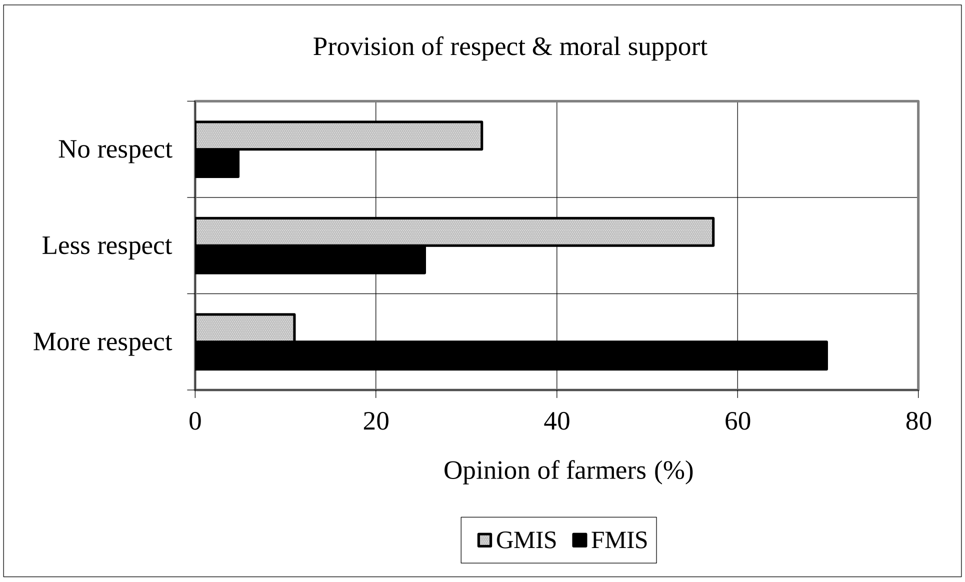


Figure 5.6. Provision of respect and moral support by staff and officials

Monitoring against water theft and outlet tampering

Figure 5.7 shows the opinion of farmers on the level of monitoring and check by authorities against water theft and outlet tampering in both irrigation schemes. WUAs and FOs have been more frequently monitoring such illegal actions, as indicated by 35% of the farmers who agreed on the “excellent” and 40% agreed on “good” efforts of authorities in monitoring of irrigation infrastructures and the water resources. Many farmers also reported that some FOs have monitoring teams visiting them in disguise and checking the outlets operation even during night time considering that most of illegal actions such as tampering of outlets and water theft using pipes usually occur at night. However, in the existing mechanisms for monitoring, some weaknesses need to be addressed such as the biased role and political influence of big landlords.

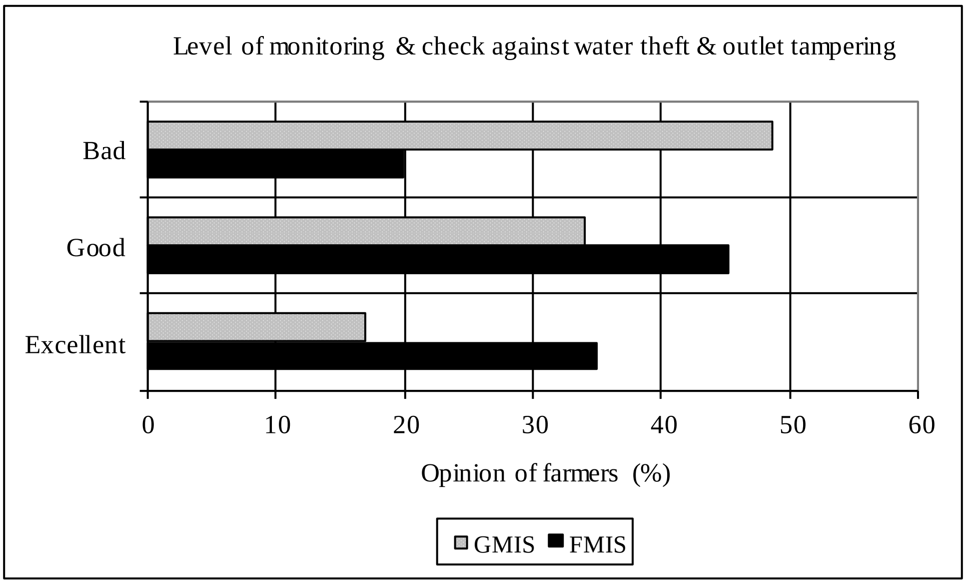


Figure 5.7. Level of monitoring and check by authorities

Nevertheless, nearly 50% of the farmers in GMIS reported the faulty monitoring procedures of IPD. As an example, field staff of IPD conducts 2 or 3 visits to the farms on a daily basis. However, no visits are made for monitoring the operations at night for lack of resources and staff. Although the Project Management and Implementation Unit (PMIU) of IPD also make few field visits but these are only conducted mostly on main canals. Moreover, since the persons responsible for monitoring the secondary and tertiary canals are provided only with bicycles, it would be difficult for them to frequently visit the entire length of the canals on bicycles. Result depicts that FMIS shows more closeness with the monitoring principle of governance given by (Ostrom, 1990).

5.2 Institutional highlights in Burala Canal Irrigation Scheme (FMIS)

This section focuses on the institutional features based upon farmers' perceptions on effectiveness of BC Irrigation Scheme or FMIS in capacity building and training activities, while an analysis of conflict resolution mechanisms is also presented.

Effectiveness of capacity building

After institutional reforms in BC Irrigation Scheme, capacity-building program had been started by PIDA to enhance the skills and capacity of the farmers. However, it had been observed that the farmers lacked the initiative to fully participate in such activity while there was also low motivation of the farmers during the training sessions conducted. Figure 5.8 shows the opinion of farmers on the level of effectiveness of capacity-building trainings. During the survey, only 15% of the farmers reported that the training activities were very informative, useful, and very helpful to enhance their skills and performance. Although another 45% agreed, but they also expressed that the capacity-building training sessions were somewhat useful while some farmers (24%) thought that the training activities were just time-wasting processes and that nothing useful could be obtained from the sessions. Such low motivation and decreased participation of farmers that were noted in the training sessions therefore require re-visiting of the contents of the training to enhance the interest of farmers, as it is also reported by Hassan (2008). It was also very noticeable that IPD does not conduct any such kind of capacity-building program.

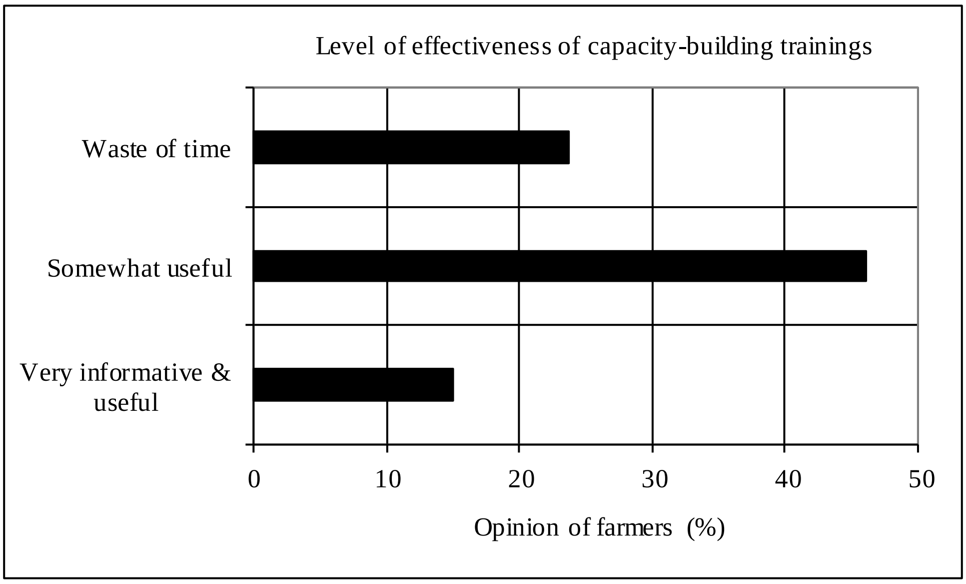


Figure 5.8. Level of effectiveness of capacity-building trainings by FOs and WUAs

Farmers' Organization wise cases of water disputes

Table 5.1 shows a list of cases water disputes and their resolution as per Farmers' Organization (based on the data from Area Water Board, LCC east, Faisalabad). The information given represents the cases of water disputes entered and resolved during the year 2009. The performance of six FOs is appreciable as they show 100% results in terms of resolving cases of water disputes at local level. The names of these FOs are Ghark, Waghi, Ditch, Kallar, Kabirwala, and kalera. It must be noted that those FOs had limited number of cases entered (less than 12 per year anyway). Bhoja FO shows the worst results, with only 7% cases of water disputes. However Bhoja FO also showed the highest number of cases entered (61 cases). These results represent only for cases resolved at FOs level. If FO is unable to resolve a case of water dispute, it is reported to police station or court after that, with the permission of the FO president.

Table 5.1. Farmers' Organizations' statistics on cases of water disputes

Name of FO	Cases of disputes		
	Entered	Resolved	Resolved (%)
Ghark	5	5	100
Waghi	10	10	100
Ditch	4	4	100
Kallar	1	1	100
Kabirwala	11	11	100
Kalera	12	12	100
Nupewala	15	14	93
Pithorana	15	14	93
Obhal	15	14	93
Naurang	16	14	88
Dulchi	13	11	85
Ranjiana	18	15	83
Kamalia	17	14	82
Arif	20	16	80
Pervaiz	15	12	80
Duravan	20	14	70
Farooq	19	11	58
Summundri	15	8	53
Bhalak	32	16	50
Muniawala	6	1	17
Bhoja	61	4	7
Tandlianwala	0	0	-
Killianwala	0	0	-
Balochwala	0	0	-

Average number of cases by each FO is $\underset{\sim}{~}$14 with median value of ~15. It shows that 90% of FOs is entered less than 20 cases of water disputes per year. Similarly, 25% of FOs resolves 70% of water dispute cases whereas 85% is the median for resolution of cases. However ~78% is the average of resolution of water dispute cases by each FO.

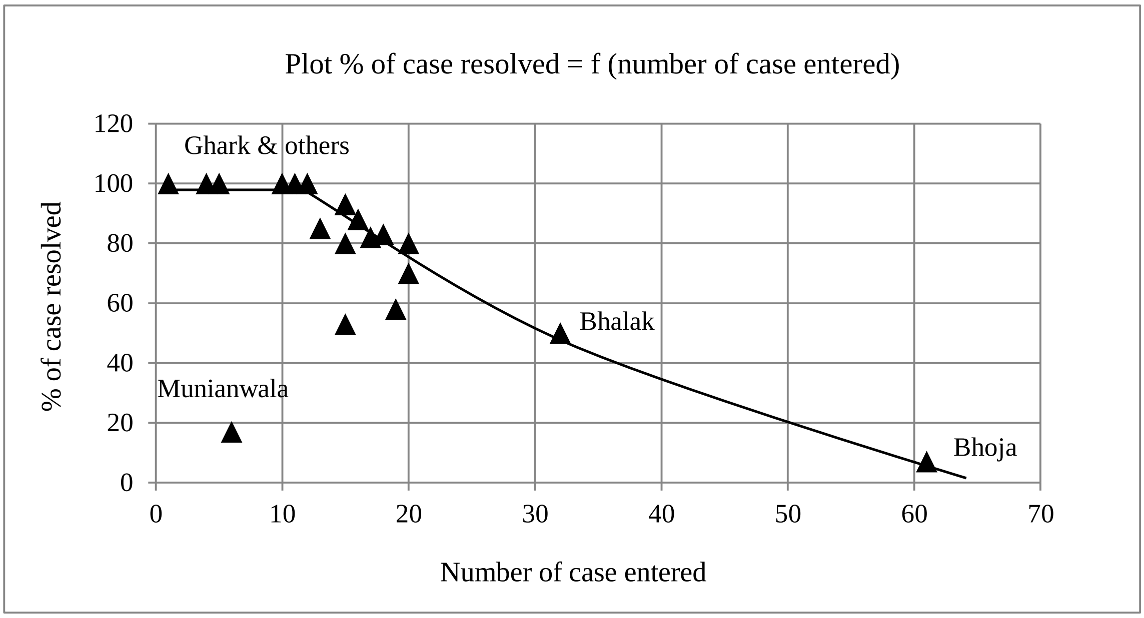


Figure 5.9. Performance of Farmers' Organizations in resolving water dispute cases

Figure 5.9 shows that except for case of Munianwala, FO manages to resolve all of water dispute cases if numbers of cases entered are less than 12 per year such as Ghark, Waghi, Ditch, Kallar, Kabirwala, and Kalera FOs. In case, number of water disputes exceeds than 12, then capacity and performance of FOs decreases gradually as in case of Bhalak and Bhoja FO. Most worst situation is observed in Bhoja FO as 61 cases of water dispute were entered whereas only 7% of them were resolved.

Farmers' Organization wise cases of water theft

Table 5.2 shows a list of water theft cases under each FO in the BC Irrigation Scheme during the year 2009. Usually, it is tried to resolve all cases of water theft at local level (WUA or FO). In case these institutions are unable to resolve a case, it is reported to local police station. It is not possible to report any case to police station without prior permission of the FO president. Police investigation team then try to resolve disputes by mutual understanding of both parties after detail investigation and hearings. If parties don't agree on the decision, case of water dispute is then registered as a FIR (First Information Report) and transferred to court for further judicial decision. If a case of water dispute goes beyond the capacity of FO, then it may take years to resolve with high expenditures.

Table 5.2. Farmers' Organizations' statistics on cases of water theft

Name of FO	Cases of water theft				
	Entered (No)	Resolved (No)	Resolved (%)	Reported to police	FIR registered
Dulchi	6	6	100	0	0
Nupewala	4	4	100	0	0
Duravan	5	5	100	0	0
Pithorana	6	6	100	0	0
Arif	3	3	100	0	0
Pervaiz	4	4	100	0	0
Ghark	1	1	100	0	0
Ditch	2	2	100	0	0
Kalera	7	7	100	0	0
Kabirwala	12	11	92	1	0
Naurang	7	6	86	0	0
Ranjiana	9	7	78	0	0
Kallar	8	6	75	2	0
Obhal	5	3	60	2	0
Kamalia	13	7	54	6	0
Waghi	7	3	43	4	0
Killianwala	91	17	19	60	20
Bhalak	187	14	7	14	0
Tandlianwala	104	0	-	100	4
Bhoja	61	0	-	56	48
Balochwala	0	0	0	0	0
Muniawala	0	0	0	0	0
Summundri	0	0	0	0	0
Farooq	0	0	0	0	0

During year 2009, it was found that out of 24 FOs; only 3 FOs registered FIRs at police stations and cases were referred to courts for resolution. These 3 FOs are Tandlianwala, Killianwala, and Bhoja. There are 9 other FOs like Dulchi, Nupewala, Durawan, Pithorana, which performed excellent and show 100% result in the resolution of water cases. These FOs resolved all entered cases of water theft with their local capacity. Table 5.2 shows that 75% of FOs entered less than 12 cases of water theft during year 2009. The average number of entered water theft cases is 27 whereas median value is 7 cases. Similarly, 30% of FOs has solved less than ~75% of cases. In average, ~79% cases are solved by each FO during year 2009. The median value of resolved water theft cases is 96%.

Figure 5.10 shows the performance of FOs in terms of resolution of water theft cases against the number of cases entered per year. First, it shows the group of 9 FOs which resolved all entered cases within their capacity such as Dulchi, Nupewala, Duravan, Pithorana, and Arif etc. It is noticeable here that there is less number of cases entered under these FOs.

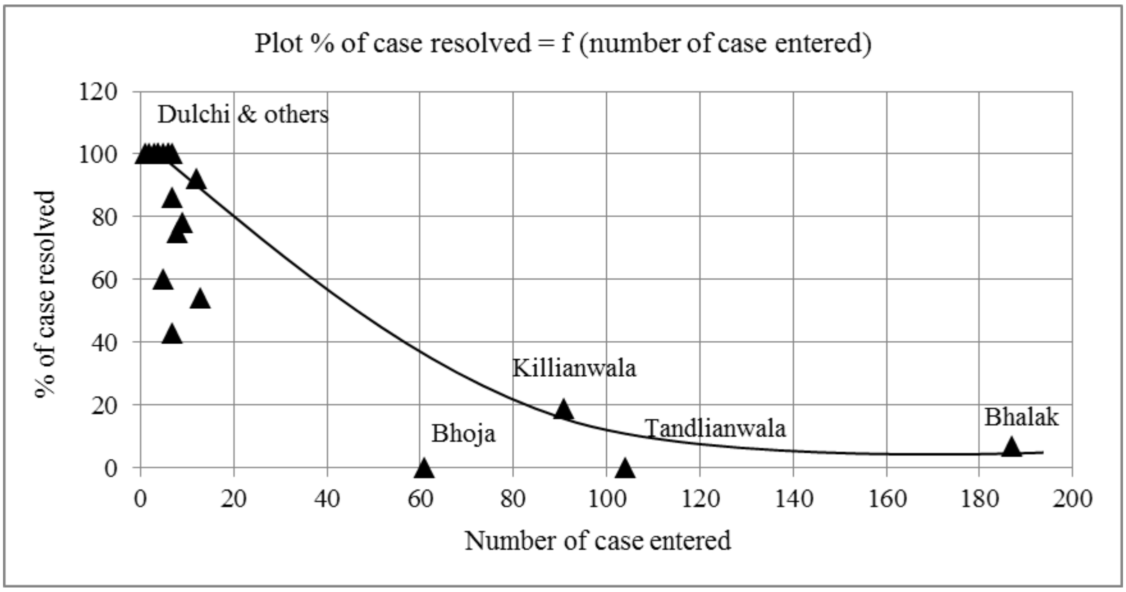


Figure 5.10. Performance of FOs in resolving water theft cases

For efficient resolution (100%) of water theft cases, maximum number of entered cases is 7 during whole year and minimum number is 1. However, with the increase of number of entered cases, the performance of FOs to resolve these cases decreased such as Kamalia and Bhalak FO. The situation is worst in case of Bhoja and Tandliawala which entered 61 and 106 cases of water theft respectively but could not resolve any of them. All of these cases were referred to police for resolution. Consequently, police investigate and try to solve these cases of water theft. FIRs (First Information Report) are registered for unsolved cases and then referred to courts for further jurisdiction and final resolution. Out of 542 entered cases, 245 (~45%) cases were referred to police station which are against the Ostrom (1990) governance principle number 6 “conflict resolution mechanism” as given in Table 2.1. These results show the inefficiency or weak performance of FOs particularly in resolving the water theft cases. As per Ostrom (1990) principle number 5 “graduated sanctions” can considered to control the attempts of water theft.

5.3 Main findings

In contrast to IPD, FOs and WUAs are performing better in terms of monitoring, responsiveness, transparency, provision of moral support and respect to farmers and in taking decisions however conflict resolution of complex-nature cases and recovery of fines and imposing penalties by FOs is still poor. It is important to mention here that FMIS shows better results in some performance indicators than GMIS only comparatively. However, GMIS is performing comparatively better than FMIS in terms of imposing fines and their recovery. There are significant number of disputes cases reported to FOs (average ~14 and Median =15) but 90% FOs have 20 or less reported cases on annual basis. Except in 1 case, when number of cases is less than 12 per year, FO can solve all. As number of reported cases increases from 12, they seem to find it difficult to solve and resolution rate decline. Overall, only 25% of FOs has a resolution rate less than 70%. Similarly, in case of resolution of water theft cases, FOs show 100% results if the numbers of entered cases are $\leq$ 7 annually. On average, 27 cases of water theft are entered and ~79% cases are solved by each FO on annual basis. GMIS with strict mechanism of policy implementation shows remarkable recovery of revenue collection and imposing high penalties and fines against water theft and cases of outlet tampering.

Chapter 6

Performance Analysis at Irrigation Scheme Level

In order to analyze and improve the performance of canal based irrigation, Renault and Wahaj (2007) suggested that the MASSCOTE approach or the Mapping System and Services for Canal Operation Techniques be adapted. The MASSCOTE approach was developed mainly for the modernization of irrigation management of surface canal system. With canal operation at its core, the MASSCOTE approach also comprises ten steps, i.e. rapid diagnosis, system capacity and sensitivity, perturbation, mapping water networks and water balance/accounting, service to users, mapping the cost of operation, mapping the demand for canal operation, partitioning in management units, operational improvements and aggregation, and consolidating management. This chapter discusses the objective 2 of this research.

In carrying out the MASSCOTE approach, RAP (Rapid Appraisal Procedures) was first conducted in Burala Canal (BC) Irrigation Scheme in February and in Upper Pakpattan Canal UPC) Irrigation Scheme in March 2010. The results of RAP (Rapid Appraisal Process) are discussed in the following sections:

6.1 Rapid diagnosis: common features in both schemes

The primary objective of rapid diagnosis using RAP is to obtain first-hand information about the nature and location of the problems and their prioritization to be able to mobilize the stakeholders in taking up modernization. RAP is also meant to generate baseline assessment against which progress could be measured (Renault and Wahaj, 2006).

Some of the common highlights of the rapid diagnosis conducted in both irrigation schemes include the following:

- Infrastructures in both schemes are about 100 years old.

- There is wide variation in the availability of water in the Indus River during the different seasons, where about two-thirds flow is observed during the Kharif season (summer) and one-third during the Rabi (winter) season. Therefore, the existing water supplies are not sufficient to meet the requirements of crops in view of the increased cropping intensity that finally results in acute shortage of canal water. The severity of the problem is increasing from the head reach to the middle until tail reaches of the distributaries/minors. As a resort, this shortage has been addressed by pumping ground water.

- The irrigation system was designed for 65% cropping intensity and now the cropping intensity has increased up to 150%.

- Large amount of silt flows from the river to the main canal, and the deposited silt which does not cause serious problem in main canals is also deposited on the surface of the distributaries and minors reducing the flow of water to the tail-enders.

- Most of the canals are made from earth so that deferred maintenance program during the previous years had made the conditions of main canal, distributaries and minor canals very bad causing the canals to breach. In an attempt to address this problem, less flow is given to these canals even if water is available in large quantities in the river in summer especially during monsoon.

- The flat rate water charging system adopted to charge farmers for the use of irrigation water is based on cultivable land holdings, does not take into account the different nature of water use, cropping intensity, among others. Nevertheless, the fee is levied regardless of the crops grown, area under crops, and so on. The amount of fees charged per ha is Rs. 210 (2.8 US$/ha) during the Kharif season and Rs. 125 (1.7 US$/ha) for Rabi season (1US$ = 75 Rs in 2008-09). Considering that the amount charged is very low, it could not cover the operational, maintenance and management costs.

- Water theft is also a major problem of the canal resulting in a remarkable number of outlets having been tampered and in view of such condition these outlets receive more water than their designed capacity.

- As most of the parts of the canal are earthen and the seepage rate in the main canal is about 20% while in distributaries, minors and water courses seepage rate is about 25% and about 20% in farmers' fields, this means that only 35% of water is available for the crops.

- The Department of Irrigation always announces full water closure and suspension of water supply to the distributaries, minors and water courses for four weeks usually in January for maintenance and desiltation of the main canals, its distributaries and minors. However, maintenance activities mostly exist only in papers. Consequently, the growth of weeds in the distributaries and minors continue to be enormous reducing the water flow while increasing seepage. This results in less water availability to the tail-enders, and in fact, many cases tail-enders do not receive irrigation water from the canal system.

- Human activities and grazing/watering/trespassing of livestock damage the canal banks which also cause perturbations in the water level. As a result, outlets receive less water and ultimately also reduce the water delivery services to some areas.

- Most irrigation structures on the main canal are un-gated. The water flow in these canals is controlled using wooden sheets (in local language called karri system). Likewise, all the minors and outlet structures are also un-gated, and as a consequence, accurate control of the flow into distributaries and minors is also lacking.

- There are large variations in the amount of irrigation water supplied to users. Those on the head receive more water per ha than the users on the tail ends. Such variations exist at the main, distributary and minor canal levels.

- Water delivery service to the users which is poor at the different levels of the canal is worst at third level canals. The reasons of poor water delivery service are proportional to the type un-gated structures, since less control of the water level could be made in these areas as well as in areas with tampered outlets.

Burala Canal (BC): specific issues

The main infrastructure of Burala Canal network is about 100 years old. After institutional reforms, a large project for the rehabilitation of BC has been launched by JICA and some other donors. As a result, many of the structures (outlets, cross regulators, and earthen up of banks) have been installed a new or repaired, mostly on the main canal.

The collection of water fee remains weak and collected fees are less than the operational, maintenance and management costs. Actually the water tariff that is set and charged is lower than operational, maintenance and management costs.
The irrigation system was initially designed for 65% cropping intensity; it has been now increased up to 115%.

Upper Pakpattan Canal (UPC): specific issues

The irrigation system was designed for 65% cropping intensity whereas now the cropping intensity has increased up to 150%.

The collection of water fee is much better than Burala Canal (BC) with more than 80% recovery efficiency. However, the tariff that is charged is lower than the actual O&M costs.

Internal performance indicators

Internal performance indicators have been assessed during the RAP survey. Results are compiled for both case study irrigation schemes and shown in Table 6.1. Most internal indicators show below average (2) in both irrigation schemes. However, Burala Canal (BC) Irrigation Scheme showed a bit better internal performance as given in Table 6.1. This is particularly because of institutional reform and the modernization and rehabilitation projects on BC, which have developed and improved hydraulic infrastructure. In this context, value 2.4 and 2.2 shows better and improved general physical conditions for the second and third level canals respectively in BC Irrigation Scheme. Although, there is not a clear difference in the general conditions of main canals of both irrigation schemes however operation of the main, second, and third level canals is better in BC irrigation scheme than UPC Irrigation Scheme.

Unlike UPC Irrigation Scheme, a clear difference is noted in the actual and stated water delivery service to individual ownership units (farms) in BC Irrigation Scheme as, actual water delivery service is lower (0.9) than the stated water delivery service to farms (1.4). Cross regulator hardware is not exist at the offtakes of third level canals in BC irrigation scheme, which provides more flexibility in the water delivery service to third level canals. However, actual water delivery service at the most downstream point in the system operated by a paid employee is better (1.9) in BC Irrigation Scheme than UPC Irrigation Scheme (1.1). FOs and WUAs has a significant involvement to secure a good water delivery service from the paid employees of IPD at main canal and within secondary canals as well.

Table 6.1. Internal performance indicators

Internal Performance Indicators	FMIS	GMIS
Actual water delivery service to individual ownership units (e.g., field or farm)	0.9	0.9
Stated water delivery service to individual ownership units (e.g., field or farm)	1.4	0.9
Actual water delivery service at the most downstream point in the system operated by a paid employee	1.9	1.1
Stated water delivery service at the most downstream point in the system operated by a paid employee	1.6	1.9
Actual water delivery service by the main canals to the second level canals	2.6	2.2
Stated water delivery service by the main canals to the second level canals	2.1	2.3
Social "order" in the canal system operated by paid employees	0.8	1
Main Canal	FMIS	GMIS
Cross regulator hardware (main canal)	1.1	0.9
Turnouts from the main canal	2	1.7
Regulating reservoirs in the main canal	0[a]	2
Communications for the main canal	2.5	2.6
General conditions for the main canal	1.8	1.6
Operation of the main canal	3	2.1
Second Level Canal	FMIS	GMIS
Cross regulator hardware (second level canals)	1.3	1.1
Turnouts from the second level canals	1.7	1.5
Regulating reservoirs in the second level canals	0[a]	0[a]
Communications for the second level canals	2.5	2.4
General conditions for the second level canals	2.4	1.4
Operation of the second level canals	2.4	2.2
Third Level Canal	FMIS	GMIS
Cross regulator hardware (third level canals)	0[b]	0.9
Turnouts from the third level canals	1	0.7
Regulating reservoirs in the third level canals	0[a]	0[a]
Communications for the third level canals	1.6	2.5
General conditions for the third level canals	2.2	1.7
Operation of the third level canals	2.2	1.9

Note: Maximum Value = 4, Minimum Value = 0

[a] Regulating reservoir does not exit.

[b] Cross regulator hardware does not exist.

External performance indicators

External performance indicators were also assessed during the RAP survey. The results were compiled for both case study irrigation schemes as shown in Table 6.2, which indicated that cost recovery ratio is much less in BC Irrigation Scheme. However; the ratio of maintenance cost to revenue is much better in BC than in UPC Irrigation Scheme.

Table 6.2. External performance indicators

Financial Indicators	FMIS	GMIS
Cost recovery ratio	0.33	0.67
Maintenance cost to revenue ratio	0.48	0.33
Total MOM cost per unit area (US$/ha)	5	4
Total cost per staff person employed (US$/person)	1,046	1,488
Revenue collection performance	0.62	0.85
Staff persons per unit irrigated area (Persons/ha)	0.029	0.013
Number of turnouts per field operator	1.5	2.8
Average revenue per cubic meter of irrigation water delivered to water users by the project authorities (US$/$m^3$)	0.0004	0.0005
Total MOM cost per cubic meter of irrigation water delivered to water users by the project authorities (US$/$m^3$)	0.0007	0.0004
Agricultural Productivity and Economic Indicators	FMIS	GMIS
Output per unit command area (US$/ha)	2,271	4,013
Output per unit irrigated area, including multiple cropping (US$/ha)	2,014	2,643
Output per unit water supply (US$/$m^3$)	0.267	0.357
Output per unit of field ET (US$/$m^3$)	0.226	0.298

Furthermore, management, operation and maintenance (MOM) cost per unit area is 5 US dollars per hectare in BC Irrigation Scheme (FMIS) which is higher than UPC Irrigation Scheme (GMIS) with 4 US dollars. With regards to the current working staff strength, 29 persons are providing services for 1000 hectares in BC compared to only 13 persons are working for same area of 1000 hectares in UPC Irrigation Scheme which reveal the deficiency of staff in one way or superior efficiency of staff for doing same job with so limited number of staff. With the fact that staff employed in FOs are paid very low salaries comparative to government employees in UPC Irrigation Scheme. However, such information could also provide a reason for higher cost of per staff person employed in UPC Irrigation Scheme. Each staff person has to look after and monitor around 3 turnouts which are almost double to BC Irrigation Scheme.

Despite of all this, agricultural productivity of per unit irrigated area is significantly higher in UPC than in the BC Irrigation Scheme. This is particularly because of the crop diversification, mechanized, and intensive farming as discussed in Chapter of farm-level performances. These results of agricultural productivity can be compared with the findings of Nabi (2009) in Pakistan (as given earlier in Table 2.5) and with another recent study by Uçar (2011) in Turkey (given in Table 2.6). The results of external indicators in this study show that agricultural output performances in BC and UPC Irrigation Schemes (Pakistan) are much lower than Turkey. However, these findings are better than assessed by Nabi (2009) in the same Burala Irrigation Scheme.

6.2 System capacity and sensitivity of offtakes

The sensitivity of irrigation structures (offtakes) had been assessed and mapped out, while singular points in terms of transport, control, and measurement of flows had also been identified during the course of this research study. The one limiting factor of this section is the sensitivity of cross-regulators which could not be assessed due to unavailability of required data.

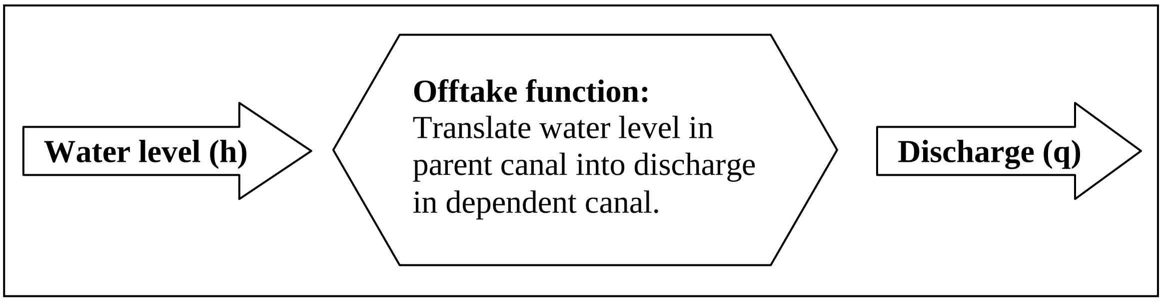
Sensitivity refers to the characteristic of the irrigation structures that identify how irrigation structures react when subjected to changes (perturbations, e.g. variations in water level or discharge) in flow conditions. The sensitivity of irrigation structures sensitivity implies change in output (water level or discharge) with every change in input (water level or discharge). Sensitivity indicators are used to quantify the magnitude of the reaction of the system as well as to trigger specific operation procedures, e.g. high-sensitive structures need to be operated more often and with more care than low-sensitive structures.

Table 6.3. Ranking of sensitivity indicators for an offtake

Offtake	Sensitivity indicator	Example
Highly sensitive	Greater than 2	Overshot type offtake Undershot type with very low head (0.25m or less)
Medium sensitive	Between 1 and 2	Undershot type with head between 0.25 and 0.5m
Low sensitive	Below 1	An undershot gated structure fed with head >0.5m Specific modulated structure

Source: FAO Irrigation and Drainage Paper 63

For offtake structures the sensitivity is the change in discharge (q) according to change in water level (h) (Figure 6.1). Ranking of sensitivity indicators is shown in Table 6.3.



Source: Renault et al. 2007

Figure 6.1. Offtake structure input and output

A. Burala Canal (FMIS)

Burala Canal has 36 offtake structures (including both gated and un-gated) which are at the head of 34 distributaries, one minor and one branch canal and taking water from the main canal. The sensitivity of these structures varies remarkably from one structure to other. The results showed a maximum sensitivity of an offtake structure at 8.20 m^{-1} which is at the head of Azmat Shah distributary (Figure 6.2). The reason for the high sensitivity of this structure is the less availability of water at the head considering that the main canal does not run at its full water supply depth. The minimum sensitivity of the offtake structure is

0.90 m^{-1} at the head of Hassoki distributary, which could be due to the availability of water at its head is high.

Similarly, the sensitivity of other offtake structures along the Burala Canal depends upon the availability of head on these structures and the presence of flow control structure downstream of the offtake structures. Figure 6.2 shows the sensitivity (S) of offtake structures as a function of head (h). However, 5% offtakes in Burala Canal are low sensitive, 17% are medium sensitive and 78% are high sensitive.

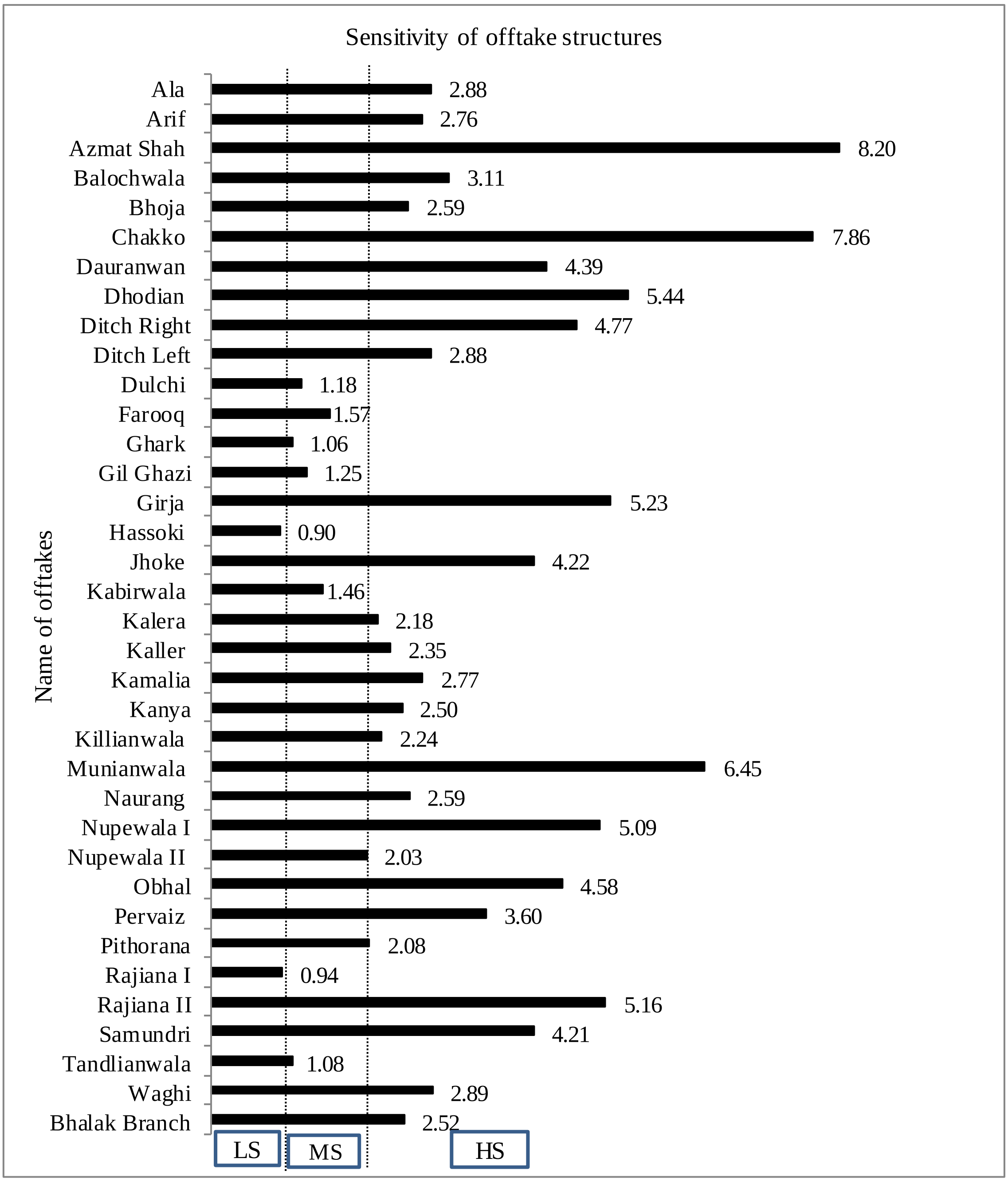


Figure 6.2. Sensitivity of offtakes structures at BC Irrigation Scheme

Note: LS denotes for low sensitivity, MS for medium and HS for high sensitivity

The average sensitivity of all offtakes is 3.25 m^{-1} and median is 2.76 m^{-1} which show high sensitivity of all offtake structures along Burala Canal regardless of sensitivity ranking i.e. low sensitive, medium sensitive and high sensitive offtake structures.

Table 6.4. Variations in discharge at different offtake structures of BC Irrigation Scheme

S.No	Diversion channel	Designed Q (m^3/s)	Variation in discharge* $\pm$0.1m (10%)	Variation in discharge* $\pm$ 0.2m (20%)
OT1	Ala	0.43	28.8	57.5
OT2	Arif	0.55	27.6	55.1
OT3	Azmat Shah	0.28	82.0	164.0
OT4	Balochwala	0.65	31.1	62.3
OT5	Bhoja	4.04	25.9	51.7
OT6	Chakko	0.11	78.6	157.3
OT7	Dauranwan	0.35	43.9	87.7
OT8	Dhodian	0.18	54.4	108.9
OT9	Ditch Right	0.34	47.7	95.4
OT10	Ditch Left	0.49	28.8	57.5
OT11	Dulchi	0.53	11.8	23.6
OT12	Farooq	1.13	15.7	31.3
OT13	Ghark	0.28	10.6	21.3
OT14	Gil Ghazi	0.20	12.5	25.0
OT15	Girja	0.37	52.3	104.6
OT16	Hassoki	0.08	9.0	18.0
OT17	Jhoke	0.35	42.2	84.3
OT18	Kabirwala	5.24	14.6	29.3
OT19	Kalera	1.03	21.8	43.5
OT20	Kaller	3.85	23.5	47.0
OT21	Kamalia	1.37	27.7	55.5
OT22	Kanya	0.51	25.0	49.9
OT23	Killianwala	6.47	22.4	44.7
OT24	Munianwala	0.10	64.5	129.0
OT25	Naurang	0.94	25.9	51.9
OT26	Nupewala I	0.34	50.9	101.7
OT27	Nupewala II	1.04	20.3	40.7
OT28	Obhal	0.41	45.8	91.6
OT29	Pervaiz	0.77	36.0	71.9
OT30	Pithorana	0.50	20.8	41.6
OT31	Rajiana I	0.29	9.4	18.8
OT32	Rajiana II	0.29	51.6	103.1
OT33	Samundri	0.46	42.1	84.3
OT34	Tandlianwala	11.13	10.8	21.5
OT35	Waghi	2.06	28.9	57.9
OT36	Bhalak	4.34	25.2	50.5

*Variation in discharge is calculated based on sensitivity value of that offtake

Table 6.4 presents the variations in the discharge at the offtake structures (head of distributaries) when there is change in water level of 0.1 m in the Burala Canal. The minimum variation in discharge is 9% at Hassoki distributary (OT 16) and the maximum variation in discharge is 82% at Azmat Shah distributary (OT 3) for 0.1 m water level change upstream of the structure. In order to provide uniform water delivery along the canals, different operational strategies are required for the different offtake structures, where structures with high sensitivity would require more frequent adjustment in their gate settings. Moreover, it is also necessary to observe the discharge of the distributaries to ensure uniform water delivery service along the canal. Nevertheless, a distributary which has high discharge and medium sensitivity can produce more variations in the discharge of main canal than a structure which has high sensitivity and low discharge.

B. Upper Pakpattan Canal (GMIS)

There are 17 offtake structures at the main Upper Pakpattan Canal (UPC). Similar with the condition of Burala Canal, sensitivity varies from one offtake structure to another depending on the availability of water at the head and in the main canal. The sensitivity of all offtake structures at UPC is shown in Figure 6.3. The offtake structure of 1-BR secondary canal shows the highest sensitivity value (4.37 m^{-1}) among all the other offtakes. As indicated in Figure 6.1, the reason of high sensitivity of 1-BR is the low availability of water at the head of the offtake structure in this secondary canal. However, the offtake structure of 1-AR secondary canal shows lowest sensitivity value (0.35 m^{-1}) which reveals high and consistent availability of water at the head of the offtake structure of the 1-AR distributary.

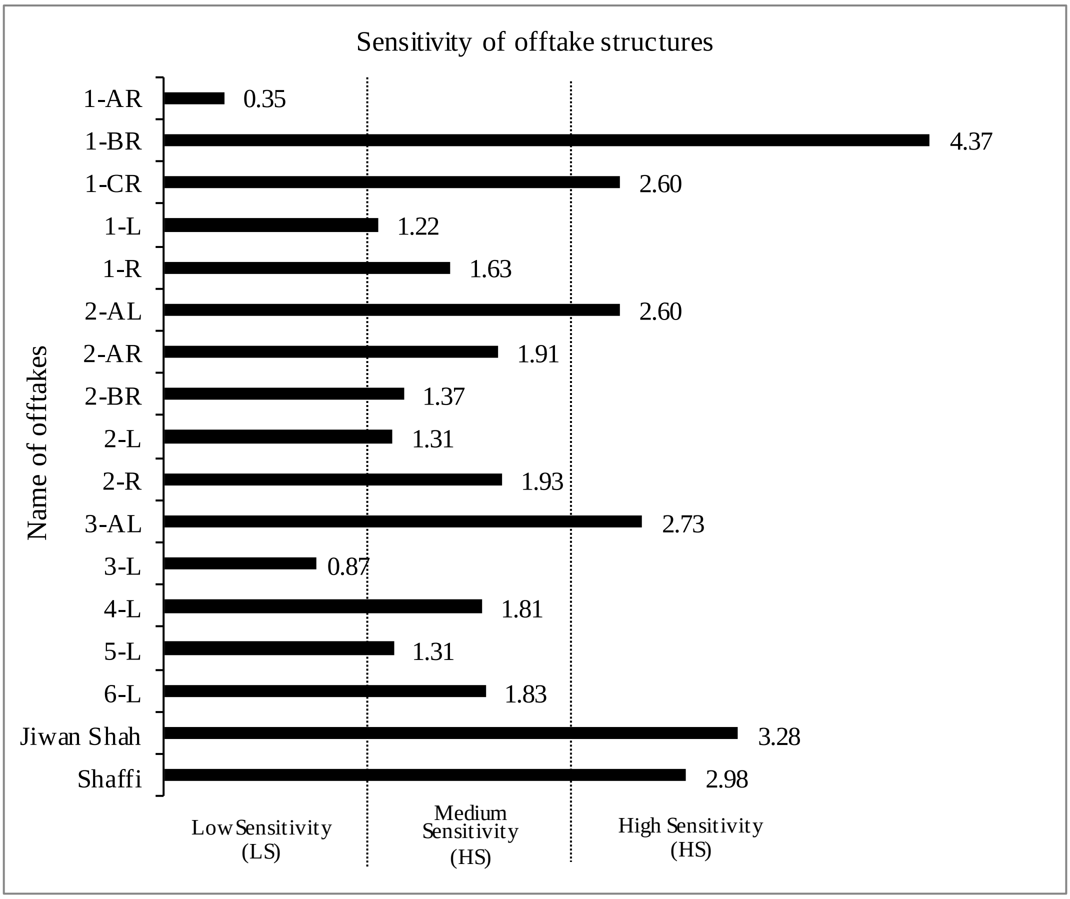


Figure 6.3. Sensitivity of offtakes structures at UPC Irrigation Scheme

The average sensitivity of all offtake points in UPC is 2 m^{-1} with median value of sensitivity of 1.83 m^{-1}. Furthermore, the sensitivity of all offtake structures can be categorized into three groups, namely: low sensitivity, medium sensitivity, and high sensitive offtakes. In this study, only two offtake structures (1-AR and 3-L) show low sensitivity against the available water at the head in the main UPC, and are grouped into low sensitive (LS) offtake structures. However, nine offtake structures representing 53% of all offtake structures fall in the medium sensitive (MS) category, which also implies that 53% offtakes in the UPC are medium sensitive to the available water at the head of the main canal. Meanwhile, the six offtakes in the category of high sensitive (HS) offtake structures represent 35% of all offtakes at the main canal.

Efforts were made to assess the variation in discharge of offtake structures against the variations of the water level in the main canal up to a certain limit of $\pm$ 0.1m (10%) and $\pm$ 0.2m (20%), the results of which are shown in Table 6.5. As indicated in the Table for the 1-AR offtake structure, if there is 0.1 m change in the water level of the main canal in UPC, it will cause 3.5% change in the discharge of the 1-AR.

Table 6.5. Variations in discharge at different offtake structures of UPC

S.No	Diversion channel	Designed Q (m^3/s)	Variation in discharge* $\pm$0.1m (10%)	Variation in discharge* $\pm$ 0.2m (20%)
OT1	1-AR	1.35	3.5	7.0
OT2	1-BR	0.24	43.7	87.5
OT3	1-CR	0.60	26.0	52.1
OT4	1-L	3.43	12.2	24.5
OT5	1-R	2.30	16.3	32.7
OT6	2-AL	0.67	26.0	52.1
OT7	2-AR	2.23	19.1	38.1
OT8	2-BR	1.79	13.7	27.4
OT9	2-L	5.90	13.1	26.1
OT10	2-R	1.76	19.3	38.6
OT11	3-AL	0.51	27.3	54.7
OT12	3-L	14.91	8.7	17.4
OT13	4-L	2.18	18.1	36.3
OT14	5-L	6.43	13.1	26.2
OT15	6-L	3.63	18.3	36.7
OT16	Jiwan Shah	0.23	32.8	65.6
OT17	Shaffi	0.28	29.8	59.6

*Variation in discharge is calculated based on sensitivity value of that offtake

Similarly, if there is 0.2 m change in main canal head, there will be 7% variation in the discharge of 1-AR. Any offtake structure with high sensitivity value will show more variation in discharge in response to the change in variation in the main canal head stream and vice versa. The offtake of 1-BR distributary with highest sensitivity (4.37 m^{-1}) would lead to 43.7% variation in discharge in response to the 10% variation in the main canal water head, as shown in Table 6.5.

Summary

In comparative to UPC, proportion of high sensitive offtake structures is more in BC. As a results 0.1 m change in the water level in the main canals leads to 32.5% variation in the discharge of secondary canals in BC Irrigation Scheme and 20.1% in UPC Irrigation

Scheme, on average basis. This is particularly due to the remodeling and redesigning of the offtakes of main BC during rehabilitation project after institutional program. The main objective behind this project is to ensure water supply at tail region which is obviously improved. Full supply depth of water is needed to overcome the high sensitive offtakes and inequity in water delivery in both irrigation schemes.

6.3 Perturbation

Perturbations analysis is used to measures the causes, magnitudes, frequency of water variation in canals, and suggests options for coping with such changes. Based on the available data on water supplies in both schemes, results are organized at main canal and one secondary canal level from each irrigation scheme and presented in the subsequent sections.

A. Burala Canal (FMIS)

Supply to Main Canal

The Burala Canal receives water from Upper Gugera Canal which takes its discharge from the Khanki Barrage. Figure 6.4 shows large variation in the water supplied at the intake regulator of Burala Canal in 2009-10. The maximum discharge supplied to the Burala Canal is 53 m^3-s^{-1} even if the canal was closed three times due to (1) annual repair and maintenance, (2) implementation of relevant development program (installation of new irrigation structures), and (3) breach of canal (Figure 6.4). Burala Canal could be considered as a perennial type in terms of its flows. Allocation of water to Burala Canal depends on the overall water supplies in the Indus Basin River System (IBRS) and caters to two main cropping seasons, e.g. winter (Rabi) and summer (Kharif). During the field survey, one case of canal breaching was reported which caused about one week closure in the main canal flows.

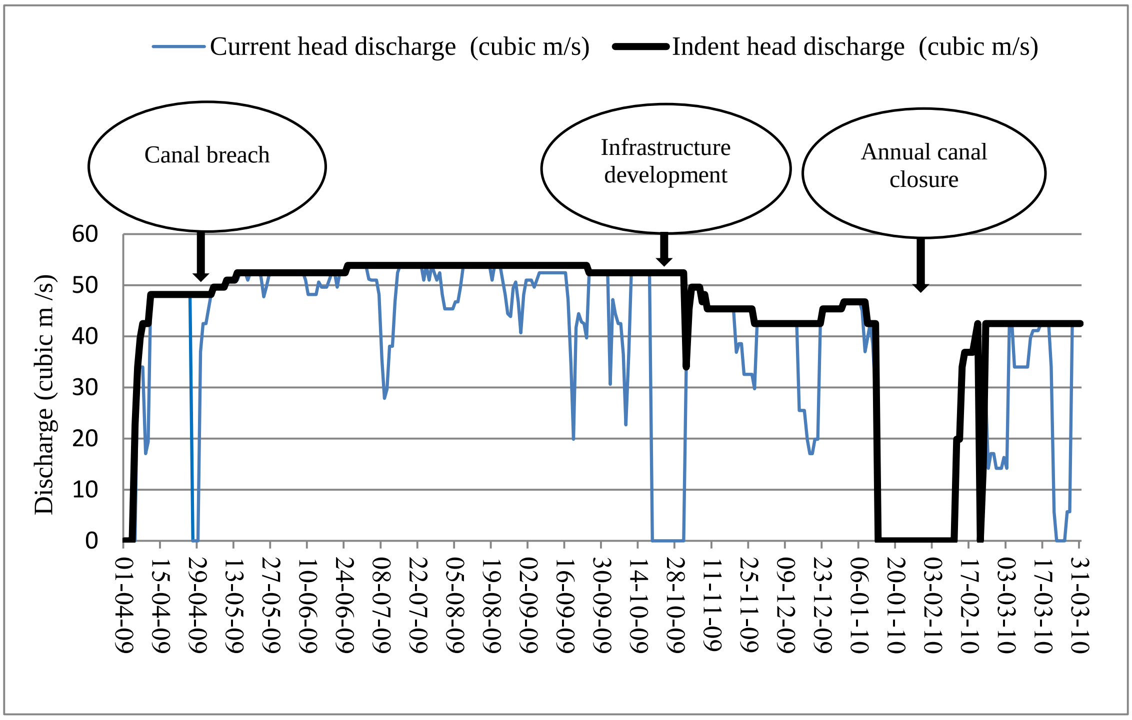


Figure 6.4. Discharge variation in main BC (April, 2009 to March, 2010)

Water level at Burala Canal intake regulator varied up to 10-15 cm on a regular basis, and since the Burala Canal receives water from Upper Gugera Canal, the many direct outlets from Upper Gugera Canal cause perturbations. Burala Canal and Upper Gugera Canal (parent canal of BC) are homogeneous in terms of structures therefore there is also the possibility that the offtake structures in the Upper Gugera Canal may have high sensitivity, which could also be one source of the perturbation. Water theft from the Upper Gugera Canal is also a main problem (pipes are illegally placed in the canal) which could also be another reason for the variations in the discharge and water level at the intake regulator of Burala Canal.

Supply to secondary canals

Figure 6.5 shows the flow of water supplied to one secondary canal (Kabirwala distributary) in the BC Irrigation System. This secondary canal is located at the tail reach of Burala Canal. The discharge delivered to the main canal substantially varies which could be the reason for the variation in the discharge delivered to the distributaries which is very high. The variations in discharge is amplified due to the presence of direct outlets in the main canal, sensitive offtake structures upstream and water theft (through personal communication, 23 unauthorized outlets present at the main canal were reported) from the main canal. These could be the main reasons for the perturbations at distributaries (secondary level canal).

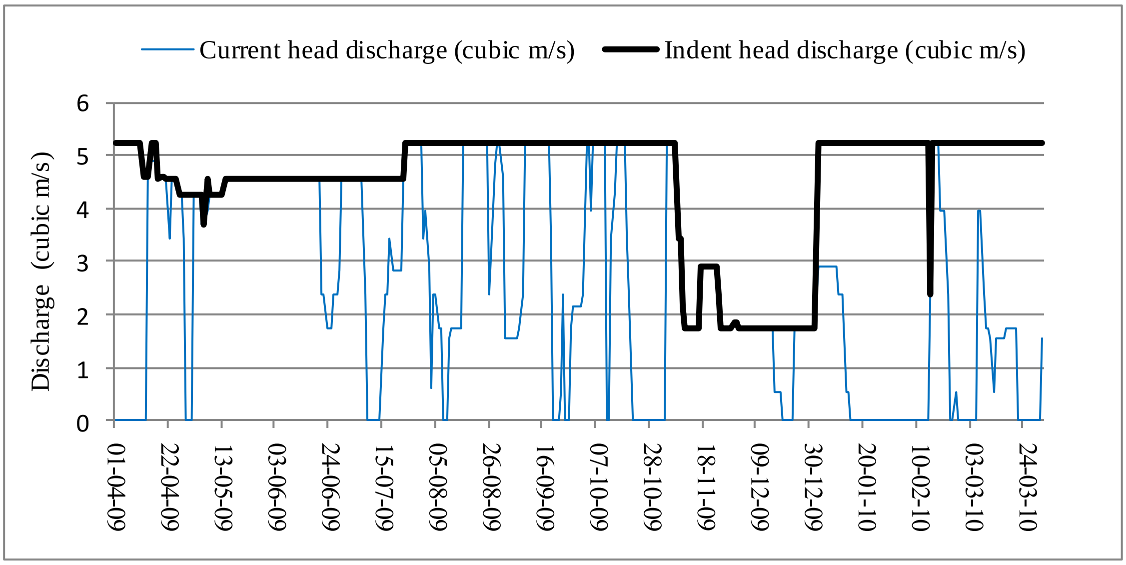


Figure 6.5. Discharge variation in a secondary canal (April, 2009 to March, 2010)

B. Upper Pakpattan Canal (GMIS)

Supply to Main Canal

The Upper Pakpattan Canal (UPC) receives water from Head Sulemanki (a diversion structure at Sutlej River) which takes its discharge from the Balloki Barrage through a link canal. Figure 6.6 shows that water supplied at the intake regulator of UPC varies largely during 2009-10. However, the canal was completely closed one time for annual repair and maintenance for one month during January 2010. UPC is also perennial type in its flows with maximum discharge of $72 m^3.s^{-1}$ (after subtracting the official discharges to seasonal canals[10] under Sulemanki Division e.g. Khadar Branch etc). Allocation of water to UPC also depends on the overall supplies in the Indus Basin River System (IBRS) and could cater into two main cropping seasons, e.g. winter (Rabi) and summer (Kharif).

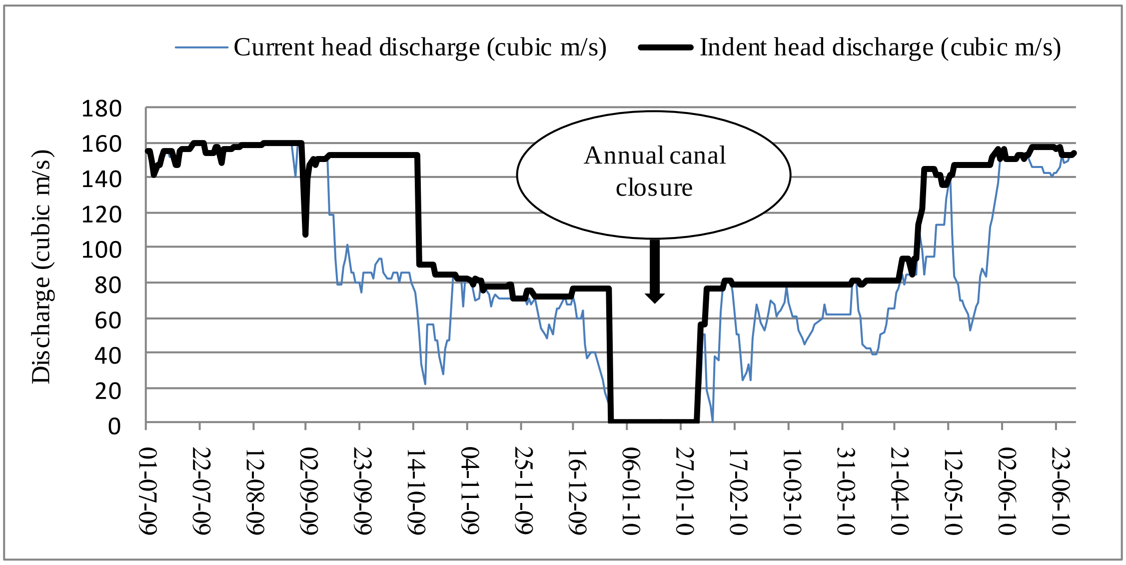


Figure 6.6. Discharge variation in main UPC (July, 2009 to June, 2010)

Supply to secondary canals

Indent discharge is the actual volume of water allocated for a certain period of time based on the availability of water flows in the parent canal or any other source like dams and barrages, among others, and is different but usually less from the designed discharge of any canal.

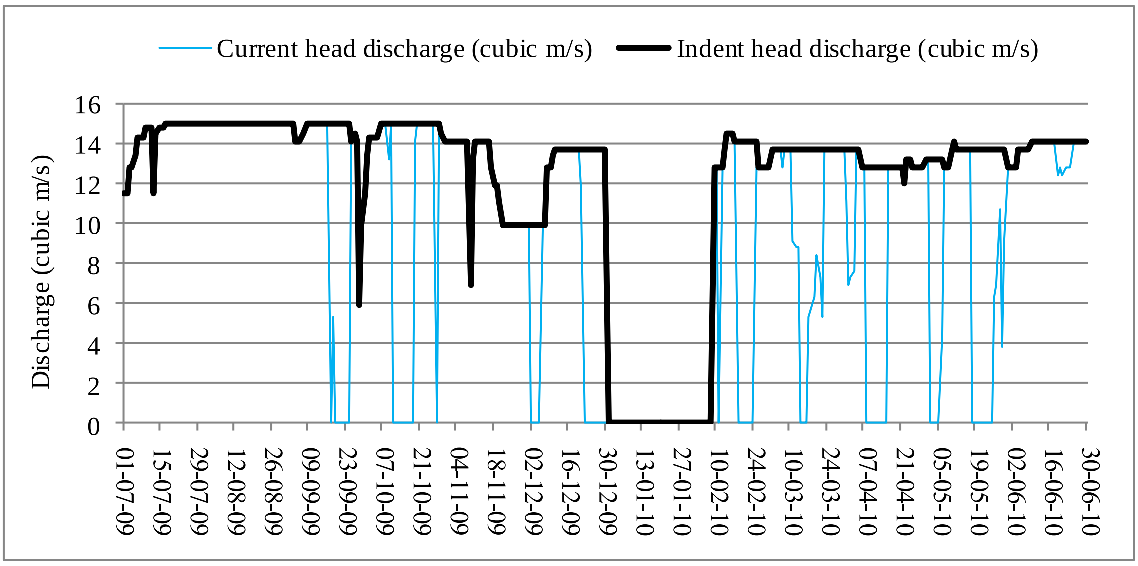


Figure 6.7. Variation in discharge in 3-L secondary canal (July, 2009 to June, 2010)

10 Seasonal canals deliver water only during Kharif season (15 April to 15 October) however these seasonal canals are not part of this study.

As shown in Figure 6.7, during the months of July, August, and September of 2009, the current discharge of 3-L distributary is same according to its indent discharge. However, after September, fluctuations in the current discharge started to occur and continued for the entire year except in January 2010, when the canal closed due to maintenance and repair. It is clear from Figure 6.7 that the current discharge of 3-L distributary does not follow the indent allocation of discharge.

6.4 Water networks and water balances

For this section, the nature and structure of all the streams and flows that affect and are influenced by the command area are mapped out. The discussion includes assessment of the hierarchical structure and the main features of the irrigation and drainage networks, natural surface streams and groundwater, and the results of the mapping of opportunities and constraints, including those of the drainage and recycling facilities.

A. Burala Canal (FMIS)

Surface streams

The command of Burala Canal (BC) Irrigation Scheme (FMIS) is surrounded by two main rivers, e.g. Chenab River from northeast to west, and Ravi River from east to west. Being part of the Lower Chenab Canal East (LCC East), Burala Canal is fed by LCC East that takes its discharge from Qadirabad Barrage on Chenab River. The designed capacity of Burala Canal is 66 CMS (cubic meter per second) and its annual peak flow in 2009-10 was 55 CMS. The total water inflow for Burala Canal in 2009-10 was 1029 MCM (million cubic meter) at the point of entry or at diversion used for irrigation purposes. Electrical conductivity (EC) of BC water is 0.2 $dS.m^{-1}$. It is also important to know that water inflows from Burala Canal are the main source of irrigation in the entire command area.

Groundwater availability and its usage for irrigation

Groundwater is also being used for irrigation as a supplementary source, and as noted during RAP survey the groundwater situation splits the command area into two parts: area with sodic groundwater and area with sweet ground water. Most part of the head reach and some parts of middle reach of Burala Canal have problem with regards to sodicity in the underground water, where groundwater cannot be used for irrigation purposes. Farmers therefore make conjunctive use of underground water with canal water. With the tail reach having good quality of underground water, no big variation was found in terms of depth of the underground water table. However, on the overall the use of underground water for agriculture could be very costly. Along with its irrigation objectives, groundwater is also being used for domestic and industrial purposes.

Water recycling and drainage facility

There are 36 secondary canals on Burala Canal that drain r to tertiary canals, and their flows are used for agriculture. Due to unreliable flows and delivery services of canal water, dependency on underground water has been increasing year to year. Drainage of available canal water is however good through a good network of delivery channels and on-farm soil texture that facilitate water seepage and infiltration. There are two other drains such as the Jaranwala Drain and Samundary Drain that mostly collect water from industries. These drains also flow out water from domestic sewage and rains into the Ravi River in the downstream. These drains are not limited to Burala Canal command, but are also connected to the outer areas.

Water balance

Water balance which accounts for available canal inflows, its delivery and groundwater supply is constrained by two main issues related to water resource. The first issue deals with unreliable water delivery and too much fluctuations of water supply in the canals, where in most times the available water volume is not enough to fulfill the requirements of agriculture. Considering that the Burala Canal was initially designed to meet the irrigation requirements for only 65% of cropping intensity, now that intensity has increased up to 110%, it has become difficult for Burala Canal to supply the water demands.

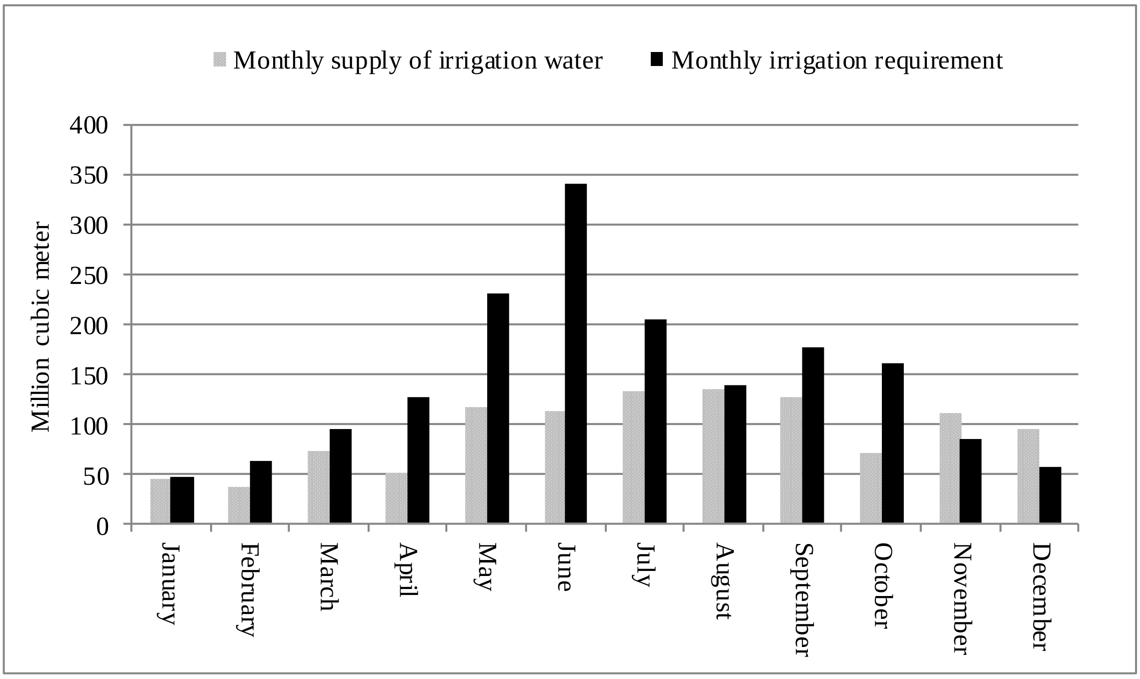


Figure 6.8. Monthly water supply and requirement in BC Irrigation Scheme

Figure 6.8 depicts this water deficiency situation very clearly. Irrigation requirement per unit of irrigated area in the command of Burala Canal is 8311 cubic meters however, canal supplies only cover 4558 cubic meter. Strikingly, this supply is in the canal head which decreased further upon reaching the farm-gate level. This issue gives rise to another issue which deals with governance and managerial problems. In view of the sodic quality of underground water, it can support only requirements up to a certain limit. Improvement in the delivery performances and governance indicators therefore could provide the solution. At any rate, the current water supplies are far beyond less than the water requirements for irrigation taking into account the present cropping patterns. Figure 6.8 shows the trend of the monthly water supplies of Burala Canal into its command throughout the year. The irrigation water requirement peaks in June and also in May and July. While the least irrigation requirement is in January, canal water supplies are more than the irrigation requirement in November and December, particularly due to extreme cool weather and less ET_o, and since this is the initial period of Rabi cropping season crops do not require much irrigation.

B. Upper Pakpattan Canal (GMIS)

Surface streams

The command of UPC irrigation scheme (GMIS) is located in Bari Doab surrounded by two main rivers, e.g. Sutlej River and Ravi River. UPC is fed by Sulemanki Barrage on Sutlej River and based on the Indus Treaty of 1959 between India and Pakistan, India was given full right to use, control and manage the supplies of Sutlej River. In this connection, water was diverted from Balloki Barrage through Balloki-Sulemanki link canal to fed Sulemanki Barrage and to UPC. The designed capacity of UPC 81.51 $m^3.s^{-1}$ and its annual peak flow in 2009-10 was 72 $m^3.s^{-1}$. The total water allocated for UPC canal in 2009-10 was 1702 MCM. However, only 1456 MCM was available at the point of entry or diversion to be used for irrigation purposes. Electrical conductivity (EC) of UPC water is 0.3 $dS.m^{-1}$. It is also important to note that inflows from UPC canal are the main source of irrigation in the entire command area.

Groundwater availability and its usage for irrigation

In the command of UPC, groundwater is also used for irrigation as a supplementary source. During RAP survey, it was observed that the quality of groundwater is very good from the point of view of irrigation particularly in the head and middle parts of command. However, the depth of underground water is an issue because farmers have to pump underground water from the depth of more than 200 feet on the average, while in some areas the underground water table could be as deep as 300 feet. As gathered during the discussions with farmers and engineers, the depth of underground water table is increasing day by day mainly because of shortage of rains and heavy pumping of water. As reported in the Punjab Development Statistics 2008, there were a total 7165 private tube wells only in District Pakpattan in 1994 and this number had almost doubled in 2004 with 10% yearly increment in terms of installations of private tube wells. Out of this total, almost 64% of the tube wells are operated by using diesel engines and rest by electric pumps. Therefore, farmers have to invest a significant amount on fuels for diesel engines diminishing the efficiency of tube well irrigations in terms of investments for inputs. According to the RAP analysis, about 434 MCM of groundwater is pumped by tube wells in the entire command of UPC.

In some parts of the tail command of UPC, sodic groundwater was also reported, which cannot be used for irrigation purposes. Thus, the farmers make conjunctive use of groundwater with the canal water. However, since the depth of groundwater table is lower compared to head and middle reaches, this makes pumping of groundwater for agriculture very costly.

Groundwater is also being used for domestic and industrial purposes along with its irrigation objectives. There are 57 government tube wells in the district Pakpattan only that are used to supply water for domestic use.

Water balance

Like in the Burala Canal, the first and foremost issue is unreliable water delivery and severe fluctuation of water supply in the canals. Therefore, the available water volume is not enough to fulfill the requirements of agriculture. Also considering that the UPC was initially designed to fulfill the irrigation requirement for only 65% of cropping intensity, and now that the intensity had gone up to 150%, UPC has not been able to cope with such requirements. The second issue which deals with governance and managerial problems could be addressed through the improvement in the delivery performances and governance indicators. The trend with respect to the current water supplies which shows that these are far less than the water requirements for irrigation with the present cropping patterns is depicted Figure 6.9.

Similar to BC Irrigation Scheme, the highest irrigation water required from the UPC Irrigation Scheme occurs in June, and also in July and May in descending order of irrigation water requirements. The monthly water requirements are shown in Figure 6.9.

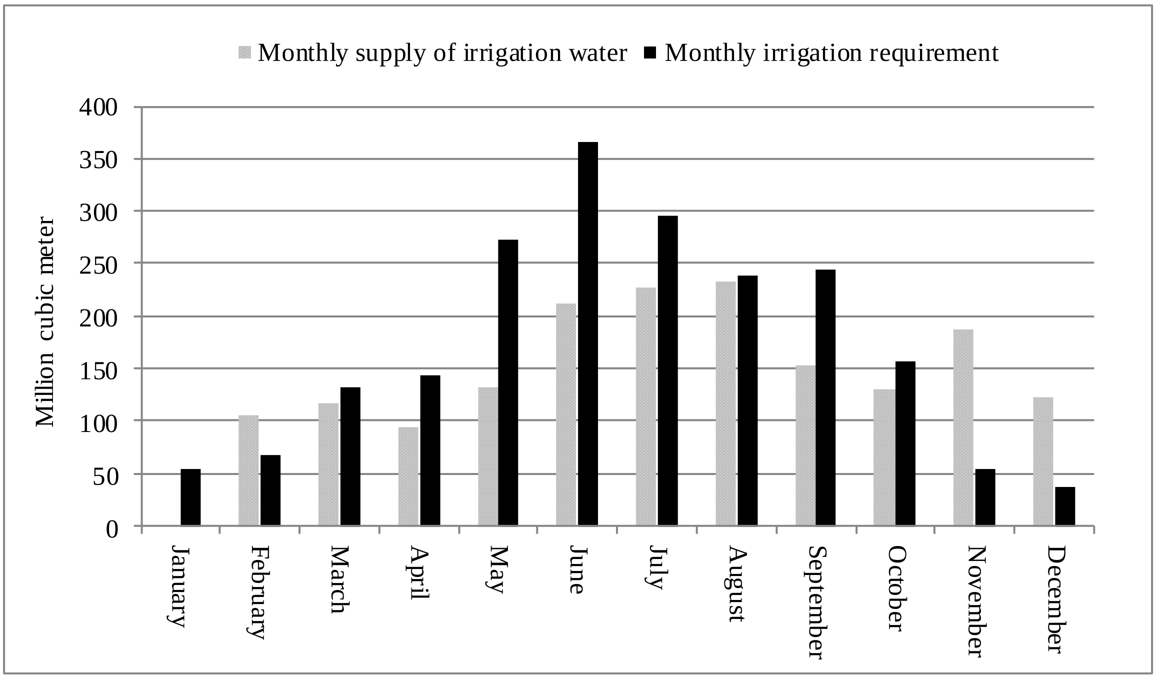


Figure 6.9. Monthly water supply and requirement in UPC Irrigation Scheme

This trend is particularly due to the period of Kharif cropping season which requires high irrigation like rice, maize and cotton. Therefore, during the months of November, December and February, the water supplies could be more than what is actually required in agriculture.

However, these results show an overall and general picture of water supply and demand. Based on the canal supply situation, both irrigation schemes are water deficit on annual basis with multiple cropping (refer to cropping calendar Figure 3.6). In both irrigation schemes, groundwater contributes a major proportion to cover this deficiency of irrigation water.

6.5 Financial aspects: costs and budgets

It is necessary to gather a complete picture of the costs pertaining to the operation of the system in order to identify where possible gains could be enhanced with respect to the current service and operational setup, and what particular cost element needs to be investigated in order to improve the services. Another objective is to map the costs of current operation techniques and services, disaggregate the elements that contribute to the costs, and valuate the options for the various levels of services based on current and improved techniques.

A. Burala Canal (FMIS)

Records showed that the management, operational and maintenance (MOM) cost to supply water delivery service under the BC Irrigation Scheme was 5 US$/ha in 2009-10, while the budget of Burala Canal Irrigation Department was US$ 0.90 million and that of the Farmers Organizations was US$ 0.27 million. This means that the total budget of the whole BC Irrigation Scheme was US$ 1.17 million in 2009-10, implying that there is a need to recover the expenditures through various appropriate means.

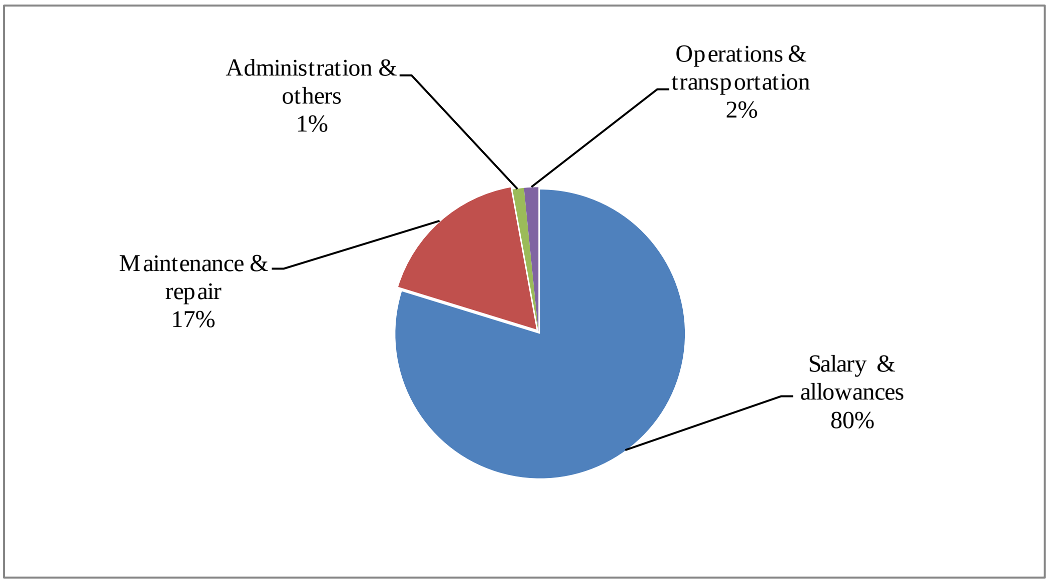


Figure 6.10. Main canal budget distribution in BC Irrigation Scheme (2008-2009)

In addition, BC Irrigation Department has 512 personnel while the Farmers Organizations have 178. Thus, there are 682 staff that include engineers, revenue staff, operators, monitoring and clerical staff who are engaged in providing the irrigation services for the BC Irrigation Scheme. Nevertheless, in spite of the 682 staff strength, 187 (27%) posts for various positions are still vacant at the main canal level only. Reports also indicated that the FOs were deficit of technical staff. Figure 6.10 shows the budget breakdown for BC Irrigation Scheme, which indicates that a major portion of the budget is expended for the salaries of staff (80% of the budget) working in offices and in the fields for management as well as for providing the irrigation services. Meanwhile, about 17% of the budget is allocated for repairs and maintenance of canal structures, 2% for operations and transportation costs, and 1% for administration utilities, stationery, and equipments.

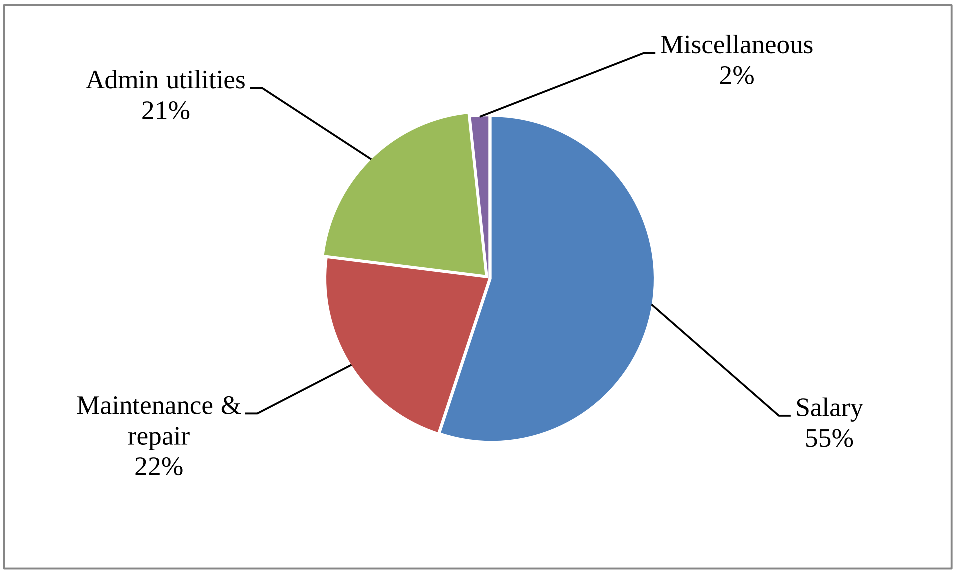


Figure 6.11. Annual budget distribution of FOs and WUAs in BC Irrigation Scheme

As shown in Figure 6.11, the breakdown of annual budget for FOs and WUAs in Burala Canal Irrigation Scheme reveals that 55% of the total budget is spent on salaries of staff, 22% on repairs and maintenance, and 21% on administration utilities such as electricity, stationery, fuels and transportation. Based on the reports of FOs from the Area Water Board of Faisalabad, many FOs are short of technical staff like engineers because the salaries of staff working under FOs are low and more importantly, most staff are hired on contract basis, while some FOs were reported to have recruited retired Patwaries and sub-engineers. In spite of such attempts to lower operations costs, FOs spend 5% more on repairs and maintenance of canals than IPD in the main Burala Canal.

Before the establishment of the Farmers Organizations in BC Irrigation Scheme, water charges were assessed by Patwaries (persons assessing the water charges) based on crops cultivated and the area used for each crop. Now, a flat rate system for water charges has been developed and implemented on per acre basis regardless of the crops being grown. While the Irrigation Service Fee (ISF) is now collected by the Water Users Associations and Farmers Organizations, the tasks of Patwaries were also finished but since they are government employees they have to be retained as such with corresponding government-related jobs. As a result, in the BC Irrigation Scheme alone, 112 Patwaries are still working and continue to receive salaries accounting for about 12.5% of the total allocations for salaries. This could be one of the reasons for the high proportion of personnel salaries in the total budget for the BC Irrigation Scheme.

Figure 6.12, results and status of ISF recovery by FOs on annual basis, indicating that after the establishment of FOs, recovery in year 2004-05 was about 83% which was much higher than present. The 5 year average of ISF collection is 62.4% with a wide standard deviation of 22.6% annually.

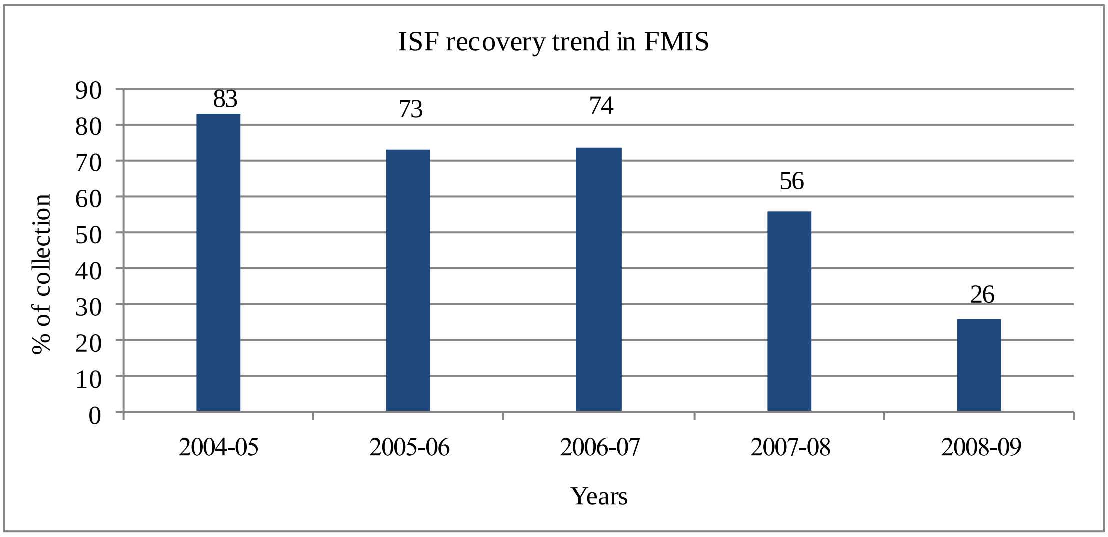


Figure 6.12. ISF recovery trend among various years in BC Irrigation Scheme

The results therefore showed that in the study area, the assessed water fee is less than the operation and maintenance expenditures. As suggested in Figure 6.12, there is continuous declining trend in the recovery of ISF from farmers. In 2004-05, recovery of ISF was more than 80% but decreased to less than 30% in 2008-09, indicating possible severe inefficiency on the part of WUAs as well as FOs particularly in the collection of ISF from farmers. After discussing this issue with officials and farmers, it was gathered that the farmers were quite flexible in their payments of ISF resulting in possible delays. This flexibility could be a result of some operational deficiencies on the part of the FOs particularly due to lack of typical rules and enforcement system for defaulters and free riders, which also prevent competent authorities of FOs to stop water delivery to defaulters. Easter and Liu (2005) also reported that there is no incentive or penalty system for the payers of water charges (ISF) for in time and late payments of water charges. This situation violates the governing principle no. 5 when (Ostrom, 1990) calls for graduated sanctions on those who violate the operational rules. As a point of consideration, declining trend in the ISF highlights the deficiencies by both sides e.g. institutions as well as farmers. Diverse and unequal social setup among farming communities (large farmers, small and poor farmers, politically influenced farmers etc.) open room for large and influenced farmers to make delay payments or not at all (Nakashima, 2005). Nakashima (2005) already reported the reservations of small and poor farmers that after IMT, landlords will exploit them in terms of water delivery services. It seems true here when many small and poor farmers highlighted the outlet tempering and mismanagement in the rotation system by a minister. When this issue was discussed with officials of AWB, it was told that many development projects and fundings were approved and facilitated by this minister, so we cannot take any action against him. FOs are not yet fully capacitated to take action mostly because of two main reasons e.g. one is lacking of strict jurisdiction and secondly, inter-personal relationships (kinships and political affiliations). As a matter of fact in Punjab, during the implementation of IMT, most focus was given on the organization of FOs and WUAs, while leaving the farmers to operate irrigation system by their selves. Implementation of rules and regulations, and enforcement mechanisms particularly under the diverse social and political structures of Punjab are still lacking to develop after the establishment of FOs and WUAs.

B. Upper Pakpattan Canal (GMIS)

The total operational, management and maintenance cost to supply water delivery services under the UPC Irrigation Scheme was 4 US$/ha in 2009-10 while the total budget of the UPC Irrigation Scheme was US$ 0.84 million. The personnel strength of UPC is 450 but only 335 persons are currently working and engaged in providing irrigation services to the UPC irrigation area. This strength of personnel includes professional engineers, sub-engineers, operators, field staff, and revenue staff. It is also significant to mention that there are vacant positions at the managerial level as well as for field staff including some very important positions such as canal patwaries, gauge readers, beldars (casual personnel responsible for monitoring and maintenance), and clerical staff. Moreover, there had been no well documented training for sub-engineers and field operators although professional engineers have gained exposure from some training sessions at national and international levels. Regarding the staffing pattern for GMIS, out of 450 sanctioned posts, 335 persons are currently appointed and engaged in services while 115 (25%) posts for various ranks are still vacant.

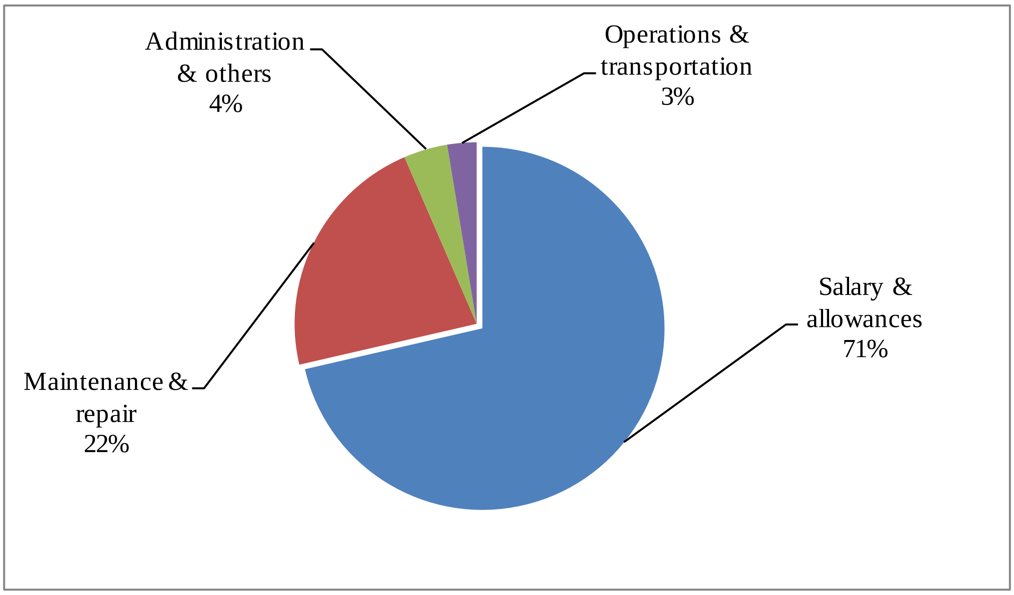


Figure 6.13. Annual budget distribution of UPC Irrigation Scheme

Figure 6.13 shows the breakdown of the budget for UPC Irrigation Scheme, indicating that major part of the budget is allocated for salaries of staff (71% of the budget) working in offices and in the field for management and for providing the irrigation services. While about 22% of the budget is allocated repair and maintenance activities, 3% is for operations and transportations and the remaining 4% is for administration, utilities, and equipments.

In UPC (GMIS), collection of ISF is in a much better situation than in Burala Canal (FMIS). As shown in Figure 6.14, recovery efficiency had never gone lower than 80% during last few years, even in 1999-2000 it could be noted that recovery was 100%. The 6 year average collection is ~91% with a small standard deviation of ~7% annually. In UPC, ISF is also assessed on per acre basis (flat rate) which is relayed to the farmers by

Patwaries[11], but collection of ISF is done by Numberdars[12]. Such arrangement denotes the proper and strict enforcement of the rules of Punjab Irrigation and Power Department.

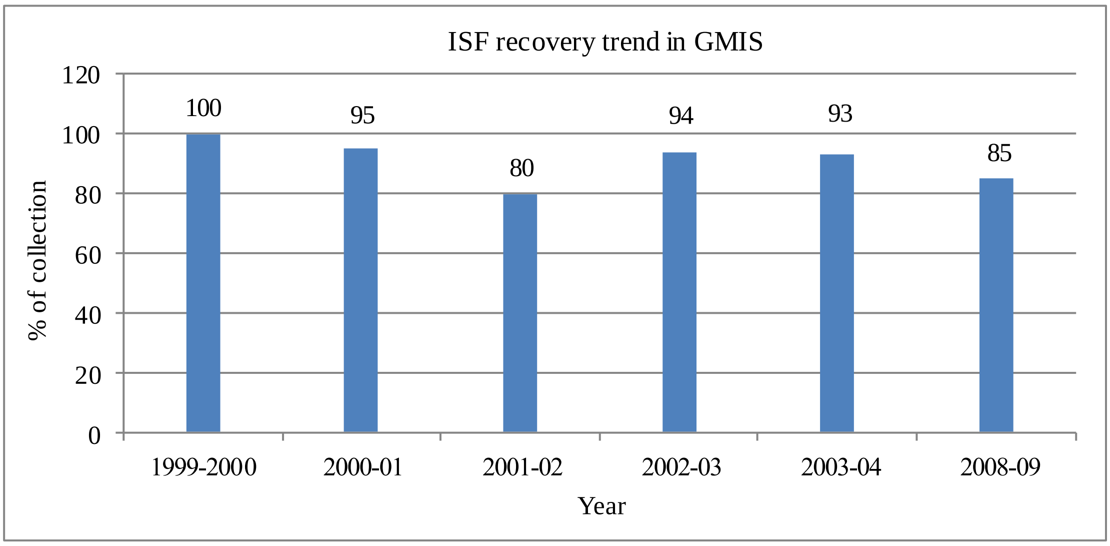


Figure 6.14. ISF recovery trend among different years in UPC Irrigation Scheme

Summary

The information and knowledge about the costs of management, operation and maintenance in the case study schemes appeared very fragmented. Table 6.6 summarizes the all financial aspects of BC and UPC irrigation Schemes. It has been made in some studies that ISF has only made up to 2 to 6 percent of the total cost of production of different crops which have to be increased considerably to have any remarkable effect on the water demand eventually (Sahibzada, 2002). It will be helpful to cover the MOM expenditures and FOs will be more financially autonomous.

Table 6.6. Financial aspects of irrigation schemes

Financial aspects	FMIS	GMIS
Total budget (US$/ha)	5.65	4.93
Non-salary budget (US$/ha)	1.47	1.41
Salary & allowance (US$/ha)	4.18	3.52
Management, Operation & Maintenance (US$/ha)	5	4
Cost recovery ratio	0.33	0.67

Further analysis should therefore be made in order to produce reliable figures specifying what should be considered as reasonable cost for a given service and the composition of the maintenance cost that should be included.

[11] Field staff of Revenue Department responsible for assessing water charges (ISF locally known as *"abiana"*), data collection and record keeping of agricultural land and seasonal and yearly crops.

[12] Representatives of government at village level contracted on permanent basis and responsible for collection of water charges from water users.

6.6 Service of users

This portion focuses on mapping the existing services provided to users and suggests possible options for improving such services with due consideration to farmers and crops as well as to other water users.

A. Burala Canal (FMIS)

The services in the Burala Canal command were assessed and ranked according to FAO standards (FAO, 2003a) during the RAP exercises in the field. The estimated service indicators are shown in Table 6.7.

Table 6.7. Services to users at various delivery levels in BC Irrigation Scheme

Indicator	Main to secondary canals	Secondary to tertiary canals	Tertiary to farm level	Farm level
Flexibility	1	1	0.5	3
Reliability	2.5	2	1.5	1.5
Equity	2	2	1	2.5

Current services

Based on the abovementioned estimated service indicators denoting the current delivery services at various canal levels, a summary of the findings is given in the succeeding sections of this paper.

Service to secondary canals

The decline in the quality of services was noted from the main canal to secondary and tertiary canals as well as at the most lower levels, e.g. agriculture fields in BC Irrigation scheme. Although it is noticeable that the services along the main canal were quite reliable but these had been very weak or poor in terms of flexibility and equity. As also observed during the RAP survey, services to secondary canals vary from one canal to another, i.e. all secondary canals do not get the same services. The levels of offtakes of many secondary canals which were redesigned and restructured (levels were upgraded) during the rehabilitation program after reforms, could be a significant reason for the high value of offtakes sensitivity. This is considering that any small change in the main flow of main canal could cause big change in the discharge of the secondary canals.

Although there is no justifiable reason for the difference in terms of soil conditions and cropping patterns, the only reason given by officials during the interview and discussions was their efforts to provide equitable water supplies to the canal tail.

Service to tertiary canals

Results of the analysis show high level of reliability and inequality at the tertiary canal levels based on the flexibility indicator which is comparatively better at an estimated value of 1.0. Although, initiatives to remodel the offtakes level along the main canal were meant to improve the delivery of water flows at the tails but such efforts decreased the services at the tertiary canal levels in the head and middle reaches. In spite of all these, many secondary canals were lined fully or partly with different materials like bricks, and were cemented, concreted, and some re-enforced with earth.

Service to farmers

The results also indicated that the current service to farmers had not been sufficient enough to fulfill their requirements considering that the irrigation schemes were initially designed for 65% of cropping intensity which increased up to more than 110% on the average. Water is distributed among farmers based on the concept of *"warabandi*[13]*"* after every 7 days for a fixed time depending on landholdings. Further, this fixed time varies from offtake to offtake depending on the size and designed discharge of such offtake. Some offtakes could have 7 minutes per acre but some 15 minutes per acre. Owing to the current service indicators, farmers are unable to grow high water demanding crops because of unreliable water supplies. As an option, they have to depend on high-cost tube wells to fulfill their needs and demands for water, particularly during summer when day time temperature could go higher than 40°C. More strikingly, it should be noted that this is a supply based irrigation system where water supplies are not delivered based on the requirements of the cultivated crops.

Flexibility

Below the secondary canals, offtakes are unregulated providing for much flexibility, but the main problem is on the unreliability and inequity of supplies. However, some elements of political influence had also been gathered from during field survey and discussions with farmers particularly after the establishment of the FOs and WUAs. Moreover, during the monsoon season when many farmers do not need water; they try to close the offtakes to save their crops from flooding even if it is not permitted. Similarly, during times of high demand for water irrigation, occurrence of water theft and tampering of outlets could be very common.

Multiple uses of water

Water from the canal is also used for other purposes such as in maintaining livestock raised by farmers. Herds of buffalos, cows, goats and sheep drink and bathe from every level of the canals but also cause damages to infrastructures. For this reason, the Department of Irrigation has developed and specified the locations for animals. However, canal supplies seem to have no other major role except for agriculture purposes although in instances when the groundwater in some parts of the study area becomes saline, many people install hand pumps near the canal banks to get water which is safe for domestic purposes.

Other services provided

Officials of the Area Water Board (AWB) identified some services which are provided to farmers such as:

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[13] Traditional irrigation water rights are defined by a "*warabandi*" system, where water supply is determined by rotation and an individual's water allocation is measured by the time of water intake proportional to the size of farmland irrigated. Therefore, the traditional water rights are based on a time-equitable system. In this way the water rights are linked with the farmland and cannot be separated from its land holding. The warabandi system has been operated for more than 100 years by farmers, with official recognition of the government.

- ➢ Training to strengthen the capability of WUAs; and
- ➢ Helping the WUAs and FOs in settling cases of conflicts, irrigation fee recovery, elections, and enforcement of rules.

Service to the environment

Based on existing relevant documents and according to concerned officials, no service has been provided to the environment. However, since the main canal and tertiary canals are earthen, a major portion of water lost due to seepage could contribute to lowering the salinity in affected areas specifically in the head and some parts of middle reaches. It should also be considered that this could also cause water logging in some areas because of the saline nature of underground water especially where tube well irrigation is not commonly used. However, Biological Oxygen Demand (BOD) of Lower Gogera Canal (parent canal of BC) is 8 mg/litre and Chemical Oxygen Demand (COD) is 14.3 mg/litre (IPD, 2008).

Service adjustment to the water holding capacity

In view of the varying properties of the soil from the head to tail-ends, farmers at tail-ends are able to diversify their cropping systems because of good and more fertile soil conditions. This means that water supplies (frequency and volumes) could be adjusted according to the local soil conditions and cropping patterns thus, improving water efficiencies and productivities.

B. Upper Pakpattan Canal (GMIS)

Similar exercises had been adopted in the UPC to estimate the service indicators at various levels of the canals. The results are given in Table 6.8.

Table 6.8. Services provided to users at various delivery levels in UPC Irrigation Scheme

Indicator	Main to secondary canals	Secondary to tertiary canals	Tertiary to farm level	Farm level
Flexibility	1	1.5	1.5	2.5
Reliability	2	1	1	1
Equity	2.5	1.5	0.5	1

Service to secondary canals

As indicated in Table 6.8, it is clear that there is a decline in the flexibility of deliveries from the main canal to most downstream levels, e.g. farms. In terms of flexibility, the RAP survey observed that the deliveries from main canal to secondary canals had a value of 1.5 suggesting that the flows for secondary canals are dictated by the project office at the main UPC. Downstream operators are not allowed to undertake any adjustments without prior directives or instructions from the project office.

The value of the reliability at 2.0 suggests that flows reach the destination in plus or minus 2 days although 4-week shortages could be common throughout the year. A 4-week complete closure has been imposed in the main UPC every January for desilting and general maintenance. Moreover, the equity value of 2.5 in Table 6.8 reveals that about 10% turnouts receive significantly poorer services than the average.

It had been observed that the service along the main canal is quite reliable but very weak or poor in terms of flexibility and equity. In fact, the RAP survey recorded that service to secondary canal varies from one canal to another, e.g. all secondary canals do not get same service. There was also no justifiable reason for this difference in terms of soil conditions and cropping patterns. The only reason noted during the interview and discussions with officials was to provide equitable supplies to canal tail reach.

Service to tertiary canals

The results in Table 6.8 show better flexibility at the tertiary canal level, but a flexibility value of 1.5 means that the delivery schedule is dictated by project office. However, schedules could be adjusted by operators on about a weekly basis in accordance with the available supplies and taking into consideration the directives from project office. Nevertheless, high decline was observed from the results of the reliability and inequities in deliveries at the tertiary canal levels. Since almost 97% secondary canals are unlined and are earthen, this situation decreases the reliability and increases the inequity in available water deliveries in the entire command. Many secondary canals are also old and damaged while in many areas, canal banks had already taken a zigzagging shape that contributes to the delay in the timely access of flows to certain reaches.

Service to farmers and environment

The flexibility indicator at farm level at 2.5 denotes that delivery schedule is fixed (*warabandi*: one time for every 7 days) for a fixed period of time, but such deliveries do not match with the actual crop needs. The current service to farmers is therefore not enough to fulfill their demands especially that the irrigation scheme was designed initially for 65% of cropping intensity which has increased on the average to 150%. Furthermore, this fixed time varies from offtake to offtake depending on the size and the designed discharge of certain offtake. While some offtakes could take 7 minutes per acre but the others could have 15 minutes. Owing to such current service indicators, farmers are unable to grow high water demanding crops because of the unreliable water supplies. Thus, the farmers have to depend on high-cost tube wells to fulfill their needs and requirements, particularly during summer when day time temperature could as high as or even over 40°C. Moreover, as a supply based irrigation system, water supplies should be delivered based on the demands of crops being cultivated. It should also be noted that about 74% of the tertiary canals are unlined, 9% are lined with bricks, and only 17% are concrete lined. Although a national program known as the National Program for Improvement of Watercourses (NPIW) was started in 2003, and still continues at tertiary canals at farm level.

In UPC Irrigation Scheme, Biological Oxygen Demand (BOD) at Sulemanki Head works is 10.88 mg/litre and Chemical Oxygen Demand (COD) is 23.2 mg/litre which are higher than BC irrigation Scheme (IPD, 2008). The higher the value of BOD and COD denotes the higher value of pollution in the canal water samples. It means that quality of canal irrigation water in UPC is more polluted than BC.

6.7 Management units

The irrigation system and command areas could be divided into subunits (subsystems and/or subcommand areas) that are homogeneous and/or separated from one another by a singular point or a particular borderline.

A. Burala Canal (FMIS)

All the 36 secondary canals of the Burala Canal are managed by farmers in accordance with the PIDA Act of 1997. The 24 managing bodies at the secondary canal levels are known as Farmers' Organizations (FOs) that further comprise the Water Users' Associations (WUAs) at the tertiary canal levels. After the FOs receive water from the main Burala Canal, the water is then diverted to the WUAs for irrigation purposes. Farmers' Organization is established to manage and operate at distributary and minor canal level however Water Users' Association do same at water course level. In the organizational structure of the BC Irrigation Scheme, there is another regional managing board on top of all FOs known as the Area Water Board (AWB), which works under the command of the Provincial Irrigation and Drainage Authority (PIDA). There are three main cells working in AWB, these are the *"institutional support and coordination cell"*, *"monitoring and evaluation cell"*, and *"capacity building cell"*.

The executive committee members of FOs and WUAs are elected by their members where each farmer (water user) bears the right of one vote regardless of their landholding size. Although farmers were very motivated during the interviews, some elements of political influence could be noticed not only in the elections processes but also in terms of the equitable distribution of water as well.

The existing structure of the 24 FOs at the secondary canals of the BC Irrigation Scheme is given in Appendix C. However, a number of issues were reported during the discussions with the water users and also observed in the data provided by them, which include:

- Uneven command area under each FO,
- Difficulties in accessing the offices and resources of FOs due to distance,
- Some FOs are very big with more numbers of WUAs while some have only few WUAs,
- Technical issues such as infrastructure and engineering information that are spread over the different sub-divisions, and
- Political affiliations and interferences.

Considering the aforementioned issues, it is proposed to restructure the overall management units (FOs) in the BC Irrigation Scheme as shown in Table 6.9 into 19 new FOs that could effectively assist the water users with respect to access, conflict resolution, and improve water delivery services. The proposal was also envisaged to improve the collection of ISF and decrease the burden of allocating considerable funds for salaries from the budgets of FOs since the number of FOs is reduced. However, 6 FOs could not be restructured mainly because of their special status even if they are very large in terms of command areas. In addition, some FOs could not also be possibly restructured into smaller units such as the Bahlak FO as well as the Tandlianwala and Killianwala FOs.

Table 6.9. Proposed management units of BC Irrigation Scheme

Sub-Division	Secondary channels	CCA[a]	Outlets	Proposed management Units	
				FOs	Remarks
Tandlianwala	Chakku	506	3	1	New
	Dulchi	2,391	13		
	Nupewala I	1,628	27		
	Nupewala II	4,629	24[1]	2	New
	Pithrana	2,281	12		
	Hassoki	502	3	3	New
	Naurang	4,493	21		
	Bahlak	13,562	78	4	Same as existing
	Tandlianwala	17,306	85	5	Same as existing
	Jhoke	1,596	8	6	New
	Pervaiz	3,412	17		
	Ranjiana I	1,615	11	7	New
	Ranjiana II	1,074	5[b]		
	Duranwan	1,508	11	8	New
	Ala	2,065	9		
	Arif	2,501	17	9	New
	Obhal	1,842	7		
Kanya	Killianwala	19,296	104	10	Same as existing
	Girja	931	4	11	New
	Dhodian	483	6		
	Gill Gazi	895	5		
	Belochwala	2,909	15	12	New
	Kanya	2,247	15		
	Samundari	1,104	5	13	New
	Farooq	4,752	28		
	Munianwala	475	3		
	Bhoja	11,458	61	14	Same as existing
Sultanpur	Kalera	4,651	28	15	New
	Ditch L	2,262	10		
	Ghark	1,397	5	16	New
	Kamalia	6,208	26		
	Waghi	9,346	41	17	Same as existing
	Azmat Shah	1,024	6	18	New
	Ditch R	1,939	12		
	Kaller	2,238	11[1]		
	Kabirwala	9,085	43	19	Same as existing

[a] Culturable Command Area, [b]Estimated value.

Based on all these issues, it is tried to propose new management units (FOs) in the BC Irrigation Scheme as shown in Table 6.10. There are 19 new FOs proposed by restructuring previous 24 FOs. Some other very important issues could also be included in the restructuring of the previous management units. These include irrigation water requirements, soil type, cropping systems, and so on.

B. Upper Pakpattan Canal (GMIS)

The Upper Pakpattan Canal Irrigation Scheme is a government-managed irrigation scheme (GMIS), and the details of its management units are given in Figure 4.4. Punjab Irrigation Department is responsible for the management of the water resource in the entire command of the Upper Pakpattan Canal (UPC) including the main canal, secondary canals, and tertiary canals. In this regard, the existing management units remain unchanged.

In its organization structure, the UPC Irrigation Scheme has one Senior Executive Engineer (SEE) who monitors and manages the entire command of the UPC with the assistance of sub-engineers and field staff. However, collection of ISF is the responsibility of another wing known as the *"revenue section"*. The UPC Irrigation Scheme has 3 sub-divisions where one sub-divisional officer (SDO) is responsible for the management, monitoring and resolving local water related conflicts among the farmers. In cases where allegations become serious or unavoidable, the cases are raised to the see and then to legal courts which could take years to resolve incurring huge amounts of penalties and fines.

6.8 Demand for operation

In assessing the means, opportunities and demand for canal operations, spatial analysis of the entire command area is undertaken together with preliminary identification of the subcommand areas (e.g. management, services).

A. Burala Canal (FMIS)

As cited earlier, the head and some middle reaches of the BC Irrigation Scheme has been confronted with some problems related to high salinity of the canal water while it is also not always possible to use underground water for irrigation. Nevertheless, it is necessary to improve the delivery of surface canal water to fulfill the requirements for crop irrigation keeping in view the equitable distribution of irrigation water throughout the entire command including the tail reaches.

Another concern of the management units to improve the performance and demand for operation of the BC Irrigation Scheme is to undertake an assessment of the canal operation demand at FOs level which can then be chosen accordingly. This is considering that it is always possible for the demand for operation to vary from one FO to another depending on the soil characteristics, cropping systems, and on-farm water applications.

Operation demand as a function of sensitivity

As a performance indicator, operation demand as shown in Table 6.11 could be taken as a function of sensitivity of the offtake points at the head of secondary canals of the BC Irrigation Scheme, and could be expressed by the tolerance of the water control. Tolerance which gives the allowable variation control on water level to achieve water discharge in secondary canals within the range of $\pm$ 10% and $\pm$ 20%, is calculated using by following expression:

$$Tolerance = \Delta h = \frac{\Delta q / q}{S_{offtake}}$$

From the results (Table 6.10), it can be gleaned that demand varies along the offtake structures of the main Burala Canal. Based on the demand, the offtake structures could be categorized into three target groups, namely: low demanding target (LDT), medium demanding target (MDT), and high demanding target (HDT). As an example, the Azmat Shah secondary canal has the highest sensitivity (8.20 m^{-1}) thus, it falls in the high demanding target category within the $\pm$10% and $\pm$20% variation of the water level, implying that the offtake structure of Azmat Shah distributary needs to be monitored frequently. Meanwhile, controlling the discharge could be achieved mainly by reducing the sensitivity of the offtakes.

Table 6.10. Demand for BC operation as a function of allowable variation on water level

Name of diversion channel	Sensitivity of offtakes	Tolerance on water level control to achieve discharge in the secondary canal within $\pm$ 10% variation		Tolerance on water level control to achieve discharge in the secondary canal within $\pm$ 20% variation	
	m^{-1}	(cm)	Remarks	(cm)	Remarks
Ala	2.88	3.48	HDT	6.95	MDT
Arif	2.76	3.63	HDT	7.26	MDT
Azmat Shah	8.20	1.22	HDT	2.44	HDT
Balochwala	3.11	3.21	HDT	6.43	MDT
Bhoja	2.59	3.87	HDT	7.74	MDT
Chakko	7.86	1.27	HDT	2.54	HDT
Dauranwan	4.39	2.28	HDT	4.56	HDT
Dhodian	5.44	1.84	HDT	3.67	HDT
Ditch Right	4.77	2.10	HDT	4.19	HDT
Ditch Left	2.88	3.48	HDT	6.95	MDT
Dulchi	1.18	8.46	MDT	16.92	LDT
Farooq	1.57	6.38	MDT	12.77	LDT
Ghark	1.06	9.39	MDT	18.78	LDT
Gil Ghazi	1.25	8.00	MDT	16.01	LDT
Girja	5.23	1.91	HDT	3.82	HDT
Hassoki	0.90	11.11	LDT	22.22	LDT
Jhoke	4.22	2.37	HDT	4.74	HDT
Kabirwala	1.46	6.83	MDT	13.66	LDT
Kalera	2.18	4.60	HDT	9.19	MDT
Kaller	2.35	4.26	HDT	8.52	MDT
Kamalia	2.77	3.61	HDT	7.21	MDT
Kanya	2.50	4.01	HDT	8.01	MDT
Killianwala	2.24	4.47	HDT	8.95	MDT
Munianwala	6.45	1.55	HDT	3.10	HDT
Naurang	2.59	3.86	HDT	7.71	MDT
Nupewala I	5.09	1.97	HDT	3.93	HDT
Nupewala II	2.03	4.91	HDT	9.83	MDT
Obhal	4.58	2.18	HDT	4.36	HDT
Pervaiz	3.60	2.78	HDT	5.56	MDT
Pithorana	2.08	4.81	HDT	9.62	MDT
Rajiana I	0.94	10.64	LDT	21.28	LDT
Rajiana II	5.16	1.94	HDT	3.88	HDT
Samundri	4.21	2.37	HDT	4.75	HDT
Tandlianwala	1.08	9.29	MDT	18.58	LDT
Waghi	2.89	3.46	HDT	6.91	MDT
Bhalak	2.52	3.96	HDT	7.93	MDT

LDT: Low Demanding Target=low sensitivity, MDT: Medium Demanding Target=medium sensitivity, and HDT: High Demanding Target=high sensitivity

Operators and other staff responsible for monitoring the performance of offtakes can play very important role in controlling the discharge by frequently checking and monitoring the sensitivity of the offtakes. The decreased tolerance and increased sensitivity of the offtake structures should be monitored and checked more frequently as these could affect the performance of the entire irrigation system.

Demand with respect to service

Managers of the Burala Canal Irrigation Scheme should also take into consideration the results of the current service indicators while checking the variation in demand of the different sections of the Burala Canal. This is necessary because some secondary canals could be very long with large command areas such as the Tandlianwala and Bhalak distributaries.

B. Upper Pakpattan Canal (GMIS)

Demand with respect to sensitivity and service

As one of the current service indicators, variation in demand in the various sections of the canal command should be assessed as part of the most important tasks for the managers of the UPC.

Table 6.11. Demand for UPC operation as a function of allowable variation on water level

Name of diversion channel	Sensitivity of offtakes	Tolerance on water level control to achieve discharge in the secondary canal within ± 10% variation		Tolerance on water level control to achieve discharge in the secondary canal within ± 20% variation	
	m^{-1}	(cm)	Remarks	(cm)	Remarks
1-AR	0.35	28.71	LDT	57.41	LDT
1-BR	4.37	2.29	HDT	4.57	HDT
1-CR	2.60	3.84	HDT	7.68	MDT
1-L	1.22	8.18	MDT	16.35	LDT
1-R	1.63	6.12	MDT	12.24	LDT
2-AL	2.60	3.84	HDT	7.68	MDT
2-AR	1.91	5.24	MDT	10.49	LDT
2-BR	1.37	7.31	MDT	14.61	LDT
2-L	1.31	7.65	MDT	15.30	LDT
2-R	1.93	5.18	MDT	10.37	LDT
3-AL	2.73	3.66	HDT	7.32	MDT
3-L	0.87	11.48	LDT	22.95	LDT
4-L	1.81	5.51	MDT	11.02	LDT
5-L	1.31	7.64	MDT	15.28	LDT
6-L	1.83	5.45	MDT	10.90	LDT
Jiwan Shah	3.28	3.05	HDT	6.10	MDT
Shaffi	2.98	3.35	HDT	6.71	MDT

LDT: Low Demanding Target=low sensitivity, MDT: Medium Demanding Target=medium sensitivity, and HDT: High Demanding Target=high sensitivity

Table 6.11 shows the results of the analysis of the tolerance and demand for operation in UPC. The secondary canal 1-AR has very low sensitivity (0.35 m^{-1}) falling under the low demanding target (LDT) within the ± 10% and ± 20% variation of the water level control, implying that this offtake structure would not need any special attention. However, secondary canal 1-BR which has very high sensitivity (4.37 m^{-1}) and falls within the high demanding target (HDT) category, needs very high attention in terms of monitoring the performance of its water discharge. Frequent checking of this offtake is therefore proposed for operators and other responsible staff to undertake. Moreover, some offtake structures of the secondary canals like 1-L, 1-R, and 2-AR fall in the medium demanding target (MDT) category with 10% tolerance in water level but once tolerance increases to 20% variation in water level, these offtakes would fall into the category of low demanding target (LDT).

6.9 Canal operation improvements

Identification of improvement options for each management unit should focus on: (i) water management; (ii) water control; and (iii) canal operation (services and cost-effectiveness).

There are some points which need critical considerations in order to improve the operation of Burala Canal. In this study, although the MASSCOTE analysis covers the detailed performance of the main canal, this approach can also be applied for further detailed investigations in the secondary canal levels.

Therefore, canal operation improvements would help in achieving the following important objectives:

- High performance in achieving the service goals even without making any major changes
- Improvement of services provided to water users
- Improvements in water management
- Reduction of the costs of operation

In order to plan and design the appropriate canal operation improvements, it is very important to know and to specify the service situation such as performance assessment with change or without change in the target services for the users. In case there is no change in the target service, the performance operation could focus on improving the process of achieving the best actual performance compared with the target in terms of reliability, adequacy, flexibility, and equity. Whereas in case there are changes in the target service, the operation could focus on providing new irrigation services.

A. Burala Canal (FMIS)

Major change in services in a water deficit situation

In a situation where there is low or deficit flows in the main canal head, the suggestions below are made to ensure flexible and equity in water deliveries throughout the main downstream canal. During the MASSCOTE survey, it was observed that the IPD adopts a rotation technique for operating water flows to the secondary canals. The weekly-based process means that in one week water is delivered to all the secondary canals on the right side of the main Burala Canal while the left side canals are closed for that same week and vice versa for the succeeding week.

Another rotation procedure is also adopted in case of high deficit flows. In this case, the main Burala Canal is divided into three sections (based on control points). Water is delivered for one week in each section which is normally undertaken in a sequence. The same rotation procedures are also applied in the secondary canals.

However, in cases where there is full supply or partially low flows, no rotation is applied and water is diverted to the secondary canals based on the available flows. Such rotation has been considered the most appropriate arrangement although some infrastructural and official weaknesses were also reported and observed during the strict implementation of rotation processes.

Management setup

Water flows of the main Burala Canal are operated (controlled and converted) by IPD while the flows of the secondary canals are managed and operated by the staff of FOs. All FOs work under the local managing body known as the AWB. In this regard, the staff of IPD is responsible for the operation and for keeping records of the measuring gauges of all offtakes at the main Burala Canal. The same types of duties are also performed by the staff of FOs at the secondary and minor canal levels.

Service from Burala main canal to secondary canals

Improving operation at regulators

Operation at the regulators could be improved by controlling the flows throughout the length of the canal. This can be achieved by initially adopting correct and precise operational procedures in terms of sensitivity, frequency of checking and monitoring, tolerance, targets, and modalities of adjustments as shown in Table 6.12.

Table 6.12. Procedures that could be adopted by the operators at cross regulators

Element for improvement	Procedures
Function	Water depth control
Type of control	Upstream control
Target Tolerance	Adjust and set a specific water level at the upstream side at plus or minus x cm about the target where tolerance depends mainly on the sensitivity of nearby offtakes and on the control of discharge which should be manipulated.
Frequency of monitoring	Based on the perturbations (frequency and magnitude) and sensitivity of the regulators, highly perturbed and sensitive regulators should be checked and monitored after every 2-3 hours. However, regulators with low sensitive and perturbed values can be checked even once a day.
Modalities of monitoring	Monitoring could be made with naked eyes while gates should be carefully observed.
Modalities of intervention	As observed, many gates of the regulators are old and could no longer function precisely, and would need to be adjusted with precise measurements. Nevertheless, some new gates have already been installed at some control points.

Improving operation at offtakes

Almost 50% of the offtakes at the entrance of secondary canals have not been installed with gates which could be considered as un-gated and open flume offtake structures. Although in other offtakes gates had been installed but the gates are very old and critically broken. This is the reason why the operation at offtakes has not been fully satisfactory with some exemptions in few areas where offtakes had been newly installed with gates and thus perform very accurately. Some form of illegal interventions (bribery and political influence) also decreases the proper operation of the offtakes which could have been minimized if only laws have been properly enforced by local WUAs and FOs. Leakage from the broken structures is also another issue which should be disclosed. Proper repair and maintenance of these structures could improve the efficiency of the water services delivery as well.

Although, it is tough but is not completely impossible to improve the operation of offtakes with more efforts exerted to fix the broken structures. Most importantly, seriousness of the concerned institutions in performing their responsibilities is therefore called for. The offtakes with high sensitivity values like those in Azmat Shah and Chakku distributaries among others should be provided with some forms of physical interventions together with frequent monitoring to reduce sensitivity and thus eventually improve their operations.

Proposal for further investigation

At this juncture, it is proposed that further investigations should be carried out with respect to the detailed operational performance of the secondary and tertiary level canals as well as at offtake points by applying the MASSCOTE analysis. It was also noted that after the implementation of institutional reforms in 2004 at the Burala Canal, many secondary level canals have been lined, rehabilitated and equipped with measuring gauges at least at their head and tail reaches. Together with such information, other supporting data should therefore be compiled such as cropping patterns, and results of soil and underground water mapping among others, for future modernization plans of the Burala Canal.

B. Upper Pakpattan Canal (GMIS)

Major change in service in water deficit situation

In a situation where there is low or deficit flows in the main canal head, the following suggestions would ensure flexible and equitable water deliveries throughout the main downstream canal. During the MASSCOTE survey, it was observed that the IPD adopts a rotation technique for operating the water flows to secondary canals. The weekly-based rotation process means that water is delivered for one week to all the secondary canals on the right side of the main UPC while the left side canals are closed for that week, and vice versa for the succeeding weeks.

Moreover, another form of rotation procedure is also being adopted in case the deficit flows is high. The main UPC is divided into three sections and water is delivered to each section for one week normally following a sequence with some forms of rotation being applied in secondary canals. When there is full supply or when water flows is partially low, the prescribed rotation is not applied and water is diverted to the secondary canals taking into consideration the trend of the available flows. However, some infrastructural and official weaknesses were also reported and observed during the strict implementation of the rotation processes.

Management setup

The water flows of the main, secondary and tertiary canals of UPC are operated (controlled and diverted) by the IPD. Meanwhile, the detailed situation with respect to the management units is as discussed earlier in the section on management units.

Service from UPC main canal to secondary canals

Improving operation at the regulators

Operation at the regulators can be improved by controlling the flows throughout the length of the UPC, which can be achieved by initially adopting correct and precise operational procedures in terms of sensitivity, frequency of checking and monitoring, tolerance, targets, and modalities of adjustments as given in Table 6.12. However, in the modalities of intervention in Table 6.12, new gates have not been installed in the case of the UPC.

Improving operation at the offtakes

Unlike in the Burala Canal, some offtakes at the entrance of secondary canals in UPC are un-gated and are open flume offtake structures. Although most offtakes had been installed with gates but are noticeably very old and broken resulting in the unsatisfactory operations at the offtake points. Some kinds of illegal interventions (bribery and political influence) had also been known that contributed to the decreasing level of the proper operation of the offtakes which could have been minimized if only laws were properly enforced by the IPD. Leakage from the broken structures is also noted and worth disclosing. Proper repair and maintenance of these structures should therefore be undertaken as this can improve the efficiency of water deliveries in the UPC.

Similar to BC Irrigation Scheme, improvement in operation of offtakes; little fixation of broken structures, and most importantly seriousness of institutions is needed. The offtakes with high sensitivity values like 1-BR and Jiwan Shah distributaries among others; some physical intervention along with frequent monitoring is needed to reduce their sensitivity in order to improve their operation.

Proposal for further investigation

Considering the aforementioned situation, it is proposed that further detailed investigations of the operational performance of the secondary and tertiary level canals and at the offtake points should be undertaken by applying the MASSCOTE analysis. Other supporting information should also be measured and compiled as these are important and should be incorporated in the future modernization plan of the UPC, such as cropping patterns, results of soil and underground water mapping, among others.

6.10 Conclusions and lessons from MASSCOTE application

As recommended in the references, aggregation of all possible operational options at the irrigation system level should focus on consolidating and designing an overall cost-effective information scheme to support the activities of a service-oriented management. However, this concern can only be addressed after the previously mentioned suggestions and recommendations have already been considered and efforts had been undertaken towards fulfilling the overall irrigation water requirements.

It is in this regard that the adoption of the MASSCOTE approach should be considered as the results could point towards the areas in irrigation schemes where improvements should be made especially in terms of effective irrigation water deliveries. MASSCOTE is an iterative process that proceeds in a step by step and turn by turn manner. Nevertheless, with the limited investigations made, it may not be possible at this point to conclude what management setup should be adopted, what services that the units created would be considered and what operation techniques should be implemented to attain the objectives.

Nonetheless, the application of the MASSCOTE analysis to the Burala Canal and UPC Irrigation Systems was considered in this study, as an attempt towards diagnosing the performance of the said irrigation systems. The results of the analysis could be used for modernizing the irrigation systems' operations and management. Since MASSCOTE provides a well-structured analysis of an irrigation system, it can be applied for the modernization of surface canal waters in many countries, especially in Pakistan although with certain modifications taking into account the specifities of local conditions. Moreover, as the concern of water scarcity is becoming acute due to climate change and increasing water demand for agricultural, industrial and other purposes, there is strong need for integrated water resource management. This is where the adoption of the MASSCOTE approach is essentially needed and extended at broader scales of natural hydrological units. In the adoption of the MASSCOTE approach, it is however necessary that stakeholders' participation and collaboration is enhanced as this is crucial for the effective application of the MASSCOTE analysis. Furthermore, MASSCOTE tools such as rapid appraisal procedure and diagnosis of external and internal performance indicators are also essential in designing the practical solutions for improved management and operation of the irrigation systems to increase their efficiencies. In view of the foregoing and taking into consideration the experience of the researcher of this study, the following aspects and concerns are therefore presented and further discussed:

1. In determining the values of the internal indicators, the use of a scale where the minimum and maximum values take the numbers from zero to four, should be considered in accordance with the MASSCOTE approach. In addition, for particular internal indicators such as for example the "indicator on water delivery services to individual ownership units", using the MASSCOTE analysis would require the sub-division of such indicator into four sub-indicators, i.e. "measurement of volumes to individual units", "flexibility of individual units", "reliability to individual units" and "apparent equity to individual units". Moreover, in order to assign the specific value for each sub-indicator based on the MASSCOTE approach, the criteria are ranked in the form of multiple exclusive options. For example, under the sub-indicator "flexibility of individual units" the following ranking criteria were developed in accordance with the requirements of the MASSCOTE approach.

4 – "Unlimited frequency, rate and duration but arranged by user within a few days".
3 – "Fixed frequency, rate and duration, but arranged".
2 – "Dictated rotation, but it approximately matches the crop needs".
1 – "Rotation deliveries, but on a somewhat uncertain schedule".
0 – "No established rules".

However, based on the aforementioned ranking criteria, it looks like there would be no consistency in assigning the values as there are more than one item in the ranking criterion while there is no uniformity of such items which serve as the basis for the comparison. For example, the criterion on "dictated rotation but approximately matches the crops' needs" may not be suitable under Pakistani conditions because there are some dictated rotations which do not match the crops' needs. Furthermore, "rotation deliveries but on a somewhat uncertain schedule" would not also work in a situation where there are rotation deliveries where the schedule is almost certain.

2. The MASSCOTE approach had been developed for modernizing a complex irrigation canal operation with the close collaboration of irrigation engineers and managers. However, it appears that the involvement of many other stakeholders such as the farmers and other water users have been overlooked especially in the development of the said approach. Basically, emphasis has been made only on efforts of the staff of the Irrigation Department to obtain information about the various items needed to critically evaluate the irrigation systems. Therefore, it is likely that the information generated could be biased since the other stakeholders had been ignored in the information collection process, and thus, the information compiled could represent only the viewpoints of particular stakeholders, i.e. the Irrigation Department. In Pakistan, for example, it has been reported that tampering of the outlets is done with the knowledge of some staff of the Irrigation Department. In their effort to make additional money, lower level staff of the Irrigation Department (of course with the confidence of higher ups) had been continuously changing the size of the outlets that affected the water distribution. Cheema et al. (1997) reported that 42 percent of the farmers are of the view that the unequal distribution of irrigation water is due to the involvement of some officials of the Punjab Irrigation Department in unscrupulous activities. Since the Irrigation Department is the major source of information in the MASSCOTE approach, it is possible that the staff concerned had not provided the appropriate information necessary for the analysis. For example, even if tampering of the outlets may not be a problem on the part of the said staff but when the farmers are asked to identify and rank their problems, it is possible that such problem would come out as the most important concern. Thus, in order to get accurate information about the problems and subsequently ranking such problems, information should be obtained from all stakeholders including the farmers, farmers' organizations, other water users, Punjab Irrigation Drainage Authority, and others.

3. Mapping the costs of operations against the services rendered is an important step in the MASSCOTE approach. It is well recognized that estimation of the costs of operations is very significant for setting up the service levels, fees for use of water to be charged to users, and for improving the performance and cost-effectiveness of the irrigation system. In this regard, various cost items could be identified, i.e. personal expenditures for salaries, energy consumption, communications, transportation, equipment, investments, and miscellaneous costs. However, the procedure to be used in estimating and valuing the total costs of operations, fixed costs and variable costs had not been outlined in MASSCOTE methodology. As a result, the estimations of such costs which serve as inputs for the MASSCOTE analysis could be varied.

4. A number of problems are confronting the farmers especially at the tail-enders, which require the immediate attention of irrigation authorities and for them to address such problems in a very serious way. For example, in Pakistan water theft and tampering of the outlets by influential farmers are among the serious challenges that adversely affect water availability at the tail-enders. Issues on how to handle such concerns and the corresponding institutional reforms that should be introduced should also be addressed in the MASSCOTE analysis.

5. Some of the questions such as those related to the effectiveness of the irrigation water delivery system with respect to demand-based irrigation scheme, should match with the requirements for the MASSCOTE analysis. However, in the case of Pakistan where its canal irrigation system is entirely supply-based, all the questions to be fed into the MASSCOTE approach should therefore be formulated from such angle. Therefore, this essentially necessitates that information to be used in the MASSCOTE analysis, should be

obtained and the corresponding spreadsheet developed in accordance with the actual situation in the fields.

6. In order to diagnose the problems facing the irrigation systems, various internal and external indicators should be established using the RAP. However, the values determined for the various indicators seem not useful in identifying the areas where actions should be taken in the first step of the MASSCOTE analysis, in order to improve the situation. For example, the value of various internal indicators is uniformly close to 1.0, i.e. for actual water delivery services to individual ownership units, communications for second level canals, social "order" in the canal system operated by paid employees, and so on. Similarly, there are also different values for the other indicators. The question is how to identify the most important problem, the next important problem and so on, taking into account the values of the indicators. Meanwhile, considering the information on the indicators, the next step would require proper identification and ranking of the problems in order that appropriate actions could be taken. Moreover, in order to determine the causes of the poor performance of canal irrigation systems, a problem-cause diagram should be constructed with the active participation of various stakeholders such as the farmers, other water users, staff of the Irrigation Department, farmers' organizations among others.

7. According to Renault et al. (2007), the RAP can be completed in two weeks. However, it this study it seemed that the time required for RAP is generally more than two weeks because of the non-availability of the required data and non-cooperation of some respondents in providing the necessary data. Considering that it could be extremely difficult to obtain data from various stakeholders in such a short time since sometimes it would be important to establish first a good relationship with respondents for this purpose, therefore sufficient time should be allocated for undertaking the RAP.

8. It had been a very difficult task to sit from morning until evening in the offices of the Irrigation Department in order to obtain the desired information and in many instances such efforts had only attained little progress. The same is true during the field visits of the entire commands at various canal levels, which had been quite intensive and laborious particularly due to the unavailability of reliable transportation services, e.g. lack of full access to each section of the canals by roads. It is therefore necessary that cooperation with providers of information be enhanced while the ways and means of accessing the entire commands in the irrigation systems be established, i.e. providing adequate transportation and related facilities.

As the MASSCOTE approach consists of many steps and each step requires a variety of data. In the field, collection of these data is very difficult job. In this study most of the data collected from the Irrigation Department. The staff of the department was not very cooperative in providing the desired data. Generally they hesitate in providing the data regarding water fees, operation and maintenance expenditures and tempered outlets. Unless one has some connections, one cannot obtain data from the staff of Irrigation Department. Further the office records are not properly maintained. For example, the registers regarding water fees assessment before the formation of Farmers' Organizations were misplaced and nobody knew about those records.

9. The MASSCOTE approach requires lots of data as inputs for the different steps. Generally however, the availability of accurate data in developing countries is still a big problem, e.g. for the estimation of indicators related to crops productivity and economics, as well as the data required for the RAP spreadsheet especially those related to

groundwater, crop yield, and cropped areas, among others. However, it seemed that accurate data are generally not available in many cases. Meanwhile, collection of data on crop yields, cropped areas and the like, from the farmers could also be very time consuming.

10. The use of the MASSCOTE approach is a good option towards modernizing the irrigation systems in this part of the world as it evaluates the different aspects of the irrigation system. However, self-understanding of this approach would require about two to three weeks. It is a fact that most irrigation engineers working in offices generally have no time and more often than not, are not also interested in any changes in the operations due to the complexity of the new processes. Moreover, the sub engineers who are mostly involved in the fields for canal operations receive some kind of diploma degree only in local language, making it quite difficult for them to understand this new approach. Therefore, in order that the MASSCOTE approach could be fully understood and implemented in the irrigation systems in developing countries like Pakistan, it is necessary that some training workshops should be conducted to raise the awareness of all concerned on this new concept and more especially create a better understanding of the importance of improving the efficiency of irrigation canal operations.

11. Finally, in order to make the best use of the MASSCOTE approach, a checklist of the necessary information should be prepared and discussed with the various stakeholders to ensure that no important information is left out for the analysis. This will facilitate the collection of all the information relevant to the analysis, the results of which are critical for the improvement and modernization of canal irrigation systems.

12. MASSCOTE approach is detailed and interesting tool which diagnosis and highlights the attention demanding issues but it does not suggest the curement of problems.

6.11 Main findings

The salient results of the analysis using the MASSCOTE approach revealed the declined performance by both irrigation schemes (FMIS and GMIS); where the values of most internal indicators had been lower than the average. However, comparing both irrigation schemes, FMIS appeared to attain better performance than the GMIS, particularly in terms of actual water delivery services from the main canal to second level canals, as well as to the most downstream points. Moreover, operations of the main, second and third level canals, and the general conditions, communications and operations of the second and third level canals, had been relatively much better in the FMIS. Nevertheless, GMIS showed better status of communications at the main canal level only, while on the external performance indicators, GMIS gave better performance in its cost recovery ratio at 0.67 and revenue collection at 0.85, as well as in the output per unit command and irrigation area. Meanwhile, FMIS gave better performance in MOM, maintenance cost to revenue ratio, and staffing. In addition, the offtake structures of FMIS were more sensitive to the change in water level in the main canal with high demanding targets and thus, require special attention and monitoring. While the GMIS had more equity in supplies to second level canals, the FMIS had more equity at the secondary and tertiary canal levels. In terms of farm level services, FMIS showed better performance in terms of flexibility, reliability and equity compared with the GMIS. On the overall, about 80% of the annual budget of both irrigation schemes had been allocated for salaries and allowances while the FOs allotted 55% of its annual budget for the same purpose. While FOs spends 22% of its annual budget on repairs and maintenance, this was much higher than that of the IPD.

FMIS is facing deficiency with respect to its technical staff at the FOs level but the GMIS is faced with deficiency in terms of well-trained field monitoring staff. Moreover, higher and un-matched number of management units (FOs) had been spotted in both schemes. Indicators of water balance in the FMIS showed better monthly water supplies against the irrigation water requirements per unit of irrigated area. Nonetheless, there was a remarkable gap in the supplies of and requirements for irrigation water in the FMIS. In the case of the GMIS, pumping of groundwater had been highlighted as a main contributor to nail the water supply-demand gap.

Chapter 7

Performance and Efficiency Analysis at Farm Level

At the beginning of this chapter, the overall socio-economic and demographic characteristics of farmers in the two case study schemes are discussed. Later, focus is given on the assessment and quantification of the performance of irrigated farms. Main sections in this chapter include farm typology, farm diversification and multivariate analysis, descriptive statistics and farm performance analysis, and farm technical efficiency analysis, the results of which are presented according to farm typology. In the last section of this chapter, irrigation water requirements which had been assessed are presented as a whole scheme. This chapter discusses the objective 3.

7.1 Socio-economic characteristics of farmers

Water is a critical resource for sustainable economic development of Pakistan and with such perspective, irrigated agriculture is of great importance in the socio-economic life of the people in the country. In order to understand the demographic and economic characteristics of farmers in the two irrigation schemes being studied, major parameters such as age, education, livelihood systems, farming experience, and farm tenancy status were assessed.

Table 7.1 features some socio-economic traits of farms in the two schemes, namely FMIS and GMIS. Overall, farmers are younger in FMIS than in GMIS although their ages are more spread in FMIS while in GMIS a large central group aged between 36-45 years old was noted, which could be considered mature age for experience and decision-making. Although 52% of the farmers in FMIS have more than 10 years of farming experience, another 17% of the farmers are very young in the farming profession with less than 6 years of farming experience. This implies that FMIS farmers are less experienced considering also their relatively younger age compared with those in GMIS where almost 70% of the farmers have more than 10 years of farming experience. Also, farmers in FMIS show significantly higher education level and less illiteracy than those in GMIS. While 15% of farmers in FMIS are illiterate, 60% have 10 or more 12 years of schooling which could be a possible reason for the existence of more government jobs as livelihood opportunities in FMIS than in GMIS. However, private businesses and jobs are more common in GMIS than in FMIS. Nevertheless, farming as a single livelihood involves more farmers in FMIS (nearly 70%) than in GMIS (62%). Furthermore, different land tenure situations were noted in both schemes where in FMIS, a large majority (more than 92%) of farmers uses only their own land with a few using both owned and rented land. In GMIS, renting land is more common where about 65% of farmers use only their own land and more than 30% use owned and rented land, while a small number of farmers who do not own any irrigated land have to rent land for crop farming.

Such socio-economic indicators manifest the potentials of farmers to invest in their farms and to mobilize their farm resources in the most efficient way. Even if socio-economic characteristics may not be directly associated with governance structures and features of the two irrigation schemes, but such scenario could help in identifying the opportunities and weaknesses in the socio-economic systems which should be properly addressed in order to improve performance at farm level.

Table 7.1. Overall socio-economic characteristics of farmers in the case study schemes

Characteristic	Unit	FMIS	GMIS
		N=126	N= 82
		%	%
Age	Year		
<26		2.4	2.4
26-35		34.1	26.8
36-45		31.7	45.1
46-55		20.6	20.7
>55		11.1	4.8
Education (schooling)	Year		
Illiterate		15.1	26.8
5		25.4	28
10		45.2	32.9
12 and above		14.3	12.2
Livelihood system	Type		
Farming		69	62.2
Farming and government job		18.3	9.8
Farming and private job		5.6	11
Farming and private business		7.1	17.1
Farm tenancy status	Percentage		
Owned		92.1	64.6
Owned and rented in		7.9	30.5
Rented in		-	4.9
Farming experience	Year		
<6		16.6	9.7
6 – 10		30.9	20.7
>10		52.4	69.5

7.2 Typology of farms

Since farmers in both irrigation systems have different characteristics in terms of socio-economic and strategic farming variables, and keeping in view the importance of all these variables, the farmers could be categorized into different groups in a typology. Thus, a typology of farms was developed based on farm size considering that in the agricultural statistics and irrigation policy documents of Pakistan, irrigation farming systems are classified based on size of the farm lands. In addition, farm size seems to be a key factor used in assessing agricultural performance in Asia as confirmed by Fan and Chan-Kang (2005). Moreover, all local stakeholders including farmers usually put a lot of emphasis in this factor when discussing the reasons for success or failure in the irrigation systems of Punjab.

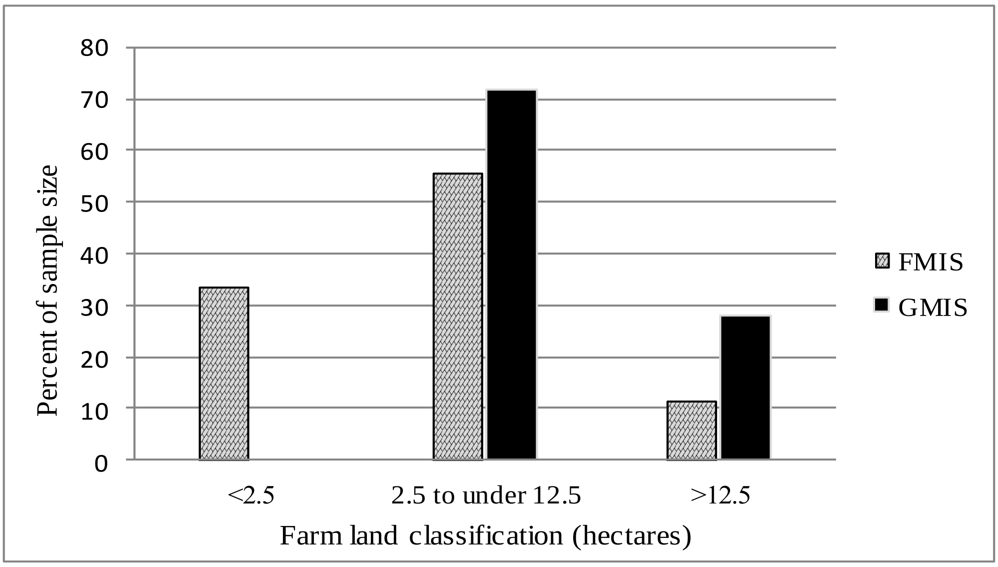

Figure 7.1. Farm size classification used for farm typology

As shown in the results, farm size has indeed contributed to the successful farm differentiation in the two case study schemes. The distribution of farms according to size in both schemes is shown in Figure 7.1. As discussed in Chapter 3, farms that are less than 2.5 hectares are considered as "small farms", 2.5 to less than 12.5 hectare farms as "medium farms", while farms greater than 12.5 hectares are "large farms".

7.3 Relationships between farming systems' variables

In investigating the relationships of the variables, the pair-wise correlation analysis revealed that the variables representing the factors of production are closely linked with positive high correlation that reflects coherent intensification strategies. For instance, the cost of chemical inputs (i.e. fertilizer and pesticides) was highly and positively correlated with the cost of seeds with Pearson's r^2 values of 0.819 in GMIS and 0.521 in FMIS which indicate significant correlation at P value of 0.01. With such pattern, the interdependent variables (fertilizers, pesticides, land rental, pumping, and seeds) were regrouped into one item as production costs for the multivariate analysis.

The pair-wise correlation matrix established (also reported partially in Tables 7.2 and 7.3) per scheme revealed important strategic and operational features of the farming systems. It must be highlighted here that all costs and income are reported on per hectare basis, and only significant correlations (Pearson 2-tailed test at P=0.01) are hereinafter reported.

Table 7.2. Correlation matrix of selected variables in FMIS (2-tailed Pearson test).

Variables	% land under wheat	% land under cotton	% land under rice	% land under maize	% land under sugarcane	Farm size	Production cost	Machinery cost	Labor cost	Annual income	Number of crops
% land under cotton	-.270*	1									
% land under rice	-.141	-.308*	1								
% land under maize	-.244*	.139	.257*	1							
% land under sugarcane	-.032	-.595*	.123	-.251*	1						
Farm size	.051	-.022	-.085	-.029	-.056	1					
Production cost	-.329*	-.050	.230*	.268*	.188	.326*	1				
Machinery cost	-.026	-.251*	.031	.006	.420*	-.244*	-.085	1			
Labor cost	-.358*	-.153	.551*	.342*	.226	.212	.877*	-.052	1		
Annual income	-.343*	-.023	.227	.389*	.274*	.356*	.806*	.018	.801*	1	
Number of crops	-.453*	.142	.396*	.587*	-.010	.204	.738*	-.064	.804*	.842*	1
Cropping intensity	.222	.222	.488*	.373*	.122	-.107	.130	.073	.290*	.264*	.336*

** Highly significant correlation (at P=0.01, Pearson 2-tailed)*

In FMIS, high positive correlations were noted among the socio-demographic variables (experience of head, family size, and number of family workers at farm) although education level of heads showed negative correlation with the other three variables. Also, only the number of family workers was related to operational features, correlating negatively with percentage of land under rice cultivation and labor costs. Overall, the socio-demographic traits did not conflict much with the operational features. As shown in Table 7.2, farm size only correlates positively with production costs and total annual income (both expressed on per hectare basis). Thus, the bigger the farm is, the higher income per ha could be obtained but would require more inputs per hectare. Interestingly, farm size showed no correlation with any crop of choice, where the percentage of farm land under wheat for example, correlated negatively with production costs, labour costs, farm annual income, and number of crops grown. Wheat farming seems to be specialized, is non-intensive but is a low-income farming strategy. Similarly, the percentage of farm land cultivated for cotton showed strong negative correlation with the percentage of farm land for rice and sugarcane, therefore cotton cultivation could be an alternative cropping strategy exclusive of rice and sugarcane. The percentage of farm land for sugarcane positively correlated with machinery costs, while the percentage of farm land for rice positively correlated with labour costs, number of crops, and cropping intensity. Since rice farming uses more labour while sugarcane uses more machinery, rice farming fits well with crop diversification strategies. The percentage of farm land for maize was the only crop variable that positively correlated with farm income, and also positively correlated with labour costs and the number of crops grown. This implies that maize could be a profitable crop, and its farming in terms of labour use fits well with any diversification strategy. Finally, it should be noted that labour costs correlated positively with the number of crops grown and the corresponding annual income that could be derived.

Table 7.3. Correlation matrix of selected variables in GMIS (2-tailed Pearson test)

Variables	% land under wheat	% land under cotton	% land under rice	% land under maize	% land under potato	Farm size	Production cost	Machinery cost	Labor cost	Land renting cost	Annual income	Number of crops
% land under cotton	.437*	1										
% land under rice	-.183	-.266	1									
% land under maize	-.514*	-.456*	.341*	1								
% land under potato	-.608*	-.315*	.051	.465*	1							
Farm size	-.166	-.167	-.143	.287*	.439*	1						
Production cost	-.590*	-.420*	.333*	.595*	.795*	.476*	1					
Machinery cost	-.446*	-.239	.414*	.592*	.443*	.011	.581*	1				
Labor cost	-.547*	-.529*	.655*	.610*	.603*	.221	.812*	.588*	1			
Land renting cost	-.387*	-.237	.061	.417*	.471*	.315*	.567*	.376*	.390*	1		
Annual income	-.602*	-.402*	.370*	.652*	.778*	.438*	.933*	.644*	.798*	.513*	1	
Number of crops	-.382*	-.501*	.767*	.554*	.164	.005	.488*	.518*	.787*	.157	.557*	1
Cropping intensity	.075	.256	.553*	.448*	.305*	.116	.379*	.377*	.451*	.169	.419*	.387*

** Highly significant correlation (at P=0.01, Pearson 2-tailed)*

Meanwhile in GMIS, similar trends were observed on the behavior of the socio-demographic variables, where education level correlated negatively with farming experience, and expectedly, family size correlated positively with the number of family workers at farm although none of these variables showed any correlation with the operational or strategic features. As shown in Table 7.3, farm size correlates positively with total farm income and production costs. Likewise in GMIS, the bigger the farm is the more farming is intensified and on the overall, higher production could be obtained. Also, farm size correlated positively only with the percentage of farm land used for potato farming, with no other crop choice significantly interacting with farm size. The percentage of farm land for wheat correlated positively only with the percentage of farm land for cotton (as a typical crop rotation) while correlating negatively with the percentages of farm land for maize and potato, all costs of production factors (labour, machinery, land rental, inputs), number of crops, and more importantly, with the total farm income. The percentage of farm land for cotton showed similar correlations as wheat indicating that wheat farming goes along well with cotton farming as strategic system although it also implies lower income, less specialization and low inputs required. Reflecting on an opposite strategy, the percentage of farm land for maize showed negative correlation with the percentages of farm land for wheat and cotton, and positive correlations with all production factors (labour, machinery, land rental, inputs), number of crops, cropping intensity, and more importantly, total farm income. Maize cropping could be characterized as productive and profitable farming with crop diversification, intensification, and acquisition of additional land through renting, allowing for intercropping with potato. Thus, the percentage of farm land for potato showed similar correlation patterns as maize. Meanwhile, the percentage of farm land for rice positively correlated only with machinery and labour costs, the number of crops grown, and cropping intensity with production costs (fertilizers and pesticides) as well as positively correlating with all other costs of production factors (labour, machinery, land renting) and with total farm income. Similarly, the number of crops grown and cropping intensity also correlated positively with the percentage of farm land for rice and maize, as well as with all costs of production factors. While the number of crops grown correlated negatively with the percentage of farm land for wheat and cotton, this shows a coherence of the intensification strategy and the capacity of these two commodities to promote improved production per unit area. The results also revealed two main opposite cropping strategies at play, one of which is combining high input maize with rice and potato (if land area allows) while the other is combining wheat with cotton in one-year rotation which requires less inputs and less crop diversification but ultimately giving lower farm income per unit area.

7.4 Main factors for farm diversity within each scheme

This part involves establishing descriptive statistics and the performance per farm, farm type and irrigation system. Most variables documented through the questionnaire survey were used for multivariate analysis (PCA) although not all, and were also mobilized to describe the established types and highlight the significant differences between farms, types and irrigation systems.

In assessing the diversity, variables that characterize the farms were collected covering the four dimensions of the farming systems, i.e. farming potential (human capital, farm demography, farm size), farming strategy (number of crops grown, main crops and relative area), level of intensification (production costs), and farming output (farm income). Table 7.4 provides a list of all these variables representing each system and for each analytical step.

Table 7.4. Variables used in multivariate (PCA) and efficiency (DEA) analyses.

Category	Type of analysis	Variables	Application domain
Farming potential	PCA	1. Years of farming experience	FMIS / GMIS
	PCA	2. Family Size	FMIS / GMIS
	PCA	3. Number of family workers at farm	FMIS / GMIS
	PCA	4. Years of education	FMIS / GMIS
	PCA	5. Farm size (ha)	FMIS / GMIS
Farming strategy	PCA	6. Number of crops grown	FMIS / GMIS
	PCA	7. % of farm land under wheat	FMIS / GMIS
	PCA	8. % of farm land under cotton	FMIS / GMIS
	PCA	9. % of farm land under rice	FMIS / GMIS
	PCA	10. % of farm land under maize	FMIS / GMIS
	PCA	11. % of farm land under sugarcane	FMIS
	PCA	12. % of farm land under potato	GMIS
Farming inputs	PCA	13. Production costs (PKR/ha) *	FMIS / GMIS
	PCA	14. Machinery costs (PKR/ha) **	FMIS / GMIS
	DEA	15. Land preparation cost (PKR/ha)	FMIS / GMIS
	PCA / DEA	16. Labor cost (PKR/ha)	FMIS / GMIS
	PCA / DEA	17. Land renting cost (PKR/ha)	GMIS
	PCA / DEA	18. Harvesting cost (PKR/ha)	FMIS / GMIS
	DEA	19. Seed cost (PKR/ha)	FMIS / GMIS
	DEA	20. Fertilizer cost (PKR/ha)	FMIS / GMIS
	DEA	21. Pesticide cost(PKR/ha)	FMIS / GMIS
	DEA	22. Tube well irrigation cost (PKR/ha)	FMIS / GMIS
	DEA	23. Post-harvesting cost (PKR/ha)	FMIS / GMIS
Farming output	PCA / DEA	24. Annual farm income (PKR/ha)	FMIS / GMIS

**Variable 13 on "production costs" adds all costs incurred (biological and chemical inputs) in production operations, and is actually combined with variables 19 to 21*

*** Variable 14 on "machinery costs" adds all costs for equipment and machinery and is combined with variables. 15, 22 and machinery rental costs*

Considering diversity in farm practices and performances, the principle component analysis (PCA) was used to identify the variables most involved in the differentiation of farms by means of a much smaller number of variables or dimensions known as factors. Since PCA contributes to achieving a linear combination of the representative variables that generate a maximum variance for multidimensional phenomenon which are also uncorrelated, the initial number of variables is reduced in a smaller number of principle factors that explain most of the variance. Thus, PCA leads to the identification of indicators that most explain the variability in farms, and also provides a correlation matrix of all input variables that enhances understanding of the relationships of variables within the samples. PCA was carried out using the SPSS program after the data were checked for appropriateness through Bartlett's sphericity. All factors with eigen values greater than 1 have been ultimately retained in accordance with the Kaiser's criteria.

The PCA was performed on the same variables for both irrigation systems with some exception, for example, the "percentage of farm land for sugarcane" only makes sense in FMIS since sugarcane is not a major crop in GMIS, while the "percentage of farm land for potato" and "land renting cost" are common in GMIS only since potato is not grown in FMIS, and land renting is only practiced in GMIS. Overall, 16 variables for FMIS and 17 variables for GMIS were used as shown in Table 7.5. Results of the PCA suggested broad variety of strategies, practices and performance at farm level.

Table 7.5. Key factors with decision variables (rotated matrix)

Decision Variables	FMIS					Decision Variables	GMIS			
	Factor						Factor			
	1	2	3	4	5		1	2	3	4
Harvesting cost	.956					Number of crops grown	.953			
Annual income	.942					Labor cost	.897			
Production cost	.888					Harvesting cost	.822			
Number of crops grown	.864					Annual income	.807			
Labor cost	.854					Machinery cost	.764			
Farming experience		.827				Production cost	.763			
Family size		.818				% of farm land under maize	.738			
Family workers		.712				% of farm land under rice	.673			
Education		-.702				% of farm land under wheat	-.652			
% of farm land under sugarcane			.883			Farm size		.822		
% of farm land under cotton			-.806			% of farm land under potato		.671		
% of farm land under rice				.851		Family workers			.902	
Farm size					.711	Family size			.837	
						Farming experience				.842
						Education				-.776
Eigen value	5.19	2.34	2.15	1.49	1.11		7.31	2.20	1.43	1.24
% of variance	32.50	14.62	13.41	9.30	6.94		43.01	12.95	8.40	7.27
% of cumulative variance	32.50	47.11	60.52	69.82	76.76		43.01	55.96	64.36	71.64

Table 7.5 displays the results of PCA (rotated correlation matrix with eigenvalues and percentages of the variance explained). In FMIS, 13 variables showed high correlation coefficient (>0.6) grouped into five main factors explaining the diversity of farms, which in turn explained about 77% of the whole variance. A first group of five variables which

explains about one-third of the total variance consists of the combination of farming intensification level (harvesting and production costs), farming strategy (number of crops grown) and performance (annual income), all of which exhibited positively high correlation. The second factor is made up of four variables which are all related to farming potentials and human dimensions (experience, family size, family workers, and education) and explain about 15% of the total variance, all of which are highly correlated including education which shows high negative correlation with the other variables. A third group is related to farming strategy where the percentages of land for sugarcane and cotton show high negative correlation (reflecting the fact that in FMIS when one grows sugarcane he does not grow cotton and vice versa). While these three main factors explain together more than 60% of the total variance, a fourth factor which includes the percentage of farm land for rice goes along well with sugarcane in the farm strategy. Noticeably, farm size which is featured alone in the fifth factor, explains only about 7% of the total variance. Thus, farm size which ranges from less than 2.5 to more than 12.5 ha is not a predominant factor that explains the overall farm diversity in FMIS.

In GMIS, 15 variables grouped into four main factors explain the diversity of farms. Such variables show high correlation coefficient (>0.6) and explain about 72% of the whole variance. A first large group of nine variables which consists of a combination of farming intensification level (harvesting, labour, machinery, and production costs), farming strategy (number of crops grown, maize, rice, and wheat) and performance (annual income), explains about 43% of the total variance. All variables exhibited high positive correlation with the exception of wheat (negative correlation) which is clearly featured as an alternative commodity where its farming is specialized and less intensified, and is a less performing farming strategy. The second factor is made up of two variables, namely: farm size and percentage of farm land for potato. Here, it is again noticeable that farm size does not relate with the main farm strategy or performance variables since it is only highly correlated with potato cropping and can be interpreted in the sense that potato is grown only when farmers have enough land to spare after the choice for all other crops have already been made. However, this second small factor explains about 13% of the total variance. The two last factors which combine family size with number of family workers (about 8%), and farming experience with education level (about 7%) have high negative correlation with education level and experience, as expected.

As shown in the PCA results, the similarities in terms of farming systems, strategies and performance in the two irrigation schemes are very striking and confirm the interpretation of the correlation matrices, even if some minor differences could be spotted between these schemes. Specifically, in both schemes, higher farm annual income is related to diversification (more number of crops grown) and intensification (more agricultural inputs per unit area, higher labour required and harvesting costs). In the GMIS, the percentage of farm land for maize and rice also positively correlates with all other factors listed above while the percentage of farm land for wheat exhibits negative correlation with such factors. Interestingly, farming experience negatively correlates with education, and is not directly linked with farming strategy, intensification level or performance. Therefore, farm size remains an isolated factor which confirms the pair-wise correlation results indicating little interactions between farm size and farming strategy (crop choices). In GMIS, while larger land is preferred to be used for potato cropping, results of the analysis highlight the clear-cut and mutually exclusive strategies between sugarcane-rice and cotton specifically in FMIS, and maize-rice and wheat in GMIS.

7.5 Relationship between farm size and farming performances

In order to further investigate the relationship between farm size and farm operating features in both irrigation systems, farms were classified into three different types in each system based on farm size. The farm distribution according to size classes is shown in Figure 7.1. Since farm sizes are larger overall in GMIS, the distribution differs between the schemes under the same classification conditions. For instance, no farms in GMIS are below 2.5 ha but this group forms the largest size class in FMIS.

Table 7.6. Farming variables according to farm size in the case study schemes

Variables (averages)	Farm types in FMIS			Farm types in GMIS		
	Small farms	Medium farms	Large farms	Small farms	Medium farms	Large farms
Farm size (ha)	2.0	5.8	25.0	4.0	8.3	28.0
Wheat growers (%)	100	100	100	100	100	100
Cotton growers (%)	26	74	79	100	100	100
Rice growers (%)	52	57	64	50	79	74
Maize growers (%)	10	17	21	50	70	87
Sugarcane growers (%)	79	84	100	-	-	-
Potato growers (%)	-	-	-	0	16	65
Number of crops grown	2.7	3.3	3.6	3	3.6	4.2
Cropping intensity (%)	111	109	109	132	143	153
% farmers with own machinery	50	71	86	31	81	100
% farmers with own tube well	21	50	79	19	60	96
% farmers with access to technical services & advise	36	44	43	31	49	100
Seed cost (USD/ha)	233[a]	301[b]	341[b]	147[a]	338[b]	850[c]
Land preparation cost (USD/ha)	225[a]	239[a]	252[a]	281[a]	326[ab]	391[b]
Fertilizer cost (USD/ha)	588[a]	782[b]	968[b]	867[a]	1,210[b]	1,787[c]
Pesticides cost (USD/ha)	162[a]	213[b]	296[c]	254[a]	336[b]	438[c]
Labor cost (USD/ha)	196[a]	254[b]	284[c]	222 [a]	292[b]	362[c]
Tube well irrigation cost (USD/ha)	116[a]	176[b]	217[c]	662 [a]	654[a]	802[b]
Harvesting cost (USD/ha)	363[a]	472[b]	541[c]	382[a]	437[a]	498[b]
Annual income (USD/ha)	4,356[a]	5,777[b]	6,844[c]	4,237[a]	5,868[b]	9,072[c]

Values having different letters are significantly different from each other (t-test at P=0.05).

* 1USD =75PKR in 2009-10

Table 7.6 provides an overview of the socio-demographic, operational and strategic dimensions of the farms according to size in the two case study schemes. The data also indicate the averages calculated for selected operational variables in all farm size and in both systems while statistical test (t-test) was carried out to determine the significant differences. The only socio-demographic features that differ among the farm sizes are the age of head, experience, and family size which are higher in large farms in GMIS. Crop choices also show some differences between the schemes, where wheat remains the main crop (per area covered and per percentage of farmers growing it) in all schemes and farm sizes. Farmers in FMIS commonly grow cotton, rice, sugarcane, and more marginally, maize, while in GMIS, all farmers also grow cotton (in rotation with wheat) although most farmers grow rice and maize. Potato is significantly grown only in large farms in GMIS which confirms what the PCA revealed that on the overall, farm size has no relationship with crop choice. However, only maize and to a lesser extent, sugarcane is cropped by large farmers in FMIS, but potato has a special status since it is only grown by both medium and large farms in GMIS. Overall, cropping intensity and number of crops grown tend to increase with farm size. More strikingly, private access to machinery and tube-wells (ownership) markedly increased with farm size making almost all of the large farms in both systems fully equipped. As, Seckler et al. (1999) argued that access to groundwater is instrumental role in food security but the management of groundwater is considerable due to overexploitation. Also, costs of all production factors are significantly increasing along with farm size.

Therefore in both systems, the larger the farms are the higher would be the intensification level which implies significantly higher total farm income in large farms. Thus, it appears that farm size is related to the intensification strategy adopted and to the available equipment used but not on the cropping strategy followed (crop choices). It can be argued that large farms have accumulated capital and higher income over the years, and thus are in a favorable financial position to invest in equipment and inputs. These results confirmed the argument of Woodhouse (2010) who cited that capital-intensive agriculture has proved to be more productive but its long-term sustainability is questionable in a broader context of political economy. He also suggested a dimension to consider with regards to efficient and mechanized agriculture compared with labor-intensive agriculture.

Discussion and interpretation could be drawn from the aforementioned results as well as from the inputs of local experts and farmers compiled during the interviews. Poor motivation towards the cultivation of rice and maize could be due to the demanding nature of cultivating such crops in terms of inputs, irrigation water, skills, and experience of farmers. Wheat and to a lesser extent, cotton are more versatile crops as their cultivation requires less inputs and less irrigation water. Nevertheless, access to private tube wells has provided more flexibility and reliability in irrigation water supply (Shah et al. 2000), and led to more crop options such as maize and potato. Nonetheless, it should be noted that potato cropping requires reliable irrigation, skills, and purchasing capacity to acquire hybrid seeds, fertilizers and pesticides, and specific machinery for planting and harvesting.

Differences in accessing technical services and advice are most noticeable in the two study schemes, since only large-scale farmers in GMIS are able to gain full access to such opportunities. In the study area, most technical services and advice are provided by large national and multinational companies selling pesticides, fertilizers, hybrid seeds, and farm equipments. As a consequence, large farms are mostly targeted for these farms are likely to use more inputs, but little interest is given to small-scale and less intensive farmers for obvious reasons. Among all farm types in both schemes, large farms in GMIS have a unique status and situation as the wealthiest, most experienced, oldest farmers, and families with larger size, are found in the area. Full access to privately owned equipment makes them autonomous providing them with special social status. However, these farmers are also known to support smaller farmers through machinery sharing or renting.

In most of the small and medium farms, fully functional sets of machinery could be hardly found so that the ill-endowed farmers rely on the facilities in large farms. Large-scale farmers also have a strong influence and grip on the local labor force available in the other farm groups by hiring them at strategic times. Potato and maize cropping require frequent and abundant labour supply and only the large-scale farmers have the capacity and status to hire and pay for such labour requirement, while the same group of farmers is also the common point of attraction for pesticide and fertilizer companies to market their products with incentives and at discounted rates. Moreover, even the staff and officers of public agricultural extension department are also more interested in keeping in touch with this group of progressive farmers.

7.6 Efficiency analysis of farms using DEA model

After the "Green Revolution" and mechanized-intensive agriculture by large-scale farmers at the global level, the need to invest in small-scale agriculture was called for as means of improving the efficiency of resource use in farming. Along this line, assessment of technical efficiency at individual farm level was conducted using the DEA model. The variables used in the DEA model are shown in Table 7.4. In conducting the relative technical efficiency analysis using DEA, the set of decision-making units (cropping systems) are compared. Results of DEA could provide efficiency scores for individual farm as well as generate information about the gap between the current efficiency and maximum efficiency per input variable, and where areas of potential improvement are identified thus, providing normative guidance for management to consider. DEA input-oriented model focuses in minimizing inputs and therefore, was selected in the research study since production costs proved to be a key factor in farm differentiation (as shown in the PCA results). BCC model which considers variable return to scale (VRS) was also used because it provides more possible solutions for efficiency. Each individual farm has been treated as a DMU to be able to process their respective relative technical efficiency.

As shown in the results, the relative technical efficiency shows the capacity of a given farm to turn selected inputs (refer to Table 7.4 for the list of variables and Table 7.5 for the cost of each farming input) into total annual farm income. In the analysis, an efficiency line (or production frontier) could be drawn with a maximum efficiency score of 100%. Farms that maximize output with minimum use of combined inputs could reach the maximum score but other farms could only attain a much lower score. In practice, a performing farm with high total farm income could still exhibit poor technical efficiency if excessive amounts of inputs are used. Conversely, an ill-performing farm could be technically efficient if low levels of inputs are mobilized to get the result. Finally, high proportion of full efficiency scores (100%) reveals homogenous practices and performance among the studied sets of DMUs otherwise, wide-ranging efficiency scores with less full efficiency scores could imply heterogeneity.

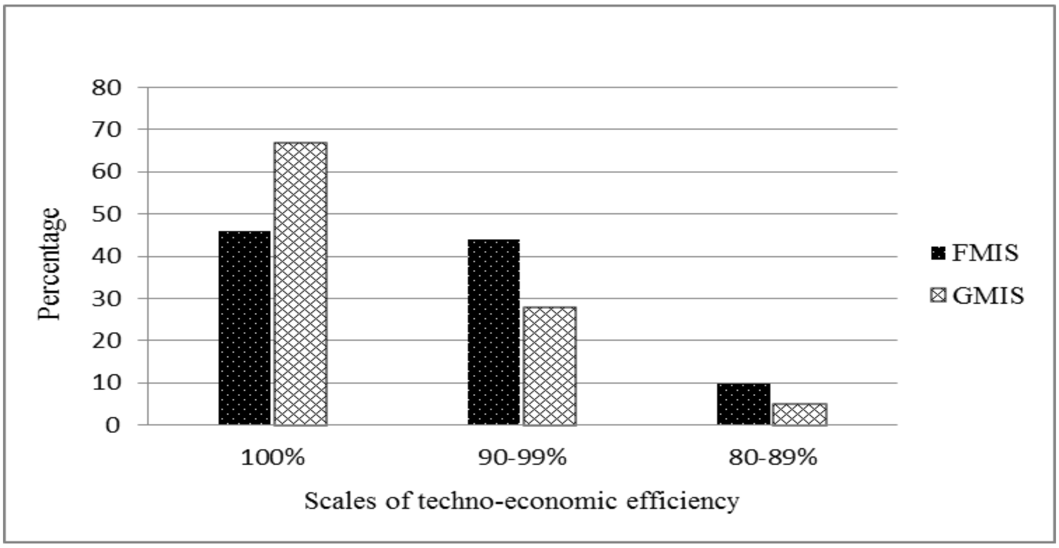

Figure 7.2. Scales of techno-economic efficiency at scheme level

Figure 7.2 displays the scales and proportions of farms which achieve different classes of technical efficiency per irrigation system level. Overall, the proportion of relatively efficient farms is higher in GMIS than in FMIS. However, regardless of the farm size, 45% of farms in FMIS achieved full efficiency compared to only 67% in GMIS.

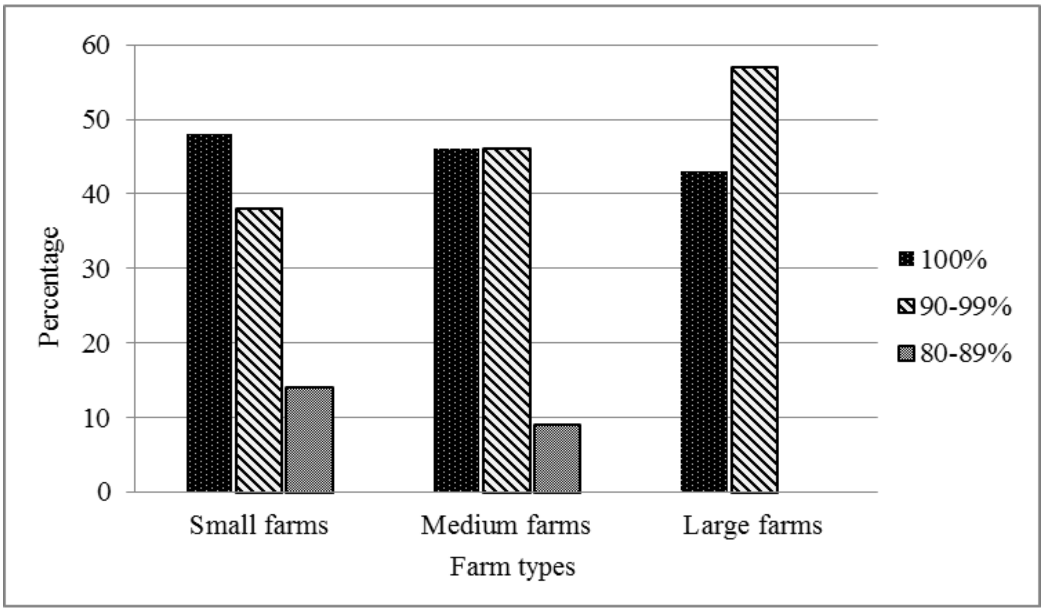

Figure 7.3. Techno-economic efficiency as per farm type in FMIS

Figures 7.3 and 7.4 show the efficiency results per farm type in FMIS and GMIS, respectively. Nevertheless, the data indicate that farm size has little impact on the efficiency scores. In FMIS, medium farms are less efficient than its other farm groups while such farm group is more efficient in GMIS. Also, in FMIS as well as in GMIS, no farms in the large size groups had attained efficiency score of less than 90%.

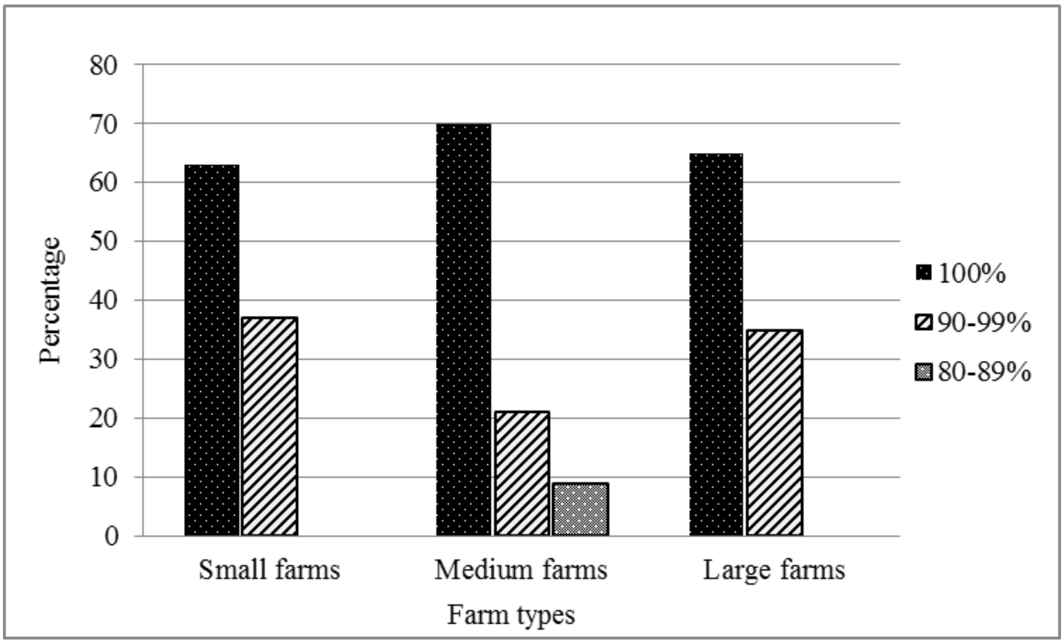

Figure 7.4. Techno-economic efficiency as per farm types in GMIS

Figure 7.3 shows the proportion of relative efficient farms per farm type in FMIS which achieved different range of technical efficiency. These are the farms that mobilized their cost of inputs at optimum level. Other farms with less than 100% efficiency are not relatively efficient as their production efficiency frontier could not attain a score of 1 in order to get 100% efficiency. However, as shown in Figure 7.3, there is no big difference in the proportion of efficient farms per farm type. All farm types have efficient farms with scores that range from 43 to 48%, which implies that farmers are mobilizing their farm inputs within this range. Also, no large farms attained less than 90% efficiency score; this means that there are nearly 60% farms which falls very near to the efficiency frontier. In the whole scheme and regardless of the farm size, 45% of all farms have achieved full efficiency as shown in Figure 7.2. Therefore, farm size has little impact on the efficiency scores although small farms appear to be more efficient than the other farm groups.

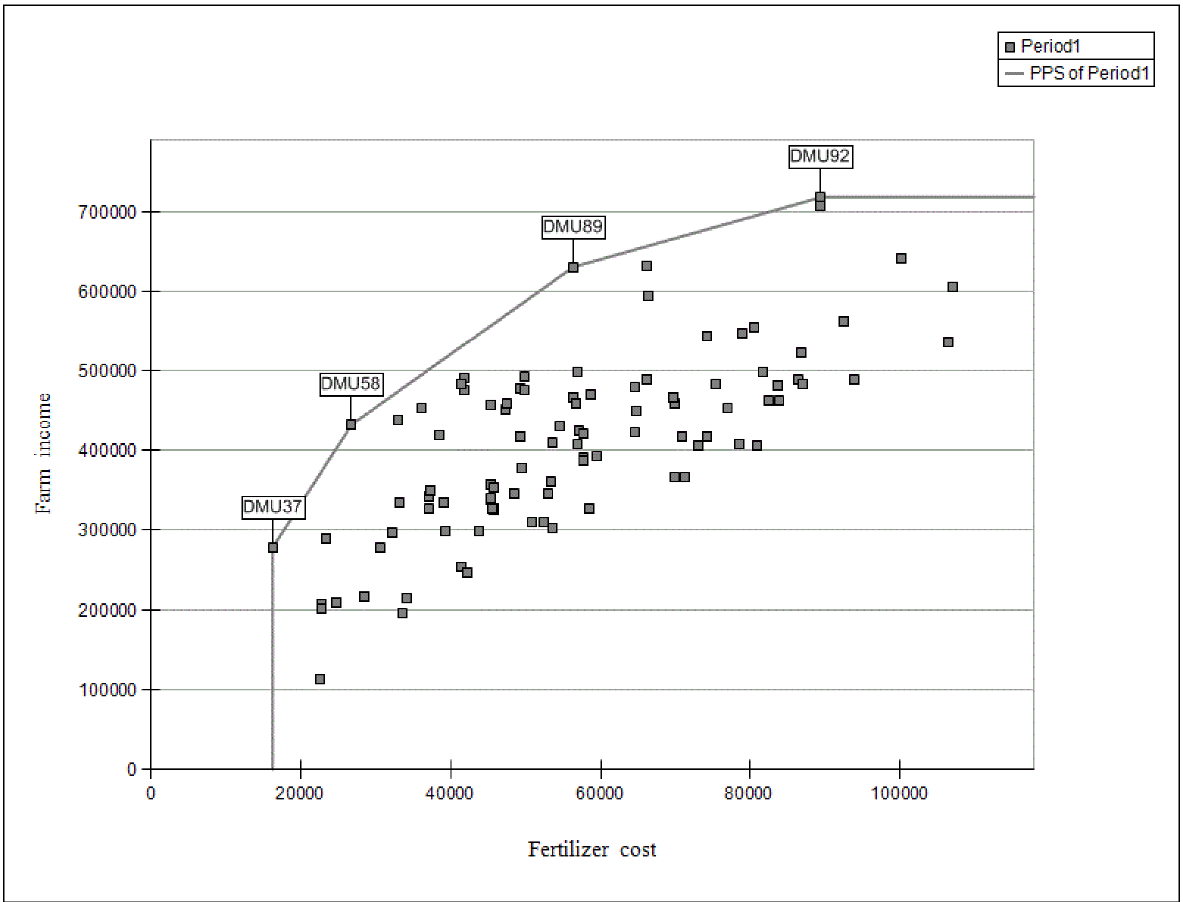

Figure 7.5. Efficiency analysis graph: fertilizer cost vs. farm income in FMIS

The efficiency frontier in Figure 7.5 indicates the efficient DMUs (cropping systems) like 37, 58, 89, and 92 in FMIS which have been efficiently mobilizing fertilizers against the total farm income. All other DMUs could not reach the efficiency frontier due to the inefficiency in terms of mobilizing fertilizers against the total farm income. Similarly, Figure 7.6 shows the efficient DMUs in GMIS with efficient mobilization of fertilizers against the total farm income, and these efficient cropping systems (DMUs) are 11, 12, 47, and 48.

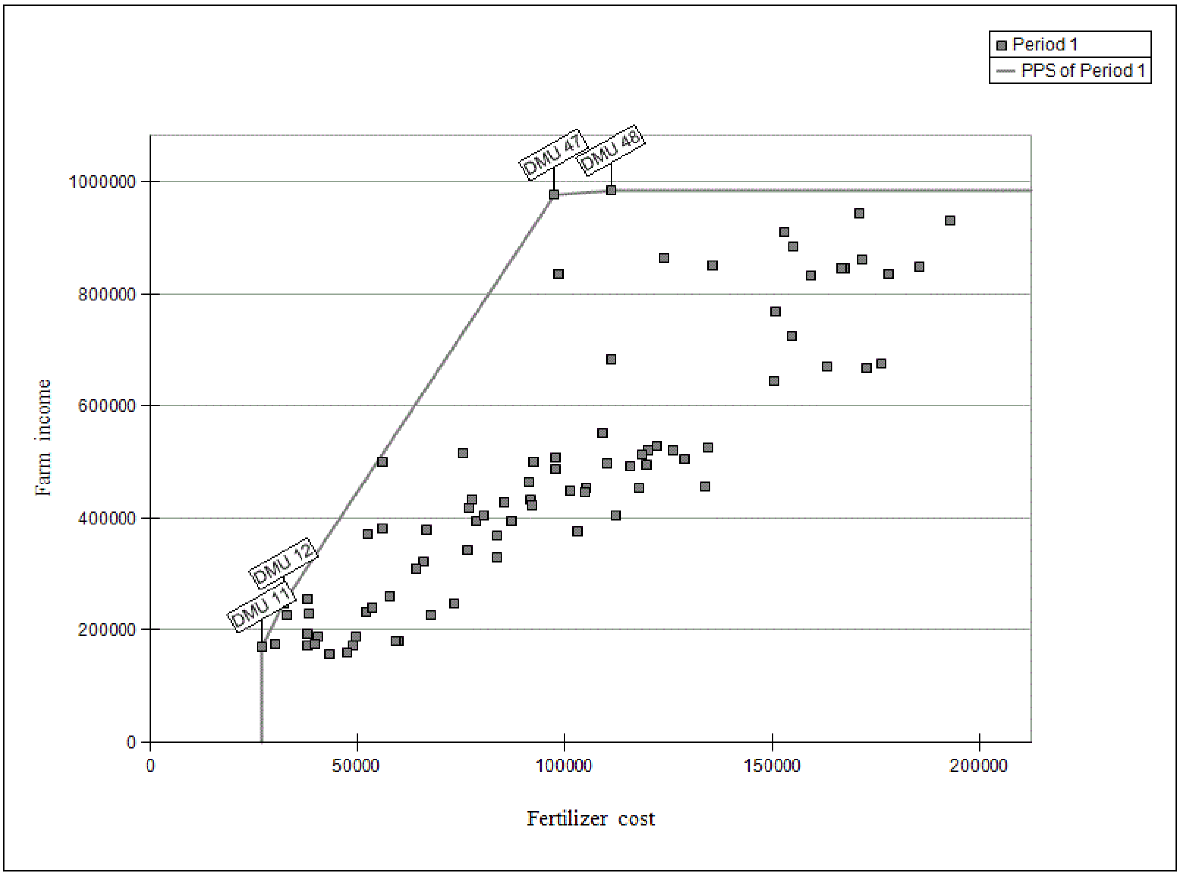

Figure 7.6. Efficiency analysis graph: fertilizer cost vs. farm income in GMIS

It is interesting to note that both irrigation schemes have the same number of efficient farms (4 each) in terms of fertilizer use only, but have different proportion at the whole scheme level because of the different sample sizes considered in both schemes. However, all inefficient DMUs (in case of fertilzer use only) in FMIS fall into specific range regardless of the level of income. Nonetheless, in the case of GMIS, the pattern of inefficient farms is more dispersed varying from low income to high income farms. The efficiency frontier in Figure 7.7 shows the efficient DMUs such as 34, 58, 86, and 92 which had been efficiently mobilizing the costs of tube well irrigation against total farm income. The rest of the DMUs could not reach the efficiency frontier in view of their inefficiency in mobilizing tube well irrigation cost against total farm income. In the same vein, Figure 7.8 shows the results of efficienct DMUs (cropping systems) in GMIS, which indicate that DMUs with number 82, 78, and 48 are 100% efficient in terms of tube well irrigations against the total farm income. In the establishment of the efficiency frontier, the distance between DMU and efficient frontier defines the efficiency score. In both irrigation schemes, this distance decreases from the small farms to large farms particularly in the case of GMIS where almost all large farms have been equipped with private tube wells and underground water which are suitable for irrigation purposes specifically reaching the head and middle canals.

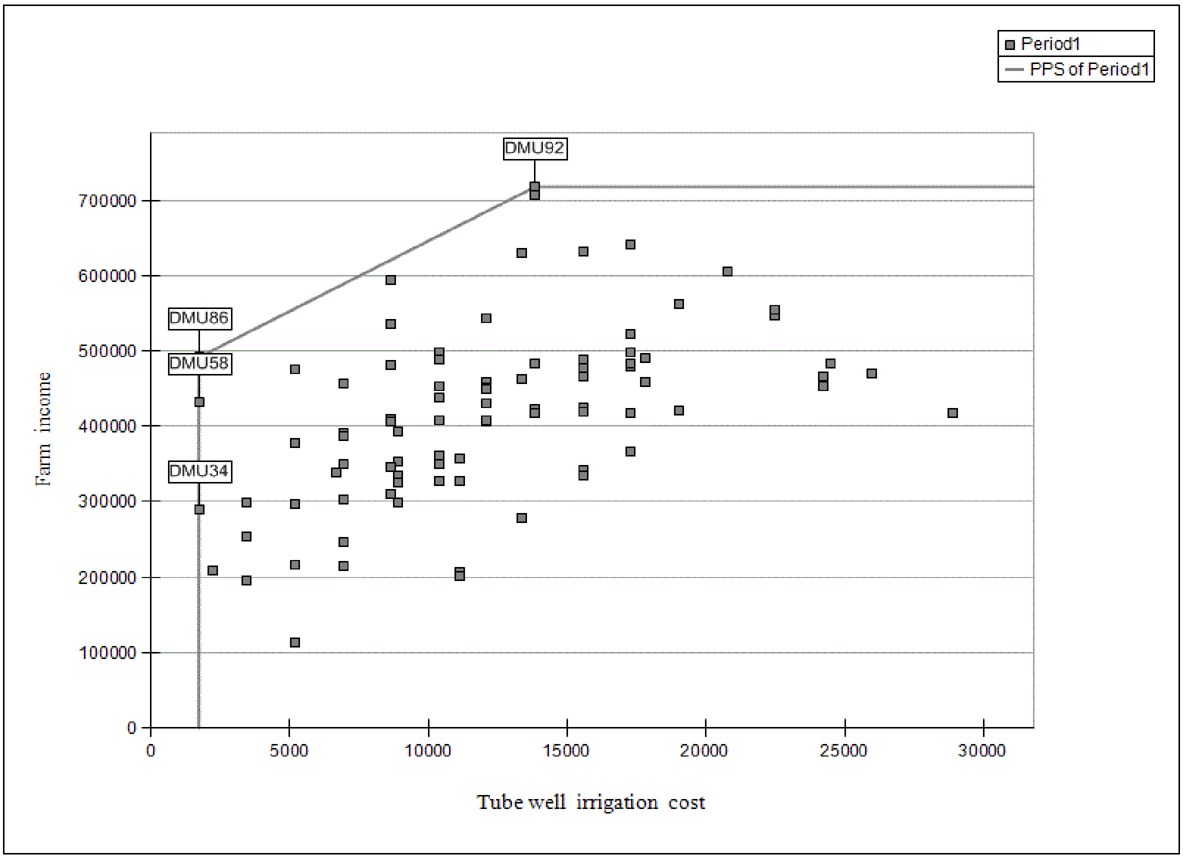

Figure 7.7. Efficiency analysis graph: tube well irrigation cost vs. farm income in FMIS

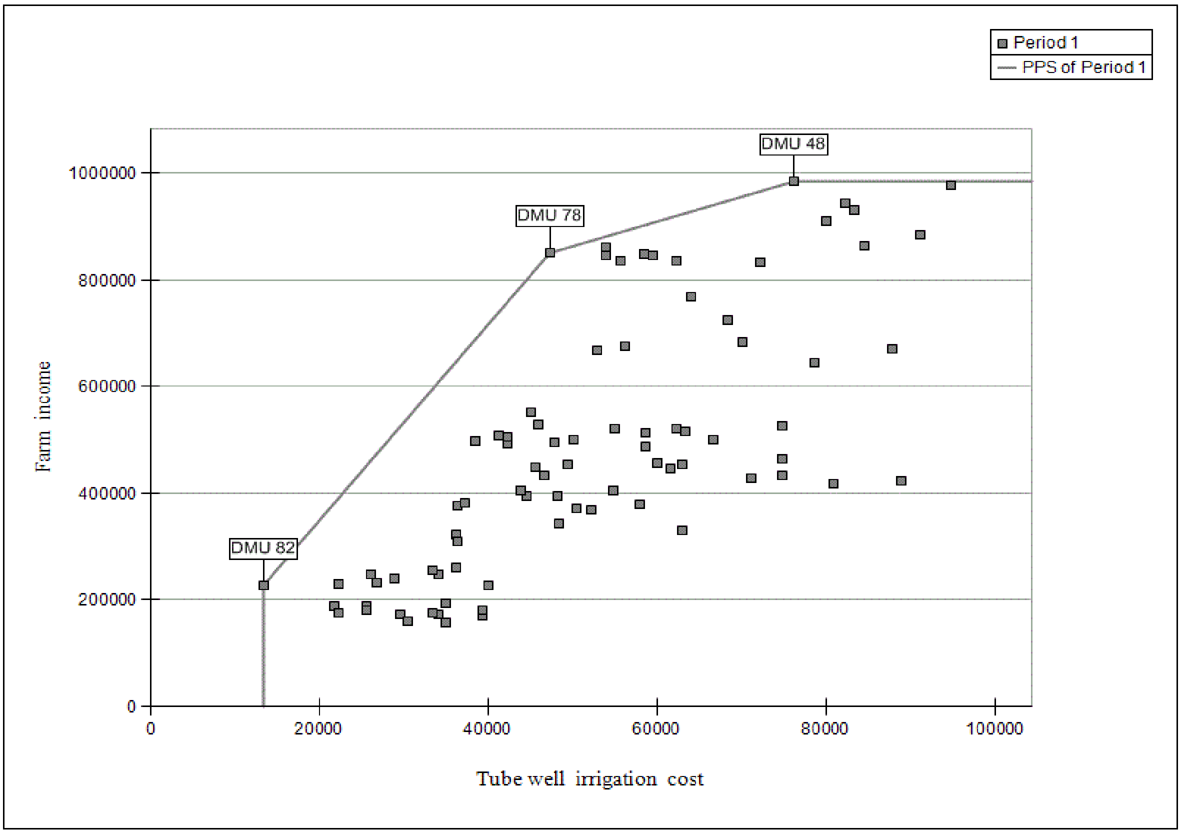

Figure 7.8. Efficiency analysis graph: tube well irrigation cost vs. farm income in GMIS

The inputs considered per farm size are shown in Table 7.7 indicating the difference between actual average values used by inefficient farms and the optimum (target) values mobilized by efficient farms. The large differences form potential gains (percentage of input potentially savable compared to current amount used) which could help in singling out the specific inputs, the use of which could be optimized (reduced).

Table 7.7. Actual value and target value for input use in inefficient farms

Input variables	Farm type*	FMIS			GMIS		
		Actual cost (USD)	Target cost (USD)	Gain (%)	Actual cost (USD)	Target cost (USD)	Gain (%)
Land renting cost	1	-	-	-	725	251	-65.3
	2	-	-	-	725	407	-50.8
	3	-	-	-	725	330	-54.4
Land preparation cost	1	239	213	-8.5	328	251	-19.8
	2	256	231	-8.5	371	282	-20.9
	3	258	239	-6.4	408	346	-13.9
Seed cost	1	299	242	-17.3	171	151	-10.2
	2	308	271	-10.7	503	393	-16.0
	3	336	321	-4.2	770	648	-17.8
Fertilizer cost	1	645	555	-11.8	820	724	-8.9
	2	903	699	-20.2	1395	1174	-15.2
	3	1041	888	-12.8	1762	1430	-17.1
Pesticides cost	1	91	69	-21.8	324	238	-18.8
	2	265	122	-41.6	393	314	-18.2
	3	268	135	-39.7	439	400	-7.7
Tube well irrigation cost	1	128	106	-14.7	709	586	-13.1
	2	191	126	-24.5	753	624	-15.3
	3	231	184	-19.4	757	716	-4.5
Labor cost	1	231	165	-24.3	263	204	-20.6
	2	282	216	-20.2	345	275	-19.1
	3	285	255	-9.1	380	334	-10.6
Harvesting cost	1	361	336	-6.3	400	372	-6.8
	2	491	454	-6.9	453	417	-7.7
	3	549	520	-5.2	512	488	-4.5
Post-harvesting cost	1	441	384	-11.6	210	196	-6.6
	2	496	435	-10.7	425	384	-7.8
	3	522	482	-6.9	666	630	-4.2

* 1 = Small farms, 2 = Medium farms, 3 = Large farms. 1USD =75PKR in 2009-10

The results further suggest that the sources of inefficiencies in FMIS could be focused first on pesticides use, especially in large farms that unnecessarily spend too much on pesticides compared with the efficient farms. However, to a lesser extent, significant economies could also be made on tube-well costs, labour costs, and fertilizer costs. In GMIS, significant economies could be made on costs of land rental, of which all farm types spend too much compared to efficient farms in the same farm groups. Nevertheless, costs on pesticides, labour and land preparation could be optimized although conversely, there is only limited room for reducing the costs for harvesting and post harvesting in all farms as well as with land preparation costs in FMIS. This could be possibly due to the fixed costs imposed by contractors in instances where farmers do not have their own equipment, but there is no clear pattern about farm size and efficiency relationship in either system.

Furthermore, the observed trends actually contradict with each other between the systems where for instance, small farms use relatively more fertilizers or tube wells efficiently in FMIS while this is rather the case for large farms in GMIS.

The farm efficiency analysis also shows that on the overall, farms in FMIS are less efficient than those in GMIS although no effect was noted of the farm size on the technical efficiency. The results should therefore be carefully considered especially that the analysis included only few input factors reflected by some production costs, and is strictly limited to the efficiency in mobilizing these inputs towards optimum farm income. Actually, large farms benefit more from the enabling and supportive environment including extension services and technical advice as well as in exchanging farmers' own experiences and the like. Those factors have not been taken into account in the technical efficiency analysis using DEA. Therefore, the two systems can hardly be compared with each other considering that farms in GMIS seem to benefit more from such amenities.

The questions about tube wells are crucial and far too many. Subsidizing tube well-based irrigation system would only lead to overexploitation of the groundwater, and in fact some parts (head and middle) of FMIS are already extracting saline groundwater. Although tube wells seem to bring higher individual performances at farm level (as shown in the above results), such impact could be temporary since salinization and resource depletion are already looming. Also, such 'atomistic' technology could only lead to the artificial privatization of resources, where many farmers could be disengaged from such collective action since this remains an absolute necessity for only those who have canal water. Finally, tube wells could also introduce much inequity in the system, since only large and better-off farms could have access to such facilities.

This study confirms with the local empirical evidences in the findings of Fan and Chan-Kang (2005) which emphasized that low productivities of small-scale farms in Asia could be addressed through crop diversification of high-value commodities, which can play an important role to improve the small-scale farms' economic performances. Further, the results of this study also support the argument of Griffin et al. (2002) that redistribution of farms through land reforms could improve the production from small-scale farming. Therefore, this study calls for a more comprehensive and integrated approach to institutional reforms in the irrigation systems of Punjab.

7.7 Water supply-demand situation and cropping strategies

This section presents the water supply-demand situation at farm level in both irrigation schemes (FMIS and GMIS). Crop irrigation water requirements are calculated under diverse cropping systems and then results are linked with canal supplies. Pumping of groundwater (volume) is also estimated and further, cropping strategies of farmers are discussed under water deficit situation.

Irrigation water requirement estimation at crop level

For assessing the irrigation water requirement by each crop at field-level of both irrigation schemes, CROPWAT software was used, the results of which are shown in Table 7.8, which also indicates the irrigation water requirement (IWR) by each crop in the farms in FMIS for a period of one year including those for multiple cropping. The cropping calendar shown in Table 3.7 can be linked with the crop irrigation requirements where three crops such as wheat, rice Kharif, and sugarcane are the highest irrigation-demanding crops in FMIS as shown in Table 7.8. Sugarcane and gardens are annual-based cultivated commodities which also require irrigation throughout the year. Some other crops such as rice[1] and maize[3] are cultivated in late Rabi or Spring season but harvested in Kharif season which result in increased requirement for irrigation water due to the rising temperatures in May, June and July. Figure 6.9 confirms the highest irrigation requirement during these months compared to water supplies in FMIS. Furthermore, the details on water supplies compared with irrigation water requirements are discussed thoroughly in Section 6.4 of this document on water balance.

Table 7.8. CROPWAT based irrigation water requirement for crops in FMIS

Crop	IWR (mm)	IWR at scheme level (MCM)
Wheat[2]	235.8	140.84
Cotton[1]	630.9	64.90
Rice[1]	853.8	296.48
Rice[3]	982.7	64.47
Sugarcane	1410.7	894.76
Maize[3]	557.6	22.40
Pulses[1]	319.7	0.16
Pulses[2]	152.1	0.10
Foddar[1]	434.8	87.40
Foddar[2]	207.9	32.99
Garden fruits	730.2	82.05
Tobacco	554	0.39
Oilseed[2]	147	1.07
Vegetables[1]	579.7	26.87
Vegetables[2]	294	5.41
Miscellaneous	387.86	0.80

[1] means Kharif, [2] means Rabi, and [3] means Spring cropping season

In the case of GMIS, the per hectare irrigation requirement is higher than that of FMIS as shown in Table 7.9 which is due to the higher ET_o values and less rainfall (refer to Figures 3.7 and 3.8). Cotton leads all other crops in GMIS in terms of the highest irrigation requirement of 811.61 MCM of water at the whole scheme level. It should also be noted that there is early and long cropping calendar of cotton in GMIS compared with that of FMIS. In the same context, Svendsen and Huppert (2003) reported that an early cropping calendar has been achieved for this commodity as a result of reforms in the irrigation system of the State of Andhra Pradesh in India, although such findings could not be confirmed in this case study of the FMIS. The monthly water requirements in FMIS are shown in Figure 6.8 and in FMIS, monthly irrigation water requirements are given in Figure 6.9.

Table 7.9. CROPWAT based irrigation water requirement for crops in GMIS

Crop	IWR (mm)	IWR at scheme level (MCM)
Wheat[2]	310.3	199.20
Cotton	1642.6	811.61
Rice[1]	1112.7	211.01
Rice[3]	1384.5	119.54
Sugarcane	2083.4	107.05
Maize[1]	548.8	109.40
Maize[3]	697.2	68.26
Pulses[1]	755.1	25.13
Foddar[1]	617.5	101.19
Foddar[2]	213.6	24.71
Garden fruits	1159.9	80.76
Oilseed[2]	211.6	8.14
Vegetables[1]	845.8	61.81
Vegetables[2]	394.3	57.45
Vegetable[3]	240.9	27.85
Miscellaneous	654	52.64

[1]means Kharif, [2]means Rabi, and [3]means Spring cropping season

Supply-demand situation and role of groundwater at farm level

The total water inflow for Burala Canal (FMIS) in 2009-10 was 1029 MCM (million cubic meter) at the point of entry or at diversion used for irrigation purposes which could reduce further after conveyance losses to farm gate level. Unreliable water delivery and too many fluctuations in water supply in the canals (see Figure 6.4), where in most times the available water volume is not enough to fulfill the requirements of current cropping system which is 1721 MCM annually for multiple cropping. Considering that the Burala Canal was initially designed to meet the irrigation requirements for only 65% of cropping intensity, now that intensity has increased up to 110%, it has become difficult for Burala Canal to supply the water demands. Monthly details of water supplies and demands can be seen in Figure 6.8. However, crop wise water requirements are given in Table 7.8. In this water deficit situation, groundwater availability and its usage for irrigation has been discussed earlier in section 6.4 on water networks and water balances.

Irrigation requirement per unit of irrigated area in the command of Burala Canal is 8311 cubic meters however, canal supplies only cover 4558 cubic meter as shown in Table 7.10. Similarly in GMIS, the designed capacity of UPC 81.51 $m^3.s^{-1}$ and its annual peak flow in 2009-10 was 72 $m^3.s^{-1}$. The total water allocated for UPC canal in 2009-10 was 1702 MCM. However, only 1456 MCM was available at the point of entry or diversion to be used for irrigation purposes which is reduce further due to conveyance losses in 156 kilo meter long main canal, then secondary canal and then in tertiary canal levels. However, these supplies are far less to meet the requirements of 2066 MCM by multiple cropping systems in GMIS. In order to meet these farm level deficiencies of irrigation water, farmers use groundwater as a supplementary source which is extremely expensive because of issues highlighted in section 6.4.

Strikingly, this supply is in the canal head which decreased further upon reaching the farm-gate level. This issue gives rise to another issue which deals with governance and managerial problems. In view of the sodic quality of underground water, it can support only requirements up to a certain limit. Improvement in the delivery performances and governance indicators therefore could provide the solution on one hand and improvement in field irrigation efficiency is another option. At any rate, the current water supplies are far beyond less than the water requirements for irrigation taking into account the present cropping patterns.

Table 7.10. Annual situation of water balance at farm level

Water balance indicators	FMIS	GMIS
Total annual IWR (m^3/ha)	8311	12079
Total annual canal water supply (m^3/ha)	4558	5567
% coverage of demand by canal	54.8	46.1
Annual groundwater pumped (m^3/ha)	860	2538
% coverage of demand by tube wells	10.4	21
Annual deficit water (m^3/ha)	2893 (34.8%)	3974 (32.9%)

Table 7.10 shows the water balance situation at farm level on annual basis under multiple cropping systems in both irrigation schemes. Based on the actual situation of cropping diversity at individual farm level, Table 7.10 might not depict the accurate situation of water balance. However, these results show an overall and general picture of water supply and demand. Based on the canal supply situation, both irrigation schemes are water deficit (3,753 m^3/ha in FMIS and 6,512m^3/ha in GMIS) on annual basis with multiple cropping (refer to cropping calendar Figure 3.6). In both irrigation schemes, groundwater contributes a major proportion to cover this deficiency of irrigation water. At scheme level in FMIS, 178 MCM (860 m^3/ha) groundwater is pumped annually which share up to 10.4% to meet total requirements. However in GMIS, share of groundwater is 434 MCM (2538 m^3/ha) which accounts 21% of total irrigation requirements.

Major reasons of more pumping of groundwater in GMIS are; 1) more water demanding crops such as cotton, vegetables, potato and maize, 2) area allocated to these crops is higher, 3) cropping intensity has been increased from 65% to 150%, and 4) evapotranspiration rate is higher. However, after all this, both irrigation schemes are water deficit as discussed earlier, which impact on the crop diversification and productivities. At the time of cultivation, farmers decide which crop should be grown and how much area should be allocated to each crop. These strategic cropping decisions are made based on the access to groundwater. If farmers do not have access to groundwater, they will not select crops to grow such as potato, maize etc. Example of small farmers depicts this situation accurately when they have to wait for rental groundwater for many days. This situation of groundwater markets is true in both irrigation schemes.

7.8 Main findings

The main socio-economic features of farmers that differ in both irrigation schemes are farm size, livelihood and land tenure system. Farmers in GMIS are more experienced in farming, and although with lesser formal education yet they engage in more diverse livelihood and land tenure systems (land renting, access and large sizes). On the farm level performance in both irrigation schemes, some key features that could be highlighted include: (1) farm size positively correlates with diversification (more crops), intensification (cropping intensity, inputs), and ultimately higher farm income per ha; (2) diversification relates to higher inputs (intensification) and higher income per ha; (3) wheat cropping (in

FMIS) and wheat-cotton rotation (in GMIS) are strategic choice but quite specialized, and exclusive of the others systems, requiring low inputs and ultimately providing low income; and (4) maize and rice cropping (and potato in GMIS) fit well in the diversification and intensification strategies leading to higher farm income per ha. Nevertheless, the inadequate financial support and extension services for small farms do not support intensification. Although there is a striking positive link between farm size and diversification, smaller farms grow only limited number of crops which are mostly the least profitable ones. Even if on the overall, farm size has no effect on technical efficiency, farms in FMIS are observed to be less efficient than those in GMIS. Sources of inefficiency in FMIS could be influenced by the costs for using pesticides, tube well irrigation and high labour while those in GMIS by the costs of land rental, land preparation, as well as from the use of fertilizers, pesticides and tube well irrigation. Small farms are not performing well with respect to total income from farming and are not more efficient than the large farms in mobilizing inputs to achieve even a meager result. Farms in GMIS seem to benefit more from the enabling and supportive environment including extension services and technical advice, and exchanging farmers' own experiences. A structural difference between the both irrigation schemes has therefore been found. Moreover, it seems that the farming intensification-diversification threshold has not been met by small farms (less than 2.5 ha). A clear positive relationship between irrigation water availability (access to private tube wells) and farm size has been established which support and sustain the intensification-diversification process leading to increased income from farming. However, based on the cropping calendar, locally prevailed climatic conditions, and biophysical conditions; the irrigation requirement by each crop in GMIS is higher than that of each crop in FMIS. Based on the high cropping intensity in GMIS, groundwater is pumped (2538 m^3/ha) which is much higher than FMIS. Yet, both irrigation scheme are water deficit to fulfill the irrigation requirements.

Chapter 8

Conclusions, Implications and Recommendations

Irrigated agriculture is one of the most important economic sectors of Pakistan. It is primarily supported by the country's vast and historic canal irrigation network, notably in Punjab. Irrigation systems have been performing well-below expectations and capacity over the years, in institutional, management, and operational terms. Water requirements are not met by delivery systems. Insufficient financial basis of management and operation systems leads to limited services. Groundwater is being used to fulfill the deficit canal deliveries which have a certain farm-level implications such as expensive groundwater markets, access to pumping technology, and salinization. These issues result in low farming performances, with low crop productivities. This study constitutes a documented and quantified investigation of performances, efficiencies, and their factors at both irrigation scheme level and farm level performances in Punjab. It is mostly based upon on primary data collected in two irrigation systems under contrasted governance arrangements (Government-, and Farmer-Managed Irrigation Scheme). A combination of analyses is used at three key levels of irrigation governance, management and operation. MASSCOTE approach was applied under contrasted governance system at scheme level. A detailed farm operation analysis including multivariate analysis, performance and technical efficiency analysis is carried out by using DEA. This methodology can be generalized to other parts of irrigated agriculture in Pakistan and elsewhere if conditions meet. Findings of this study are helpful for local and international policy makers, irrigation managers, and for agriculture development agencies for sustainable management of irrigation and agriculture sectors in order to meet the food demands.

The first objective of this study was to describe overall institutional settings existing in these two contrasted governance systems (FMIS and GMIS). Institutional reforms in Pakistan have been implemented with well-defined laws, rules, and administrative structures.

In FMIS, the newly established institutions like AWB, FOs and WUAs in FMIS have specific, pre-defined and documented boundaries of functions and roles under the PIDA Act of 1997 and by various legal frameworks, rules and regulations issued from time to time. Compared with head and middle reaches, tail-end farmers have been given more representation in the general bodies and management committees of FOs and WUAs. Under such revised governance structure, farmers were found to be very motivated and inspired especially in terms of monitoring water theft and outlet tampering, as well as in carrying out inspection procedures and ensuring responsiveness, providing moral and self-respect, and facilitating decisions to be taken by the authorities of FOs and WUAs. However, many farmers have also reported weak governance especially in terms of imposing fines and penalties as well as cost-recovery (due to poor recovery of irrigation services fees), ineffectiveness of capacity building and training, and also in conflict resolution mechanisms.

In the case of GMIS, there had been no amendment or new rules and laws in the Canal Irrigation Act of 1873, although since that time there was only one amendment on irrigation service fees. Farmers in GMIS also reported low transparency, high level of fines and penalties imposed, and inefficiency of authorities to increase recovery of irrigation service fees. Farmers also mentioned poor monitoring and checking against water theft and outlet tempering, poor provision of moral support and overall disrespectful attitude shown to farmers by officials and staff of IPD, weak decision-making and poor responsiveness.

Overall, the empirical assessment shows that farmers in FMIS are getting better services, with institutional settings that are more favorable and supportive, with emphasis on water delivery, social aspects, monitoring of water resources and infrastructure. However, irrigation governance system and institutional settings under FMIS could perform even better if FOs could become the legitimate level to deal with water theft and outlet-tempering, and defaulters of irrigation service fee. The main issue is that the main canal remains under public authorities' control and management.

The second objective of this study was to assess and analyze the performances of both irrigation systems in terms of water supply system and service delivery to users. Using the MASSCOTE approach, the current performances, weaknesses and capacity to support and orientate modernization of irrigation system have been highlighted under the two governance systems in Pakistan.

Several common features were identified such as the old age (more than 100 years) of irrigation structures, wide variations in the availability of water, very low per ha allocation of water, increase in cropping intensity beyond designed capacities (from 65 at construction time to about 150% nowadays), deposition of silt in distributaries and minor canals, deferred and poor maintenance programs, very low water fee compared to MOM cost, widespread water theft, unavailability of water to tail enders, un-gated irrigation structures particularly at secondary canals, tempered outlets, damaged canal banks due to human activities and livestock movements along the canals, among others.

The physical hydraulic infrastructures at main and secondary canals in FMIS have been largely improved and some engineering works are still in progress to meet the irrigation water requirements at farm level. Overall, the system performance, as shown by the internal indicators (i.e. water delivery service, operation of the canal, turnout, communications and general conditions at different levels of canals) seems better in FMIS than in GMIS. The values of the internal indicators of the main canal in FMIS remain low compared to what could be expected in similar conditions (e.g. values observed in Jaunpur Branch Canal in India; Kumar et al., 2010). Also, its secondary and tertiary canals could operate better.

It is observed that the values of most internal indicators are below average, indicating the current poor performance of both irrigation schemes. However, overall performance shown through external indicators (i.e. financial, agricultural productivity and economic aspects) is better in GMIS than in FMIS.

Agricultural output per unit of irrigated area with multiple cropping is slightly higher in GMIS. There is no significant difference in the output per unit of irrigation water supply, while potential in FMIS could provide opportunities to improve water productivity. The cost recovery ratio in FMIS is 0.33, and water fee collection performance is 0.62. In GMIS, the cost recovery ratio is 0.67, and water fee collection performance is 0.85. On an annual basis, water fee collection performance of FOs in FMIS decreased from 83% in 2004-05 to 26% in 2008-09 which is contradictory with the findings of McKay and Keremane (2006) that increase in fee collection could be a result of PIM. This results for a mismatch between service level and fee level, as perceived by farmers, who are dissatisfied with the system. Sensitivity of irrigation structures was also noted to be higher in FMIS than in

GMIS. About 78% offtake structures in FMIS and 35% in GMIS show high sensitivity, producing large variations in the discharge of the distributaries when subjected to given changes in the upstream head. These offtake structures with high sensitivity have been pointed out as the high demanding targets to improve water delivery services in both irrigation schemes. Services to users had also declined from upstream to downstream in both irrigation schemes while a large-scale inequity existed at the secondary and tertiary canals in GMIS. Results from the better service delivery in FMIS orientate the improved performance of IMT. As for the strength of staff, 27% positions of various ranks in FMIS and 26% in GMIS are still vacant affecting the level of monitoring which had considerably declined. In addition, inadequate technical staff prevails in the FOs. Moreover, the budget breakdown of IPD and FOs showed that major portion goes to salaries of staff, where about 80% of the budget of DoI and 55% of the FOs were spent on salaries in FMIS and 71% in GMIS. The total MOM cost per unit area in FMIS was 5 US$/ha and 4 US$/ha in GMIS in 2009-10. The study also reveals that the operational and maintenance expenditures are higher than the total amount of water charges being collected. Moreover, water balance indicators showed a significant gap between the canal supplies and irrigation requirement at the whole system level in both schemes. Results therefore confirm the argument that new farming systems require demand-driven water supply, not supply-driven as is currently widely practiced.

As a conclusion to investigations on objectives 1 and 2, it must be emphasized that while internal indicators (i.e. water supply system indicators in MASSCOTE jargon) and overall institutional setting indicate a better situation in FMIS, external indicators (i.e. sub-systems interacting with water supply: production, finance, economics) illustrate a better situation in GMIS. The sharp decline in irrigation fee recovery in FMIS might result from farmers' frustration and declining motivation, in view of poor farm performance, overall limited water supply (not matching demand) and poor management of water conflicts and theft.

In order to further investigate the interactions between farm and system levels, the third objective of this study was to assess and analyze the operation, performance and efficiency of the irrigation farms.

The overview of the socio-economic traits in both schemes showed few critical differences; only differences could be observed in farm size, livelihood and land tenure systems. Farmers in GMIS are more experienced in farming, and although with lesser formal education but with more diverse livelihoods and land tenure systems that those in FMIS. Such socio-economic differences could not have been affected by the difference in governance, since it had only been few years since the institutional reforms took effect. Results of the pair-wise correlations analyses, PCA and descriptive statistics per farm type concur and confirm the fact that the socio-economic variables hardly interact with the technical factors.

More strikingly, land access and tenure are different. FMIS farmers only access own land, which means operating only in limited area, while many GMIS farmers also rent extra land, which allow them to pursue diverse strategies (e.g. diversification) and to strengthen their financial basis (e.g. for investment in tube-well, hence higher and more reliable water supply). As a result, average land size is bigger in GMIS than in FMIS.

The results of the farming performance analysis concur with general documentation and knowledge, and may be summarized as follows: the larger the farm the larger the financial investment, leading to increased access to reliable irrigation (through groundwater access), inputs, land (renting), labour, and machinery eventually resulting in increased production and more diversification towards skill-, water- and input-demanding crops (sugarcane, then rice, then maize) and risky but high-input crops (potato). The clear positive relationship between irrigation water availability (through access to private tube-well) and farm size had been established. The bigger the farm, the more likely is the ownership of private tube-well. Insufficient reliable irrigation water in all farms, especially for small farms with no access to private tube wells, explains the measures taken by government to guarantee the price of grains.

Small farms usually grow only limited number of crops (specialization instead of diversification), which are also mostly the least profitable commodities. There is a strikingly higher allocation of land for wheat cultivation in small farms; wheat being less demanding in irrigation water, yet also being a less profitable crop.

There is no clear effect of farm size on technical efficiency but smaller farms appear to be not performing well in terms of total farming income, and are also lesser efficient than large farms regarding input use. Also, inadequate financial and technical support to smaller farms hinders profitable strategies such as diversification (e.g. small farms do not benefit extension).

It appears that the starting point to a virtuous loop leading to profitability remains the farm size. As discussed above, this is the main structural difference between the two systems, where the farming intensification-diversification threshold is not met by small farms (less than 2.5 ha). Access to groundwater is also a contributing factor to efficiency since canal irrigation only cannot sustain an intensification-diversification process required to attain improved income. As a result, tube-well irrigation is resorted to as a solution that supports intensification and diversification and for reliable, timely and adequate supply of irrigation water. Through this private tube-well option, irrigation becomes atomistic and individualistic rather than a collective venture. Agricultural development has then little to do with pure collective action and scheme-level institutional arrangements. Under such conditions, it is understandable that IMT and the setup of FMIS do not readily show improvements at the farm level, compared to GMIS.

Whether under farmers or government management, irrigation systems in Punjab will continue to be confronted with concerns related to water – land – farming strategy nexus. Although recent reforms are mostly if not exclusively aimed at changing ways and patterns of canal management, the design of the country’s canal irrigation system was after all not meant for all-farms’ intensification and diversification. Therefore, even if service-oriented and improved management could help in securing more reliable, timely and water delivery, change in irrigation governance at scheme level could only provide one part of the solution. Conjunctive use of groundwater has proven its significance as life security of irrigated agriculture in Punjab. Meanwhile, questions surrounding tube wells are many and crucial because of groundwater governance and its linkages with livelihood (Prakash, 2008), possible environmental impacts (salinization and declining water table) and farmers’ lack of interest in collective actions, and in the end would not be cost-effective. Nonetheless, the future of irrigation in Punjab still lies on its historical assets: canals and groundwater. Supporting to the arguments of Levine (1977) and Coward (1980), the findings of this study calls for strong linkages and assistance from bureaucracy to farmers as farmers cannot emerge spontaneously. In contrast to global successful examples, IMT in Pakistan can only give better results if other surrounding issues are fixed such as farm size, perturbation in canal supplies, agricultural extension services, and education and capacity building of small farmers, proper jurisdiction for revenue collection and conflict resolution, credit and marketing system etc. Therefore, newly established local institutions through IMT (Area Water Board, Farmers' Organizations and Water Users' Associations) in coordination with public agencies will develop new grounds as basis for sound collective actions and small farmers will also be able to get equal services and benefits.

Recommendations

The recommendations of this study are given as follows:

- Proper jurisdiction and enforcement system of Farmers' Organizations (FOs) for collection of revenues and conflict resolution should be revisit and improved while FOs should be more empowered to implement rules and laws in more strict and transparent manners. Alternatively, recovery of revenue can be given back to irrigation Department, just similar to GMIS.
- FOs with deficit technical staff (e.g. engineers, gauge readers, patwaries etc) should ensure the recruitment of technical field staff as per requirement to conduct regular monitoring of high sensitive offtake structures.
- In FMIS, potential areas for improvement for specific sources of inefficiency in farming performance are cost of pesticides, costs of tube wells, labour and fertilizers which could be significantly addressed. In GMIS, prudence could be made significantly on the costs of land rental and marginally on the costs pesticides and land preparation. Awareness campaigns and capacity-building trainings of farmers by Agricultural Extension Department, Agriculture Marketing and Information Service Department and PIDA jointly can play an important role towards efficient, service-oriented and cost-effective mobilization of farm inputs and can facilitate farmers for quality production and its non-monopolized marketing so that all types of farmers can access services and can get equal benefits.
- Irrigation Management Transfer (IMT) can only be one part of the solution. There is still the shared role of both State and local FOs, and WUAs in transferring irrigation schemes for better, timely and equitable services for all types of farms. Reform in the irrigation system of Punjab should be accompanied with land reform and increased farm size, possibly through facilitating arrangements towards tenure flexibility and land renting, as well as reforms of public institutions in order to help small-scale farmers and enable them to have access to credit, extension services, marketing, and farming technology.
- Policy makers should also consider the access to and management issues of groundwater in the future strategies of IMT.

For Future Research

As an emerging issue of groundwater depletion because of continuous deficit canal supplies, a detailed study should be carried out in a multi-dimensional context of water balance, diverse cropping situation, access to groundwater and land.

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APPENDIX-A

Questionnaire number [ ]
Date of interview [--------/ ---------/2010]

Questionnaire Survey

INVESTIGATING IRRIGATION SYSTEMS' PERFORMANCE UNDER TWO DIFFERENT GOVERNANCE SITUATIONS: CASE STUDIES IN PUNJAB, PAKISTAN

Respondent Information

Respondent name	
Address	
Contact No.	

This survey is being conducted to examine socio-economic and physical impacts of governance changes on the water users by the institutional reforms under PIDA act. 1997 in irrigation sector in Pakistan; moreover, this survey is also a part of doctoral research being conducted by the researcher.

(All the information you will provide would be purely used for academic purposes and will be kept in secret)

Asian Institute of Technology
School of Environment, Resources and Development
Thailand
December, 2009

QUESTIONNAIRE: The questionnaire deign is comprising of different sections (mentioned in left column). Each section contains questions both in open and close ended format. For ease in data processing, coding has been done shown in [ ] format. Brief description of each section has also been provided for facilitating the respondent. The questionnaire will be printed on legal paper size for more clarity and space.

Section 1	Members	Gender	Age	Education level	Main occupation	Nature of Farm activity (skills)	Experience of farming
Demography *This section focuses to investigate the demographic information about farmers*	**Key code**	[1] Male [2] Female	Years	[1] Illiterate [2] Primary [3] Secondary [4] Graduate [4] Above	[1] Farming [2] Farming & Govt. job [3] Farming & private job [4] Farming & private business	[1] Sowing/harvesting [2] Cropping practices [3] Irrigation [4] Marketing [5] Others	Years
	Head						
	Spouse						
	Others 1)						
	2)						
	3)						
	4)						
	5)						
	6)						
	7)						
	8)						
	9)						
	10)						

Section 2	Crop	Area	Yield (Monds+Bags)/acre										
Crop production		(Acre)	2009		Price (PKR)	2008		Price (PKR)	2007		Price (PKR)	Best Yield recorded	Expected/potential yield if all conditions met
			Max	Mini		Max	Mini		Max	Mini			
This section gathered information to quantify the farm production	Cotton												
	Wheat												
	Rice												
	Maize												
	Sugarcane												
	Cucumber												
	Potato												

Why there is a difference between potential best yield and actual yield, what do u think?

1) Water shortage 2) Input supply problem 3) Post-harvest problems 4) Unfavorable weather conditions 5) Any other………………

Section 2A	Type of Input	Commercial Name	Wheat	Cotton	Rice	Sugarcane	Maize	Potato	Market price
Crop budget			bags/acre	bags/acre	bags/acre)	bags/acre	bags/acre	bags/acre	PKR/unit
This section seeks the information about the under-practice inputs per crop and their market prices.	Fertilizers	Urea							
		DAP							
		SSP							
		Potash							
		Farm-manure							
		Zinc							
	Agro-chemicals		Number/acre	Number/acre	Number/acre	Number/acre	Number/acre	Number/acre	
		Pesticide							
		Insecticide							
		Fungicide							

Section 2A	Type of Input	Commercial Name	Wheat		Cotton		Rice		Sugarcane		Maize		Potato		Market price
Crop budget			Number/acre		Number/acre		Number/acre		Number/acre		Number/acre		Number/acre		PKR/unit
	Land preparation	Tillage													
		Disc plough													
		Leveling													
		Ridger													
	Tube well irrigation		no	hr/irri	no	hr/irri	no	hr/irri	no	hr/irri	no	hr/irri	no	hr/irri	
	Harvesting	Harvesting cost													
		Threshing cost													
	Post-harvesting	Packaging/bagging													
		Storing													
		Transportation													

Section 2A	Crop	Task	No of people	No of hours	Cost
Labour	Wheat	Seed broadcasting			
		Fertilizer			
		Irrigation			
		Chemical application			
		Threshing			
	Cotton	Sowing			
		Fertilizer			
		Irrigation			
		Chemical application			

		Task	No of people	No of hours	Cost
	Rice	Irrigation			
		Fertilizer			
		Chemical application			
	Sugarcane	Seed broadcasting			
		Fertilizer			
		Irrigation			
		Chemical application			
	Maize	Sowing			
		Fertilizer			
		Irrigation			
		Chemical application			
		Threshing			
	Potato	Sowing			
		Fertilizer			
		Irrigation			
		Chemical application			
		Harvesting			

Section 3	**Cropping Calendar**				
Land preparation + Manuring	[1]	Insecticides spray	[4]	Harvesting	[7]
Sowing	[2]	Irrigation starts	[5]	Drying/threshing	[8]
Weeding/herbicides spray	[3]	Irrigation ends	[6]	Marketing	[9]

Crop	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Wheat												
Cotton												
Rice												
Sugarcane												
Maize												
Potato												
Cucumber												
Pulses												
Fodder												

Which are the main kinds of higher expenditures and for what?

(1) For buying farm-inputs (2) For tub well irrigation (3) Farm labour (4) Any other (please specify)……………………………………….

Please mention months with highest income………………………………and month with lowest income…………………………………...
Please mention months with highest expenditures………………………and months with lowest expenditures…………………………….

Section 4 **Source of income** *This section focuses to investigate the major sources of income and its regularity and sufficiency*	What are the main sources of household income?	[1] Agriculture [2] Salary [3] Pension [4] Rent [5] Others, specify [ ]		
	What is average total HH income per month?	[ ] PKR	Income regularity [1] Yes, [2] No, if no please give reason? …………………………………………..… ………………………………………..……	
	Does the present HH income is sufficient against your expenditures? [1] Yes, [2] No, if no please give reason? ………………………………………………………………………………………… …………………………………………………………………………………………			

Section 5 **Physical & natural capitals** *This section seeks the information about the physical capital of the water users*	Means of communication	[1] Landline [2] Mobile (3) Any other…….	Utilities	[1] Electricity [2] Gas [3] Telephone [4] Water supply
	Landholding size (acre)	[1] < 1 [2] 1 to 2.5 [3] 2.5 to 5 [4] > 5 to 12.5 [5] > 12.5	Availability of farm machinery	[1] Tractor and trolley [2] Tiller [3] Leveler [4] Ridger
	Status of farm land	[1] Rented…..acres [2] Owned…...acres	Status of farm machinery availability	[1] Rented [2] Shared [3] Owned
	Location of farm	[1] Head [2] Middle [3] Tail	Means of Transportation	[1] Private [2] Rented [3] Others
	Tube well	[1] Rented [2] Owned	Type of farm to market roads	[1] Katcha [2] Pacca [3] Others
	How do you report the quality of soil in the area? [1] Very good [2] Good [3] Fair [4] Bad			
	How do you report the availability of surface water? [1] Very good [2] Good [3] Fair [4] Bad			
	How do you report the quality of underground water? [1] Very good [2] Good [3] Fair [4] Bad			
	How do you report the quality of roads? [1] Very good [2] Good [3] Fair [4] Bad			
	How do you report the physical conditions of main water channels? [1] Very Good [2] Good [3] Fair [4] Bad			
	How do you report the physical conditions of farm water channels? [1] Very Good [2] Good [3] Fair [4] Bad			

<table>
<tr><td rowspan="13">Section 6

Social capital

This section access the impact of governance change in term of participating in community level activities</td><td colspan="2">Are you a member of any WUA organization? [1] Yes or [2] No.
If yes then as a [1] Executive member [2] Member as a water user</td></tr>
<tr><td>What kind of contribution you render to this organization?</td><td>[1] Operation & maintenance
[2] Planning
[3] Meeting organization
[4] Others, please specify
[ ]</td></tr>
<tr><td>How often you participate in O&M activities?</td><td>[1] Every time
[2] Mostly
[3] Some time
[4] Never, Why? [ ]</td></tr>
<tr><td>How often you participate in</td><td></td></tr>
<tr><td>What is your level of participation in planning and training?</td><td>[1] Very low
[2] Low
[3] High
[4] Very high</td></tr>
<tr><td>What is your level of participation in training organized by WUAs?</td><td>[1] Very low
[2] Low
[3] High
[4] Very high</td></tr>
<tr><td>What is your status of participation in trainings and meetings?</td><td>[1] Just as a silent member
[2] Active member</td></tr>
<tr><td colspan="2">How many training you have attended? [ ]</td></tr>
<tr><td colspan="2">Do you have any affiliation with political party? [1] Yes , [2] No</td></tr>
<tr><td colspan="2">Number of political dispute resolve? [ ]</td></tr>
<tr><td colspan="2">Number of farm workers? Male [ ]
Females [ ]</td></tr>
<tr><td colspan="2">Do you get support from your friend and relatives? [1] Yes , [2] No</td></tr>
</table>

<table>
<tr><td rowspan="8">Section 7

Coordination among the water users, WUA and external environment

This section focuses to investigate the major sources of income and its regularity and sufficiency</td><td>Do you have access to credit?</td><td>[1] Yes
[2] No</td><td>How many credit institutes present in the area? [ ]</td></tr>
<tr><td>Do you have any borrowed loan?</td><td>[1] Yes
[2] No</td><td>If yes, then how much amount is outstanding towards you?
[ ]</td></tr>
<tr><td colspan="2">Does do you get the pre-season announcement of support price of farm product?

[1] yes
[2] no</td><td>Do you have any savings?

[1] yes
[2] no</td></tr>
<tr><td colspan="3">Do you have access to the extension services? [1] Yes [2] No</td></tr>
<tr><td colspan="3">Do you have access to the weather data? [1] Yes [2] No</td></tr>
<tr><td colspan="3">Do you plan your farm activities according to weather forecast? [1] Yes [2] No</td></tr>
<tr><td colspan="3">What type of farms goods marketed in the local markets?
____
____
______________________________</td></tr>
</table>

<table>
<tr><td>Section 8

Occurrence level
This section will incorporate the respondent's level of occurrence on different farm level activities and societal response</td><td>Read the statement and cross (X) against the number that is closely depict your occurrence level regarding the statement presented.

<table>
<tr><td rowspan="3">Statements</td><td colspan="4">Level of occurrence</td></tr>
<tr><td>[1]</td><td>[2]</td><td>[3]</td><td>[4]</td></tr>
<tr><td>Mostly</td><td>Sometimes</td><td>Occasionally</td><td>Never</td></tr>
<tr><td>Water sharing</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Technology sharing</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Casual meetings with relatives & friends</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Collecting marketing of farm inputs and outputs</td><td></td><td></td><td></td><td></td></tr>
</table>
</td></tr>
</table>

Section 9		
Governance	What does u think about the transparency of your irrigation system in financial and organizational matters?	[1] Highly transparent [2] Less transparent [3] Not transparent
	What is the level of fines & penalties imposed on farmers by authorities against illegal actions?	[1] Too much fine [2] Little bit fine [3] No fine at all
	What is the level of recovery of fines & penalties imposed from farmers?	[1] Recovered always [2] Partial recovery [3] No recovery
	What is the level of responsiveness by authorities regarding complaints and actions?	[1] Quick response & action [2] Delayed response & action [3] No response & action
	What is your satisfaction level by the decision taken by authorities?	[1] Satisfies [2] A bit satisfied [3] Not satisfied
	What is your opinion about provision of self-respect and moral support?	[1] More respect [2] Less respect [3] No respect
	What is your opinion about the level of monitoring & check by authorities against water theft & outlet tempering?	[1] Excellent [2] Good [3] Bad
	What is your opinion about the level of effectiveness of capacity building trainings?	[1] Very informative & useful [2] Somewhat useful [3] Wastage of time

Section 10 **Problems, needs, and suggestions** *This section will find out the major problems being faced by the farmers' family and will access their immediate need and asks for suggestion for future.*	What are the main problems you are facing after the policy intervention? …………………………………………………………………………… …………………………………………………………………………… …………………………………………………………………………… What are your immediate needs that you prefer to avail in order to solve these problems? …………………………………………………………………………… …………………………………………………………………………… …………………………………………………………………………… Any suggestion for the improvement of our irrigation system? …………………………………………………………………………… …………………………………………………………………………… ……………………………………………………………………………

Appendix-B

Checklist for Interviews

Government and NGO officials

1) What is the main functionality of your office?
2) How do you perceive the policy of institutional reforms in the water management sector?
3) Do you agree that water management institutions are more stronger after institutional reforms?
4) Do you agree that water management institutions are technically performing better after institutional reforms?
5) Do you agree that water management institutions are economically performing better in terms of revenue collection and budgeting after institutional reforms?
6) What are the main lacking things (social, economic, technical and institutional) that are required for the proper operation of irrigation system?
7) Do you believe that Farmers' Organizations (FOs) and Water Users' Associations (WUAs) are successful in terms of ensuring water at tail-ends?
8) How often and regularly, your office is organizing trainings, workshops and meetings for farmers' awareness?
9) How do you perceive about the farmers' participation in water management?
10) What is the level of satisfaction of farmers about irrigation system performance?
11) Do you think, farmers are happy and enjoying the services provided by your office after institutional reforms?
12) Do you think that ratio of water related conflicts are decreasing after the transfer of water management powers to farmers?
13) What are the major proses and cons of PIDA Act. 1997?
14) Do you think that transfer of water management powers to farmers is feasible/successful in Punjab?
15) What are the procedures and mechanisms you adopt to handle the water related issues?
16) What are the main problems you face while handling the water related issues?
17) What do you suggest to tackle these problems?
18) What do you suggest to improve the overall performance of the irrigation system?

Politicians

1) How do you perceive the policy of institutional reforms in the water management sector?
2) According to your opinion, what are the major proses and cons of PIDA Act. 1997?
3) Do you think that transfer of water management powers to farmers is feasible/successful in Punjab? If not then why?
4) What necessary steps government should take for the better management of our irrigation system?
5) What necessary and immediate actions your office takes in case of any water related issue at local level?
6) What would you suggest to improve the performance of our irrigation system?

Lawyers

1) How do you interpret the policy of institutional reforms in the water management sector?
2) How do you perceive about the farmers' participation in water management?
3) What type of water management related services your office is providing to water users?
4) What are the legal implications of PIDA Act. 1997 on the water management, water allocation, O&M and related conflicts on local level?
5) Do you think that ratio of water related conflicts are decreasing after the transfer of water management powers to farmers?
6) What would you suggest to improve the performance of our irrigation system?

Intellectuals (Academicians)

1) What is the main functionality of your office in irrigation system management?
2) How do you interpret the policy of decentralization in water management sector?
3) Do you think that transfer of water management powers to farmers is feasible in Punjab? How is future of PIDA?
4) Does your office coordinate with department of irrigation and farmers? If yes then how?
5) Does your office conduct trainings and courses for capacity development of students, farmers and staff of irrigation department?
6) What is the scale of research under your research centre?
7) What is the nature of research going on under your office?
8) Have your office introduced any course on IWRM, Water Governance and PIM?
9) What would you suggest to improve the performance of our irrigation system?

Village heads

1) How do you perceive about the farmers' participation in water management?
2) Are farmers are more organize in terms of farm activities?
3) Is this system of management is facilitating the farmers in terms of water distribution, O&M activities and revenue collection?
4) What are the main advantages and disadvantages of this system at local level?
5) Do you think that ratio of water related conflicts are decreasing after the transfer of water management powers to farmers?
6) Do you think, farmers are happy and enjoying the services provided by Farmers' Organizations (FOs) and Water Users' Associations (WUAs)?
7) What are the main lacking things (social, economic, technical and institutional) that are required for the proper operation of irrigation system?
8) What is your opinion about the crop productivity after institutional reforms? Is there any change?
9) Do you think that the livelihood status of farmers is being improving after institutional reforms?
10) What would you suggest to improve the performance of our irrigation system?

Appendix-C

Existing Management Unit at secondary canals of Burala Canal	
Name of Farmer Organization	**CCA (ha)**
Dulchi Distributary	2,454.3
Nopewala Distributary	5,855.1
Ranjiana Distributary	2,640.1
Duravan Distributary	3,397.6
Pithorana Distributary	3,077.3
Naurang Distributary	4,510.1
Arif Distributary	3,126.7
Obhal Distributary	3,400.4
Pervaiz Distributary	3,425.1
Tandlianwala Distributary	27,415.8
Bhalak Distributary	23,076.9
Balouchwala Distributary	3,282.6
Munianwala Distributary	3,004.0
Killianwala Distributary	27,232.0
Samundari Distributary	6,423.5
Farooq Distributary	5,078.9
Bhoja Distributary	17,066.0
Ditch Distributary	2,388.3
Waghi Distributary	8,382.2
Kamalia Distributary	5,425.1
Gharak Distributary	1,415.8
Kabirwala Distributary	20,810.5
Kallar Distributary	6,897.2
Kallera Distributary	4,594.7

Appendix-D

MASSCOTE framework

Mapping……... Phase A - Baseline information	
1. Rapid diagnosis	This involves diagnosis and performance assessment through RAP. The objectives are (a) to identify systematically key indicators of system in order to prioritize modernization improvement (b) to mobilize actors for modernization (c) to generate a baseline against which progress can be measured.
2. System capacity and sensitivity	Assessment of the physical capacity of irrigation structure and their ability to perform the function of conveyance, control, measurement etc. (b) Assessment of the sensitivity of irrigation structures (offtakes and regulators) identification of singular points, mapping the sensitivity.
3. Perturbations	Causes, magnitudes, frequency and options for coping perturbations.
4. Water networks and water balances	Assessment of hierarchical structures and the main features of irrigation, water balances at systems and subsystem levels considering both surface and ground water along with opportunities and constraints related to them.
5. Cost of O&M	Current costs related to operation techniques and services, disaggregating the cost into its elements, costing of various levels of services with current and improved techniques.
Mapping........... Phase B - Vision of SOM & modernization of canal operation	
6. Service of users	Range of services to be provided to users
7. Management units	Division of irrigation and service area into homogenous subunits
8. Demand for operation	Assessment of resources, opportunities and demand for improved canal operation of entire service area/subsystem unit
9. Canal operation improvements	Identifying improvement options for each management unit (a) water management (b) water control (c) canal operation
10. Integration of options	Aggregating options at the system/subsystem level, design of overall information management system for supporting operation.

Appendix-E

Details of data required for RAP and MASSCOTE approach

Steps	Purpose	Data Specification
RAP	To assess the current performance of the system	• Volume of water available at user level • Seasonal water supplied or delivered • Rainfall • Evaporation • Irrigated area • Command area • Total management, operation and maintenance cost • Total revenue collected • Total no. of employees engaged in a particular canal and their costs • Value of agricultural production • Financial, Agricultural and economic indicators
System sensitivity	To analyze the sensitivity of irrigation structures	• Water level • Discharge
Perturbation	Reason of perturbation, magnitude and frequency	• Daily water level data • Daily discharge data
Service to users	To analyze the existing service and other possible options of services	• Flexibility • Reliability • Equity • Adequacy
Cost of operation	To assessing the cost of present operation techniques and services, cost of improved services and cost of management, operation and maintenance (MOM)	• Cost data related to MOM • Budget of Irrigation Department • Budget of Farmers organizations • Cost of groundwater abstraction
Demand for canal operation services	To analyze the opportunity and demand for canal operation	• Sensitivity of cross regulator • Tolerance on water level control • Discharge data
Partitioning of management units	Divide the command area in subcommand areas	• Existing management committee at different levels of canal and their service area etc.
Canal operation improvement	Identification of improvement option by considering water management, water control and canal operation	• Analysis of all previous step

Appendix-F

Some selected photos captured during field surveys

A discussion with large farmers

A discussion with small farmers

A view of a broken outlet at tertiary canal

An offtake structure at main Burala Canal

A structure for livestock water drinking at main Burala Canal

A view of a newly lined secondary canal in Burala Canal Irrigation Scheme

Head regulator of main UPC at Sulemanki Headworks

Broken banks and silt condition in a secondary canal of UPC Irrigation Scheme

A view of mechanized wheat threshing

Woman labor sowing cotton crop on furrows as a water saving technique commonly in UPC Irrigation Scheme

A tube well pumping groundwater from a depth of more than 300 feet

A view of water deficit maize crop