A Comparative Study of Improved and Traditional Irrigation System in the Gilgit District of Northern Areas of Pakistan: From the Farm Management Perspectives

パキスタン北部ギルギット地域における改良型/伝統型灌漑システムの比較研究

－農業経営学の視点から－

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A Dissertation

By

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DEDICATION

*This dissertation is dedicated to the memory of my beloved (late) **FATHER**, who strived to give me the best; prepared me to face challenges with faith and humility. Although he is not here to give me strength and support I always feel his presence which motivates me to strive to achieve my goals in life.*

*May **ALLAH** (SWT) forgive him and make the paradise his permanent residence.*

And also

*I would like to dedicate this thesis to my loving **MOTHER** whose prayers and faith in **ALLAH** (SWT) were what brought me through to completing this thesis.*

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CHAPTER I

GENERAL INTRODUCTION

1.1 Background of Research

Pakistan has a rich and vast natural resource base, covering various ecological and climatic zones; hence the country has great potential for producing all types of food commodities (FAO, 2000). Agriculture has an important direct and indirect role in generating economic growth. Agriculture is the largest sector of the economy and plays a pivotal role in economic development of Pakistan. Pakistan is predominantly an agriculture country. In spite of favorable condition of soils, irrigation water and climate, agriculture suffers from low production in terms of yield per hectare.

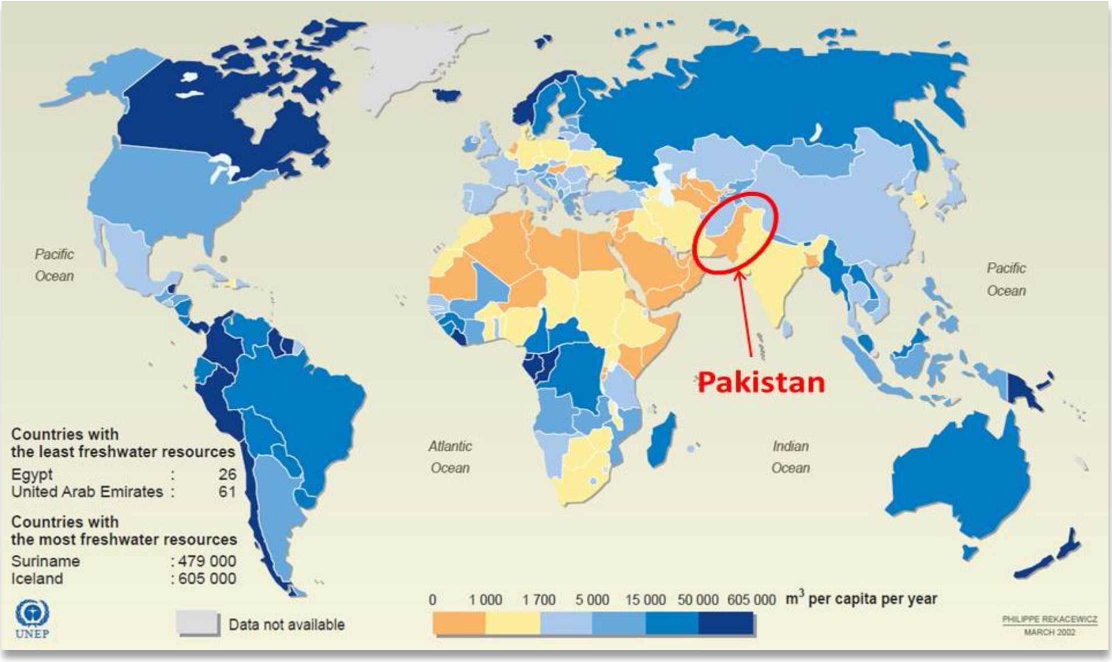
Water is important for human and plant life on the earth. It plays a critical role in the sustainable livelihoods of rural people. Improvement in access to water serves as a strong tool to increase livelihoods and decrease vulnerability for small farmers, since irrigation water generate choices for extended production across the year, increases yield and creates employment opportunities. Agricultural productivity has also improved in recent decades due to usage of hybrid seeds, increased fertilizer use, and major investments in water resources infrastructure. A huge investment in irrigation infrastructure has been the key component of the Green Revolution. Agriculture today accounts for about 80% or more of water withdrawals in developing countries (Cai, et al., 2001). As populations continue to grow further, the demand for agricultural water will increase and irrigation will be required to provide increasing share of total food production to meet the growing food demand (Rosegrant and Ringler, 1998).

Agriculture is the largest consumer of water, to fulfill the demand for increasing population of the earth, is putting more pressure on the agriculture sector, especially for the food requirements. Irrigation water can be consider the single most important element for the agriculture growth, is even under more stress as compared to other inputs due to limited supplies. Need for improvement in efficiency and productivity of irrigation water has become one of the key issues for the irrigation as well of the agriculture sector (Raza, 2009). The world experiences on irrigated agriculture have clearly showed that without joint approach of water resources including irrigation, drainage and environment, the agricultural productivity and sustainability would not be possible in the developing countries. The linkages and coordination among all stakeholders of irrigated agriculture is the most important institutional intervention.

1.2 Irrigation Water Availability at Global Level

Amongst global resources, water is emerging as the most critical but misused natural resource. It is an important input to agricultural production and an essential requirement for many domestic, municipal and industrial activities. Growing national, regional and seasonal water scarcities in much of the world pose severe challenges to agricultural development. The challenges of growing water scarcity are increased by the increasing costs of water development, and wasteful use of already developed water supplies. Until the late 1800s, the bulk of irrigation in the world was developed by users and operated through a participatory process at the village level. These irrigation systems were developed, operated, and maintained using local resources largely provided by the water users. Working together, users made decisions about water allocation, established priorities for repairs, system expansion and jointly established contributions in cash and kind to be provided by all who received irrigation and drainage services from the system (Martin et al., 1986).

This graphic shows the availability of freshwater through average river flows and groundwater recharge, in cubic meters per capita per year, at the national level in the year 2000. The graphic highlights the countries with the least freshwater resources (Pakistan, Egypt and the United Arab Emirates).



Source: World Resources 2000-2001: People and Ecosystems: World Resources Institute, Washington DC (2000)

Figure 1.1: Freshwater availability: groundwater and river flow (2000)

According to the Comprehensive Assessment of Water Management in Agriculture, one in three people are already facing water shortages. Around 1.2 billion people, or almost one-fifth of the world's population, live in areas of physical scarcity, while another 1.6 billion people, or almost one quarter of the world's population, live in a developing country that lacks the necessary infrastructure to take water from rivers and aquifers (known as an economic water shortage).

Among the stakeholder having experience in Irrigation Management Transfer (IMT) USA, Mexico, Australia and Turkey are few good examples. Countries, such as Chile, Mexico and China, are well along in this process. Other countries, such as Indonesia and the Philippines, and some States in India have embarked on transfer programs but appear to be bogged down in problems of implementation. Some countries have transferred small scale systems and now are considering transferring large scale systems (Vermillion and Sagardoy, 1999). Table 1.1 shows list of countries that have adopted irrigation management policies over the last 30 years.

Table 1. 1: Countries or States Those have Adopted IMT During the Past 30 Years

Latin America	South, South East and East Asia	Africa& Near East	Europe &Central Asia
Brazil, Chile, Colombia, Dominican Republic, Ecuador, El Salvador, Guatemala, Peru, Mexico	Bangladesh, China, India, Indonesia, Laos, Nepal, Pakistan, Philippines, Sri Lanka, Vietnam	Ethiopia, Ghana, Jordan, Madagascar, Mali, Mauritania, Morocco, Niger, Nigeria, Senegal, Somalia, South Africa, Sudan, Turkey, Zimbabwe	Albania, Armenia, Bulgaria, Cyprus, Georgia, Kazakhstan, Macedonia, Moldova, Romania

Source: Vermillion and Sagardoy, (1999)

The development of irrigation in 20th century played an important role in generating food surplus that have led to economic development in Asia. Over 60% of the world's irrigation is in Asia and since 1965 the irrigated area has almost doubled (Barker, 2002).

1.3 Agricultural and Economic Scenario of Pakistan

Pakistan is basically an agricultural country. Agriculture is the mainstay of Pakistan's economy. It is not only the importance of the population, directly or indirectly for seeking food, clothing employment and perhaps everything but also viewed as a dominant way of life. In Pakistan, irrigated agriculture covers 16.2 million hectare (74%) out of the total cultivated area of 22 million hectare. Irrigated agriculture uses 97% of the available water and provides over 90% of agricultural produce (Shaikh, 2004). Agriculture accounts for 20.9% of GDP, and employs 43.4% of labor force

There are two principal crop seasons in Pakistan, namely the (*Kharif*) wet season and the (*Rabi*) dry season. Rice, sugarcane, cotton and maize are major *Kharif* crops while wheat, gram, lentil tobacco, vegetables, potato, barley and mustard are *Rabi* crops. In the dry season, fodder crops are produced in the irrigated areas because of high importance of livestock sector in Pakistan (Nakashima, 1998). Major crops such as wheat, rice, cotton and sugarcane account for 88.7% of the value added in the major crops. The major crops accounts for 36.3% of the overall agriculture. Thus, the four major crops (wheat, rice, cotton, and sugarcane), on average, contribute 32.2% to the value added in overall agriculture. The minor crops account for 11.7% of the value added in overall agriculture (GOP, 2007).

Table 1.2 compares area occupied by important crops in Pakistan and it provides prominent evidence that increase in area under cash crop cultivation is negligible compared to major crops like wheat, cotton, rice, sugarcane, etc. During 1972, area under wheat cultivation was reported to be 16.01 million acres, which increased to 23.40 million acres in 2000 showing a change of more than 46%. Potato area has increased from 0.08 million acres in 1972 to 0.24 million acres in 2000.

Table 1. 2 : Area under Important Crops in Pakistan (million acres)

Crops/year	1972	1980	1990	2000
Wheat	16,01	17.94	20.18	23.40
Rice	4.42	5.53	5.98	7,21
Cotton	5.90	5.73	6.62	7.91
Sugarcane	1.23	1.61	1.78	2.18
Maize	1.68	1.34	2.04	2.16
Oil seeds	1.34	1.21	l.11	1.13
Pulses	3.98	3.62	2,60	3.15
Fodders	6.74	6.72	6.81	6.14
Potato	0.08	0.12	0.27	0.24
Vegetables	0,69	0.69	1.31	1.18
Orchards	0.41	0.58	0.95	0.94

Source: Government of Pakistan. 2000

The area under potato is very small compared to the wheat area during the same period. However, vegetables excluding potato have increased the area from 0.69 million acres in 1972 to 1.18 million acres in 2000 implying a change in vegetable area by 71%. Although the change in vegetable area is higher compared to that of wheat, nevertheless, area under vegetable cultivation is nominal compared to wheat and other major crops. The large farmers are more interested in growing major crops like wheat, cotton, rice, sugarcane, etc. and they do not take interest in growing vegetables except potato due to intensive care required in vegetable cultivation from sowing to marketing. The small potato and vegetable area in Pakistan causes low vegetable production.

Low yield per acre is another crucial factor causing small vegetable production. It is said that with increased use of inputs, yield also increases. But Byerlee, (1992) reported that the input use level per acre is moderately high in Pakistan. In spite of this higher level of input use, there exists gap between potential yield at the experimental station and observed yield at the farm level.

Moreover, yield of vegetables in Pakistan is far below compared to other Asian countries. By looking at Table 1.3 it is found that Pakistan has very low yield of vegetables compared to neighboring Asian Countries. The gap in yield of potato between Pakistan and Taiwan is substantial, amounting 34 tons per acre. However, per unit yield of potato is higher in Pakistan than India and China. Onion is another important vegetable consumed in a bulk quantity. Onion yield per acre is higher in Pakistan than India but the gap in the yield between Pakistan and China is 22 tons per acre.

Table 1. 3 : Comparison of Vegetable Yield (t/ac) in Different Countries

Vegetables/Counties	China	Taiwan	India	Pakistan
Potato	16.33	51.00	12.00	17.00
Onion	35.00	-	10.00	13.00
Carrot	-	51.00	-	19.00
Tomato	39.00	55.00	17.00	19.00
Radish	39.00	45.00	-	9.00
Bitter gourd	-	19.00	-	12.00

Source; AVRDC, 2000, 2002; Government of Punjab, 2002

This yield gap between Pakistan and China or Taiwan can be attributed to the differences in the farmers' fields, managerial qualities and availability of technology. Even within farming community in Pakistan, yield varies from farmer to farmer with the same use of inputs and other facilities in a particular area or region. Dissimilarities in farm management practices are possible sources of technical inefficiency. Pingali and Heisey, (1999) are of the view that the benefits of the latest technologies cannot be realized in the presence of higher technical inefficiency. Thus, the existence of technical inefficiencies leads towards offsetting the potential gains of high technologies.

1.4 Current Situation of Water Availability in Pakistan

In Pakistan, average rainfall is less than 240 mm a year. Pakistan is located entirely in the temperate zone and within the monsoon belt the position of high mountain ranges in the north keeps its climate generally as arid and semi-arid, tropical and sub-tropical. The rainfall is strongly influenced by the monsoon circulation. The low precipitation level means that rain-fed agriculture is not possible on a large scale in Pakistan.

The irrigated agriculture of Pakistan mainly depends on Indus River System and its tributaries. The annual flow of Indus River is 143 million acre feet (MAF) out of which 103 MAF are diverted into different canal commands. Being semi-arid climate of the country, having an annual rainfall of 240 mm, the 90% of the irrigated agriculture is being carried out in Indus Plains. The 80% flow of the Indus River is generated during monsoon i.e. from June to September, which necessitates effective water management for sustainability of irrigated agriculture (Qureshi and Haq, 2006). Pakistan's agricultural output is closely linked to the supply of irrigation water. Actual surface water availability in Pakistan against the normal surface water availability is shown in Table 1.4.

Table 1. 4 : Actual Surface Water Availability (million acre feet)

Period	Kharif (Wet season)	Rabi (Dry season)	Total	% increase/decrease Over the average
Avg. system usage	67.1	36.4	103.5	-
2003-04	65.9	31.5	97.4	-5.9
2004-05	59.1	23.1	82.2	-20.6
2005-06	70.8	30.1	100.9	-2.5
2006-07	63.1	31.2	94.3	-8.9
2007-08	70.8	27.9	98.7	-4.6
2008-09	66.9	24.9	91.8	-11.3
2009-10	67.3	26.0	93.3	-9.9

Source: IRSA, 2011 and GOP, 2011.

The water availability during *Rabi* season is estimated at 26.0 MAF, which is 28.6% less than the normal availability, and 4.4% more than 2008-09 year's *Rabi* season. Thus, it is clear from the above table that water availability during the last many years have gone down. The pressure on the available water resources increase in terms of increased domestic and industrial uses, increased agriculture activities required to feed the growing population. Since all these uses are interrelated with each other and increased use of one component may affect the other.

The irrigation sector plays a vital role in the food supply as well as in the economy of Pakistan. The Indus Basin Irrigation System (IBIS) of Pakistan is the largest contiguous irrigation system in the world, serving in excess of 14 million hectares (Johnson III, 2004). The IBIS of Pakistan is now facing multiple problems like deterioration of infrastructure, high conveyance losses and inequitable water distribution both under normal supply and shortage conditions. Keeping in view the above mentioned problems the World Bank proposed that involving of the stakeholders in decision making and operation and maintenance process of the irrigation system is the only solution for rehabilitation of the existing irrigation systems. Consequently, the government of Pakistan agreed to introduce institutional reforms in the irrigation sector of provinces and different regions. Therefore, in 1997 Pakistan's provincial Assemblies passed bills to implement institutional reforms in the country's irrigation sector (Nakashima, 1998).

Pakistan is one of the world's most arid countries, with an average rainfall of under 240 mm a year. The water shortage scenario is further aggravated with high variability of rainfall. The onset of climate change and global warming are likely to severely affect the availability of water. According to the benchmark water scarcity indicator (the Faulkenmark Indicator), Pakistan's estimated current per capita water availability of around 1,066 m3 (Table 1.6) places it in the "high water stress" category (Table1.5).

Table 1. 5 : Water Scarcity Indicators (Faulkenmark Indicator)

>1700M^3/Capita	Water Scarcity Rare
<1700M^3/Capita	Country faces seasonal or regular water-stressed conditions
<1000M^3/Capita	Water shortages hamper the health and well-being of the human beings-Economic activities are affected
<500M^3/Capita	Shortages are severe constraints to human life

Source: Indus River System Authority (IRSA), 2011.

The unbalance between population and available water makes Pakistan one of the most water-stressed countries of the world. Per capita surface water availability was 5,300 m^3 in 1951, which reduced to 1,066 m^3 in 2010. The minimum water requirement per capita to avoid being a "water short country" is 1,000 m^3 (GOP, 2011). In the year 2012, Pakistan reached the stage of "acute water shortage country" in the world. Large part of Pakistan has good soils, abundant sunshine and hardworking farmers but yet crops yield, both per hectare and per cubic meter of water are much lower than international benchmarks and also much lower than the neighboring countries.

Table 1.6 : Water availability Vs Population Growth in Pakistan

Year	Population (Million)	Water availability per capita (m^3)
1951	34	5300
1961	46	3950
1971	65	2700
1981	84	2100
1991	115	1600
2000	148	1200
2010	168	1066
2020	196	915
2025	209	850

Source: GOP, 2011

Pakistan has needed to double its annual food production every 15 years in order to maintain its status in meeting requirements of food for the rapidly growing population. Pakistan is bestowed with enough fertile and productive lands and sufficient labors.

Despite the availability of these basic resources unfortunately the country has to import large quantities of some food commodities every year. With the current population of about 167.7 million people in 2010, which are growing at the rate of almost 2.6% per annum (GOP, 2011) the country would have to feed 120 million additional mouths by the year 2025 (Kahlown, 2005). In such a situation, it is inevitable to keep a balance between production of crops and crop water requirements, if the necessary action has not taken.

1.5 Issues of Irrigation Management

Pakistan has significant natural water resources but it is inadequate for crop production on the available land. River flows are highly seasonal, roughly 85% of annual flows are in the (*Kharif*) summer wet season and only 15% in the (*Rabi*) winter dry season. Moreover, due to inadequate water availability in winter and at the beginning of the summer seasons cropping intensity is exceptionally low. The stagnant crop yields and increase in the country's population demand enhancement of agricultural production in the irrigated areas. The agriculture in Pakistan is dependent on irrigation, while, the system is performing poorly (World Bank, 1994). The deterioration of the irrigation system is considered the main cause of stagnant agriculture (Vermillion, 1997). The irrigation system of the Northern Areas of Pakistan is also beset with large number of problems. These were:

1.5.1 Low irrigation and water use efficiencies

The overall efficiency is the product of conveyance losses, distribution losses and the application losses. The overall efficiency of Pakistan's irrigation system is estimated to range between 35-40% of water from canal head to the root zone (World Bank, 1994). It implies that for every 100 units of water diverted at the canal head, only 40% units are available to the root zone.

1.5.2 Poor irrigation infrastructure

Most of the irrigation infrastructure is in poor condition. Pakistan is extremely dependent on its water infrastructure, and it has invested in it massively. Due to a combination of factors such as age, time neglecting attitude of the department towards repair and maintenance of existing infrastructure, much of the infrastructure is crumbling.

1.5.3 Inadequate maintenance of the system

The operation and maintenance (O&M) of the entire irrigation network is one of the major management issues of the water sector which starts from the main channel to the farmer's fields. Maintenance of distributaries includes desilting, restoration of distributary banks, secure hoes, rebuilding of regulators and bridges. Such works are carried out by contract unless they are very small. Increasing water demand, deferred maintenance, siltation of distributary prisms, excessive withdrawal by outlets and illegal water extractions all contribute towards the increasing inequity in the system.

1.5.4 Need for institutional reforms in irrigation sector

The poor functioning of the irrigation system in Pakistan has been a source of concern since 1960s and then it has been the subject of considerable external assistance and internal policy reforms (Latif and Pomee, 2003). However, the need for improving irrigation management has become a major priority on the agenda of most national and international agencies in the recent past. Considering the situation, the government has introduced institutional reforms in the irrigation sector of the NAs. One important aspect of the reforms is irrigation management transfer (IMT) by user's participation in the management of the system called Participatory Irrigation Management (PIM).

1.5.5 Participatory irrigation management (PIM)

The term PIM normally refers to involvement of water users in irrigation management along with the government (Vermillion and Sagardoy, 1999). Recently, planners and administrators in Pakistan have realized that the farmers' participation is very important and many projects of such nature are being implemented in different irrigation zones. Moreover, the Provincial Irrigation and Drainage Authorities (PIDA) have been established by legislation in each province and these authorities have formally initiated participatory irrigation management (PIM). In view of exploiting these participatory institutional changes in the irrigation sector, several pilot projects have to organize farmers at the main water channel or watercourse level has already been initiated by the government, non-government organization (NGOs) and community based organizations in the country.

1.6 Need for the Study

As it is evident from the above facts and figures, Pakistan is far behind in crop production. But the question arises, how to increase crop production in the country such as Pakistan?

There are three possible ways to increase crop production, as follow:

a. By allocating more area for crop production,
b. By developing and adopting new technologies in crop production to increase per acre yield,
c. By utilizing the available resources more efficiently.

Further, water is the major constraint in bringing new area under cultivation. It is also evident that land area has reached its ultimate limit (Hassan, 2004). The third option of using available resources more efficiently becomes viable in the current situation. Crop production can be increased by improving productivity i.e. yield per unit area. Since, additional area, development and adoption of new technology are not feasible in a short period of time; therefore the plentiful potential exists for improving productivity i.e. output per unit area. Efficiency research is needed to fill serious information gaps, suggesting how to improve the crop production system. It is also essential to gather information regarding crop yields and constraints limiting crop production in various regions.

The literature on mountain irrigation system's characteristics, performance, management and problems in Pakistan is not extensive. The absence of reliable data on irrigated area, crop production, irrigation systems and other relevant statistics for agriculture in Northern Areas of Pakistan virtually defines one priority research issue on the subject. The crop production in the area is completely dependent on irrigation derived from high altitude snow and ice melt (MacDonald, 1998). Water availability, especially during dry season is a serious problem due to low rainfall in the valley bottoms. Water from glacial melt is mainly used for irrigation and irrigation is done through water channels locally called (*kuhls*). These irrigation channels constructed with stone and mud by hand dug or cutting the rocks, which is not properly designed. Therefore, leakage of water and soil erosion occurs with higher conveyance losses. Various investigations have revealed that most of the watercourses are improperly designed leading to considerable water losses, and valuation of the improved watercourses shows substantial saving of water losses control from different parts of Pakistan as well around the world.

Pakistan is now essentially at the limit of its water resources and it became a water scarce country. The issue of water losses through irrigation systems has a major impact on water supplies and management. A majority of 86.5% of the farmers perceived that there was great improvement occurred in water delivery efficiency through watercourse improvement (Siyal, 2007). Although a number of national and international organizations had attempted to assess the degree of losses from the watercourses, (Arshad et al., 2009). However, in our knowledge there is no study had done to compare an improved and traditional irrigation system in terms of socio-economic and farm management perspectives, such as crop production, profitability and determinant of technical efficiency effect and farmers' participation in PIM, in NAs of Pakistan against water scarcity problem for sustainable agriculture.

One of the major contributions of this study is to support policy makers in implementing economic policies for sustainable improved irrigation system. Furthermore, the emphasis is to improve agricultural production, resource management and identifying factors for structural improvements in NAs of Pakistan. The main focus is to attain long term development in irrigation sector through sustainability which will bring growth in rural areas of Northern Pakistan as well as in national economy.

1.7 Objectives of the Study

The broad objective of this study is to determine the benefits of the improved irrigation system to the farmers' economy. This is achieved by comparing an improved irrigation system (IIS) with a traditional irrigation system (TIS) in terms of overall management of irrigation system, land use, productivity, profitability and technical efficiency of crop production in NAs of Pakistan.

This study will identify the impact of improvement and the way how to increase outputs from the available resources with following specific objectives:

- To evaluate the benefits derived by farmers from improved irrigation system in terms of land use, crop productivity and profitability.
- To examine the productive performance of the irrigation systems in terms of dry season crops i.e. wheat, vegetable and potato using a stochastic frontier production function with technical inefficiency model to estimate farm level technical efficiency of crop production and determine the factors influencing on technical inefficiency.
- To assess the level of farmers' satisfaction with irrigation system and to determine the factors influencing farmers' participation in PIM.
- To propose recommendations to improve water use efficiency and crop productivity to enhance sustainable livelihood of farmers in the area.

1.8 Summary and Organization of the Study

Agriculture continues to play an important role in the economy of Pakistan. Water is crucial for Pakistan agrarian economy because overwhelming majority of population is directly or indirectly dependent on agriculture as a source of livelihood. There is indisputable evidence that irrigating land leads to increased productivity. Irrigation is a necessary input into the high yield varieties developed during the Green Revolution. Irrigation allows farmers to apply water at the most beneficial times for the crop.

The existence of enormous irrigation system and vast networks of irrigation channels alone, do not necessarily mean that a high level of agricultural productivity is ensured to help poverty alleviation. The higher level of agricultural productivity, which also is environmentally sustainable, has many other important elements that need to be considered. Among these, the most important factors are improvement of infrastructure in irrigation systems, involvement of stakeholders such as (farmers, farmer organizations and WUAs), transformation in how irrigation systems are operated and managed but also reliable and equitable supply of irrigation water to the farmers. Past research in Pakistan shows that a low level of agricultural productivity is associated with low performance and poor management of the irrigation system (Mirza et al. 2000). The poor performance of the irrigation system results in unreliable water supplies associated with many other problems. This problem invited the attention of the government to introduce irrigation system improvement programs such as (NPIW) in Northern Areas of Pakistan

The thesis has been organized in eight chapters. The second chapter is devoted to discussing the agriculture and irrigation sectors of NAs of Pakistan including an overview on study area. The third chapter discusses the review of the relevant past studies related to the study, with efficiency and profitability studies in concern special focus on Pakistan. The fourth chapter deals with the nature and sources from where relevant data have been collected, the analytical tools employed for evaluating the objectives and interpreting the results and various concepts used in the study. The fifth chapter describes results of the study and analysis presented through a variety of tables about the dry and wet season crop production, cost of production and profitability. The sixth chapter describes the results and discussion related with the technical efficiency analysis, while chapter seven discusses the factors influence farmers participation in participatory irrigation management and their satisfaction level. Finally, a brief summary of the overall results and the main findings of the study have been presented in the chapter eight along with the policy implications that emerged from the findings of the study.

CHAPTER II

AGRICULTURE AND IRRIGATION SECTOR OF NORTHERN PAKISTAN

This chapter seeks to provide a brief description of the Northern Areas (NAs) of Pakistan, in particular the Gilgit District's natural environment, land use activities; irrigation system and key issues of irrigation.

2.1 Location of Northern Areas (Gilgit-Baltistan) in Pakistan

The Northern Areas of Pakistan recently (Gilgit-Baltistan) are dominated by one of the most mountainous landscapes on earth, with an arm of the Hindukush to the west, the great Himalaya to the south, the Karakoram to the east, and the Pamir to the north. Human need water in the NAs are catered by the streams and rivers carrying melt water from these higher-lying areas. The major challenge in such a terrain is to redirect the water into the cropping fields and pastures due to rugged mountain. Thus, an intricate network of irrigation canals has been developed in this area since ancient times (Kreutzman, 2000 and Ehlers, 2000).

Seasonal fluctuation in river discharge poses challenges to the farmers as they go through periods of low discharge in the months from October to April, followed by a period of high discharge from May to September (Young and Hewitt, 1990). The major challenge in such a terrain is to redirect the water into the cropping fields and pastures due to rugged mountain. Thus, an intricate network of irrigation canals has been developed in this area since ancient times (Kreutzman, 2000 and Ehlers, 2000). Peak flow in the rivers of this area occurs in June to September, and can cause flooding which damage irrigation canals, roads, and crops. Low flow periods in March, April, September and October, on the other hand, may inhibit the early growth and maturation of crops (Khan, 2006).

The region share borders with China in the North, Afghanistan in the West and India in the East (figure 2.1). As a result of their politically sensitive location, the area has been accorded special territorial status, and is administered directly by the Government of Pakistan (GoP). The region has been divided into seven districts recently: Astore, Baltistan, Diamir, Ghanche, Ghizar, Gilgit and Hunza-Nager. The region's administrative headquarter is Gilgit district. The main political center is the towns of Gilgit.

Source: http://gbtribune.blogspot.jp/p/tourism.html

Figure 2. 1: **Location of Northern Areas (Gilgit-Baltistan) in Pakistan**

2.2 Topography of Northern Pakistan

The Northern Areas have a unique and critical role to play in the sustainable development of Pakistan. Although it spans a relative small geographical area, it serves as a vital catchment for the Indus River upon which a majority of Pakistan's irrigated agriculture and hydroelectricity depends. It is located between 35-37º N and 72-75º E. The majority of the area is mountainous with a population of 1.8 million including seven districts in 831 villages, scattered all over the area. Human settlements are on alluvial fans and terraces from 2,000 ft. to 11,500 ft. elevation on either side of the Indus River and its tributaries where water is available for agriculture. Agriculture is irrigated owing to scanty precipitation subsequent aridity all over the mountainous region of NAs Pakistan.

The total area of NAs comprises 72,496 km^2, 90% of the total area i.e. 64,066 km^2 are rugged mountain area. The total forest covered area is 4% spread over an area of 3,029 km^2. Due to rugged mountain and severe weather conditions, the total cultivated area is only 1.80% which is approximately 1,080 km^2, Table 2.1.

Table 2. 1: Total Land Use of Northern Areas of Pakistan

Total areas	72,496 sq. km	% Of area
Mountain Area	64,066 sq. km	90.00%
Forest Area	3,029 sq. km	4.00%
Cultivated Area	1,080 sq. km	1.80%
Cultivable Waste	4,325 sq. km	4.20%

Source: Statistical year book (2005-06) for Northern Areas of Pakistan

Based on the elevation, NAs of Pakistan are divided into 4 ecological zones, table 2.2. Human settlements are concentrated along the valley floors, where glacial melt provides sufficient water for cultivation. Table 2.2 shows crops and cropping zone in NAs of Pakistan. Agricultural system is very significant with elevation between 1,200 and 2,500 meters. Both summer and winter crops are grown between 1,000 to 3,000 meters, beyond 3,000 meters cultivation ends and high forests and alpine pastures begin. The principal food crops are wheat, maize, barley, vegetables, (especially potato as major cash and staple crop) and temperate fruits (apricot, apple, cherry, peach, grape, pear, almond and walnuts etc.). Livestock are an integral component of the agricultural system.

More than 90% of the population depends on agriculture. The climate is ideally suited for the cultivation of vegetables and deciduous fruits. Out of the total cultivated land of 58,607 hectares, the area under Rabi crops are 48,065 hectares which is 82.0% of the total

Table 2. 2 : Agro-ecological Zones of the Northern Areas

Zone	Location	Settlement Type	Elevation (m)	Characteristics
I	At the base of valleys, near the Indus river.	Compact winter villages.	1,000-2,000	Double cropping zone, Wheat is typically/ grown in the winter crop and maize is main crop of summer. Approximately one-third of the total cultivated area is found in this zone.
II	In the middle and higher reaches of the valleys.	Usually dispersed settlements	2,000-3,000	Single cropping zone; snow in winter. Approximately two-third of the total cultivated area is found in this zone.
III	High pasture and forest land	Scattered summer shelters.	3,000>	No cultivation; summer pasture, snow-bound in winter.

Source: NASSD 2002, SDPI, 2002.

cultivated land. Similarly, the area under potato crop is 3,275 hectares which is 5.58% of the total cultivated land Table 2.3. Potato has emerged as commercial cash crop in the area over the last two decades, which is mostly cultivated in the high elevated valleys of the area due to availability of ideal climatic conditions. Hot sunny days and cool nights prevailing in these high valleys make the conditions conducive for the production of this crop. In the valleys, potato crop is sown during March to April and harvested in August-October as summer crop.

Table 2. 3: Land Utilization in Northern Areas, Pakistan (hectares)

Classification of Cropped Area	Area (hectares)	Percentage
Total area	80,223	-
Cultivated area	58,607	-
Uncultivated area	21,616	-
Area under Rabi crop	48,065	82.01
Area under fruits	5,230	8.92
Area under vegetable	4,155	7.08
Area under potato	3,275	5.58

Source: GoP, Agriculture Census Report, Northern Areas, 2000.

2.3 Climate of Gilgit District

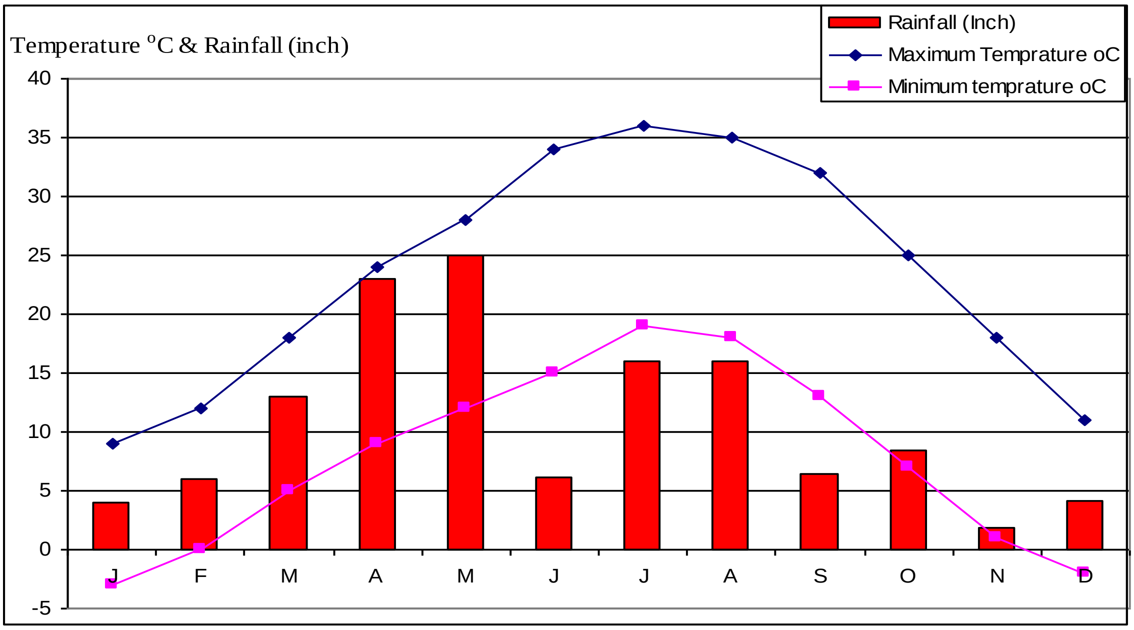
The weather conditions of Gilgit are dominated by its geographical location. The prevalent season of Gilgit is winter, occupying the valley eight to nine months a year. Gilgit lacks significant rainfall, averaging in 120 to 240 millimeters annually as monsoon breaks against the southern range of Himalayas. Climatic conditions varying widely in the area, ranging from the monsoon-influenced moist temperate zone in the western Himalaya, to the arid and semi-arid cold desert in the Northern Karakoram and Hindukush. However, the area is characterized by low precipitation and a great range of mean monthly temperature values, low winter temperatures, and severe frosts during portions of the winter season. In contrast to the mountain tops above, the inhabited valleys receive miniscule amounts of precipitation. Long term precipitation records of the Gilgit district (1460m a.s.l.) shows an annual rainfall of 131 mm to 222 mm for the former duration (Fowler & Archer, 2004). As a consequence most of the inhabited parts of this region can be classified as semi-arid to arid (Du, 1998). Long-term precipitation and temperature records are available from a number of locations, including Astore, Chilas, Gilgit, Gupis and Skardu Tables 2.4. These indicate that both precipitation and temperature vary substantially with topography, altitude and aspect. Below 3,000 meters, precipitation is minimal rarely exceeding 200 millimeters annually. Temperatures in the valley bottoms can range from extremes of nearly 40°C in summer to less than –10°C in winter Figure 2.2. As a result of this extremity in the weather, landslides and avalanches are frequent in the area. However, it is always cool in the shade in summer season.

Table 2. 4 : Mean Rainfall (mm) at Selected Locations in the Northern Areas (1960-90)

Station	Years	Altitude (meters)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Chilas	27	1,260	8.5	14.9	36.5	40.2	26.4	6.6	7.7	11.1	2.6	1.2	4.0	5.4	165.1
Gilgit	30	1,490	4.4	6.3	15.0	28.3	27.4	6.3	15.0	14.4	6.8	6.8	2.1	3.4	136.2
Gupis	26	2,144	4.7	8.4	10.4	22.1	32.8	9.0	9.3	15.7	7.6	6.3	1.7	5.4	133.4
Astore	24	2,148	37.9	52.0	92.9	90.3	76.0	20.0	20.4	25.3	18.5	33.4	15.6	19.4	501.7
Skardu	29	2,197	20.7	23.6	40.1	26.1	29.2	7.3	12.2	11.6	6.2	7.9	5.4	11.9	202.2
Karimabad	9	2,405	4.2	4.3	7.0	21.6	23.2	13.3	21.7	26.5	13.7	4.6	1.1	3.7	144.9
Yasin	3	2,450	6.4	0.0	28.0	15.6	25.4	2.6	10.9	6.7	18.6	8.3	2.9	2.6	128
Naltar	3	2,880	11.5	15.5	63.8	25.3	93.0	23.0	13.5	69.8	43.2	0.5	3.8	3.1	366
Babusar	1	3,003	21.1	37.1	23.1	76.4	27.9	34.8	25.1	39.9	42.4	10.7	9.1	47.7	395.3
Misgar	17	3,088	6.2	6.8	13.7	18.7	25.3	4.7	10.1	10.6	6.8	6.6	5.1	14.1	128.7

Source: Muhammad, 1995.

The region's climate is well-suited for the production of vegetables especially potatoes and fruits. Thus, there has been a growing shift due to production of cash crops; because of the high profits associated with potatoes and fruits many farmers have largely abandoned the cultivation of traditional crops. The drive to reach higher levels of production has led to the excess use of chemical fertilizers and uncertified seed; these trends, coupled with the continuous use of land, have contributed to soil degradation and increased levels of crop disease.



Source: Met Office, Gilgit; World metrological organization (http://en.wikipedia.org/wiki/Gilgit, _Pakistan)

Figure 2. 2: Monthly mean maximum and minimum temperature (°C) at Gilgit city

2.4 Historical Overview of Irrigation System in NAs

As discuss above, the literature on mountain irrigation systems and problems related is not extensively available. This essentially defines one priority research issue on the subject of irrigation development. In terms of system "types" available evidence suggests that small-scale irrigation systems (*kuhls*) predominate. Given the importance of water as the major limiting factor in agriculture, local communities in Gilgit can be termed as 'hydraulic societies' (Emerson, 1984). A hydraulic society is a type of society which is organized around the management and control of water (Wittfogel, 1957). Emerson (1984) assumes that the level of social organization needed in order to construct canals to irrigate the land led to the early state formations in the area. The agriculture development in Gilgit-Baltistan depends on the distance from a reliable water source and on the feasibility of constructing an irrigation channel. Such constructions are labor demanding and cannot be undertaken by farmer families or lineage groups alone. Thus a higher authority transcending lineages and families are needed to organize such efforts. Traditionally, local rulers called 'mir' or 'raja'[1] would engaged in the construction of major irrigation canals directly by extracting forced labor from the peasants they ruled over, or by granting land to people with resources to invest in the building of a canal (Khan and Hunzai, 2000).

The building of these channels constituted the economic basis for the "mir and raja" and their families a distinct group of functionaries, as they levied taxes from individuals and communities farming this newly irrigated land. At the villages in NAs today construction of irrigation channels is still the central focus of infrastructure development and still carries implications for the government and social organization. After the abolishment of the old principalities in 1974, an institutional gap arose for the management of irrigation facilities as there was no government body to fill the space left by the mir or raja's (Khan & Hunzai, 2000). Much of the work carried out by the development agency Aga Khan Rural Support Program (AKRSP) in this area since 1982 has been geared at filling this institutional gap. Thus new social arrangements have come into existence, which among other things have connected local communities to new markets, given access to bank loans and introduced new technologies.

2.4.1 Type of irrigation systems in NAs of Pakistan

The main objective of any effective irrigation system is to provide ensured water supply to the farmers throughout the year without any interruption. As water is scarce resource in Pakistan as a whole and in NAs particularly. The desired pattern of water allocation was to be achieved through design of systems' structure. Therefore, the irrigation system of NAs of Pakistan is classified into two systems, traditional irrigation system (TIS) and improved irrigation system (IIS).

2.4.2 Traditional irrigation system

Traditional irrigation channels called *(kuhls*) usually constructing with stone and mud by hand dug or cutting the rocks in northern mountain areas of Pakistan. This type of channel is not properly designed therefore; leakage of water and soil erosion occurs with higher conveyance losses through seepage due to steep slopes. In the traditional irrigation system (TIS) need more labor to clean and maintain the irrigation channels and also takes much time to reach water in the field from the source. Water is distributed to the farmer's by turn for short period of time due to shortage of irrigation water and time limitations. Farmer cannot irrigate the whole area and can't grow many crops in dry season.

Traditional channels lack control device for effective and conveyance and distribution. Generally, these channels are relatively narrow and shallow with low water carrying capacity. Water diverted from main channel to watercourses using temporary mud and stone dams etc. There are no drainage channels leading to individual farmer's field. However, water passes from one farmer to another farmer's field, due to such flow results water being recycled between several farmers. This kind of arrangement sometime creates conflicts between upstream and downstream farmers. Water users at downstream experience water scarcity, low crop production and low household income which lead to poverty. This increasing shortage of irrigation water in term of seasonal crop requirements clearly makes NAs irrigated agriculture a potential beneficiary of irrigation improvement,

[1]Before the abolition of the princely states by the Pakistanian government in 1974, Gilgit-Baltistan were divided into several semi-autonomous or independent principalities. Each principality was ruled by a 'mir' or 'raja', who received their power by heritage. The mirs and rajas dominated the peasant farmers aided by a military class and a distinct group of functionaries (Emerson 1984).

scheduling and management.

In order to overcome water losses occurring in tertiary components of irrigation system, a series of On Farm Water Management projects including the National Program for Improvements of Watercourse (NPIW) and Command Water Management Project (CWMP) have been launched in the country. The watercourses improvement/lining activities of these projects attempted to save canal water losses thereby increasing the supply of water for irrigation crops.

2.4.3 National program for improvement of watercourses (NPIW)

Government of Pakistan has taken a mega initiative for improvement of all traditional/unimproved watercourses within minimum possible time. Therefore, NPIW in Pakistan is being implemented at a total cost of Rs. 66,373.4 billion. The program envisages improvement of 186,000 watercourses in the country as first phase-1. The project is under implementation throughout the province and is planned to be completed within a period of 10 years. The purpose of establishing of NPIW in Gilgit-Baltistan was to control water losses, increase cultivated area and increase agriculture productivity as the region have a high risk of water losses due to rocky terrain and steep slopes. Water availability, especially during the dry season, is a serious problem across the NAs.

Keeping the above background, the NPIW was setup in 2003/2004 as a significant initiative to improve irrigation infrastructure in NAs of Pakistan. The target of NPIW was to improve 600 watercourses initially. The total cost of the project was Rs. 326.7 million, in which the share of government of Pakistan was Rs. 238.2 million while farmers contributed Rs. 68.5 million. This project mainly aimed at increasing water availability for farming by converting the traditional irrigation channels (i.e. channels made from mud and stones) to improved irrigation channels (i.e. channels made from cement concrete and stone). The purpose of improved irrigation channel is to carry maximum amount of water from river/stream or spring to the farmers’ fields. The design objectives include: achieving conveyance efficiency (low water losses), preventing silting or erosion and the full supply level in the watercourses.

2.4.4 Criteria for watercourse selection

Prior to start the improvement of irrigation system one team of technical staff undertakes a field-visit of the selected water scarcity area to make a visual assessment of field conditions. Watercourse selected for improvement should be those where there will be a high likelihood for success; where farmers' interests are high. In selecting irrigation channel (watercourse) the following factors should be considered for improvement:

- Farmers must be willing to provide labors required to improve the watercourse and to organize and direct during the planning and construction phase.
- Efforts should be made to select the watercourse having high water losses.
- Priority should be given to the watercourse having percentage of rural poor or small landowners.
- The cost, in term of input (laboring) required from the farmers.
- Water users association should be formed for proper execution and maintenance of the watercourse improvement program

2.4.5 Improved irrigation system (IIS)

Tertiary irrigation conveyance network in Pakistan is called watercourses. The watercourses are operated and maintained by the shareholders receiving water through the channels. Studies have indicated that about 40% of irrigation water is lost during its conveyance through about 140,000 watercourses because of their aging and deteriorated conditions. Previous experience of watercourse improvement has shown that on an average, annual water saving in an improved watercourse is about 100 acre feet besides other socio-economic benefits (Akhtar, 2006).

Improvement of watercourse consists of complete demolishing of community channels and rebuilding/realigning according to the engineering design by stone cement and concrete in NAs of Pakistan. In the lined channels necessary water control structures are installed to improve conveyance of irrigation water.

Table 2. 5: Major Benefits of Watercourse Improvement

S. No.	Particulars Extent	(%)
1	Time saving in irrigation	28
2	Labour saving	50
3	Increase in cropping intensity	23
4	Enhancement in cropped area	17
5	Improvement in yield	16-37
6	Addition in net farm income	20

Source: Akhtar, (2006)

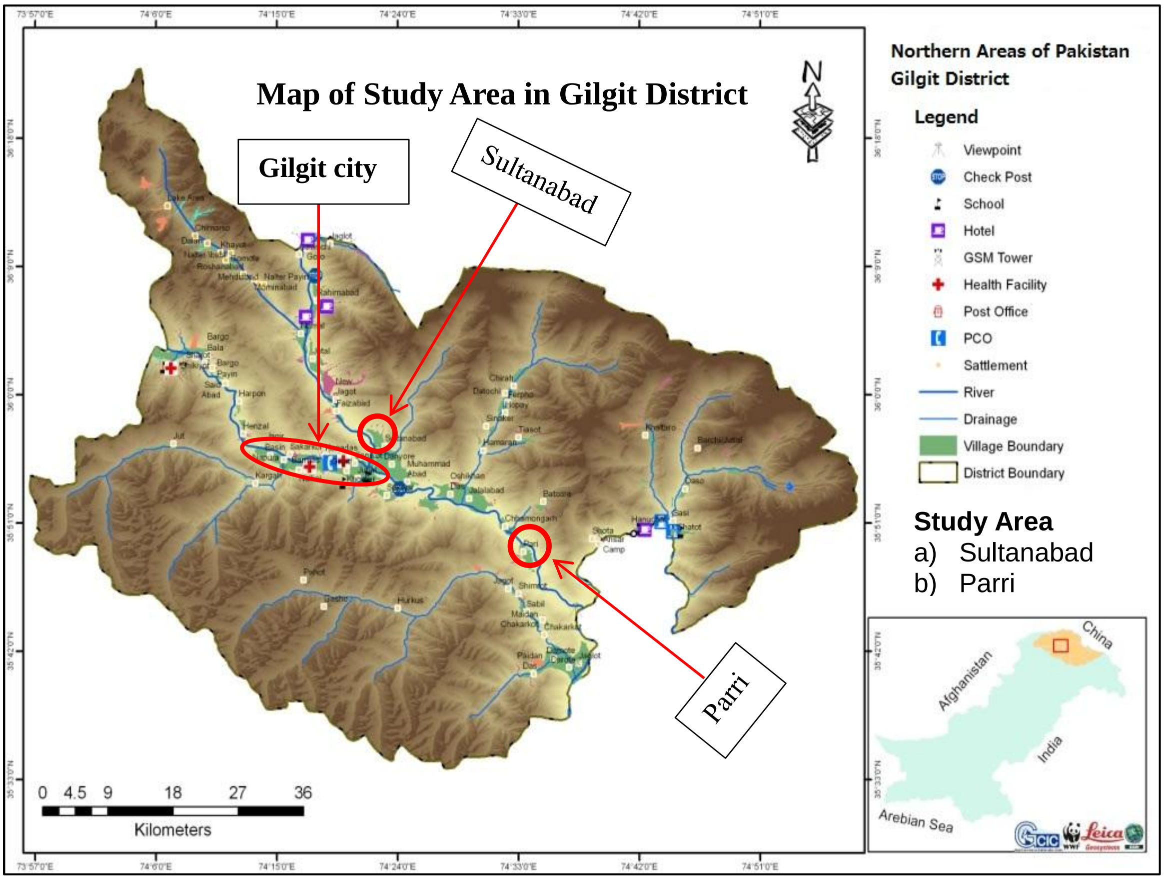
All these works are carried out through active participation of the beneficiary farmers who contribute entire skilled and unskilled labor. IIS has various positive effects such as increasing crop production, conserving rural environment and improving rural amenity Table 2.5. In this system less time need to reach water in the farmer's field, and also cleaning of the channels is much easier compare to TIS. In this system, the water availability is higher due to less losses of water. As a result, the farmer's turn come soon and get much water with in short period of time during dry season. A total of 600 watercourses are improved/lined in 2009/2010 and lining of around1,200 are underway in NAs of Pakistan. However, there are still much more to be improved in the irrigation sector in the NAs of Pakistan.

2.5 Selection of the Study Area

2.5.1 The Gilgit District

The villages in NAs were settled over time by people from surrounding regions. Being an area of low rainfall, the most vital requirement is water for irrigation, livestock, drinking and domestic use. Where water available from the glacier melt people asked land from the “Mir” or “Raja” to construct a water channel to irrigate the land, when he agree they settle the matters and made cultivation possible for the traditional crops. Gilgit strategically the most important region in the Karakorum and the trade center of the region for centuries is the capital town and administrative center of the Federally Administered Gilgit-Baltistan. The area is watered by the Ghizer/Gilgit, Hunza and Indus rivers and several other tributaries. Gilgit is an important city on the Silk Road through the region.

Gilgit district is the provincial headquarter of Gilgit-Baltistan and plays a critical role in the management and administration of the region. Besides its administrative role, it also contains the beautiful natural features and resources, which aids to the natural wealth of



Sources: (Babar et al. 2011) http://www.wwfpak.org/gcic/Pages/Maps.html

Figure 2. 3: Showing study area in Gilgit district

the region. Being mountainous and supporting critical ecosystems, the district is highly vulnerable to the impacts of climate change. Collective information of last two decade shows that the maximum increase of temperature was 0.44°C per decade had been observed during the winter months (Babar et al., 2011). Weather conditions for Gilgit are dominated by its geographical location, a valley in a mountainous area, southwest of Karakoram Range. Irrigation for land cultivation is obtained from the rivers, abundant with melting snow water from higher altitudes. The intense sunrays raise the temperature up to 40°C, however, it is always cool in the shade. As a result of this extremity in the weather, landslides and avalanches are frequent in the area.

The main objective of this study was to assess the impact of the improved irrigation system comparing with traditional irrigation system in terms of improving water delivery, equity in water distribution and overall agricultural productivity. Therefore, based on above consideration to meet the objectives of the study, two villages were initially selected (Sultanabad and Parri) from the Gilgit district figure 2.3, to compare the two irrigation systems: improved (channels made from cement concrete and stone) and traditional (channels made from mud and stones) irrigation systems, where both irrigation systems were available in the villages.

2.5.2 Sultanabad village

Sultanabad is a small village, which is located 7 km south east of Gilgit city along both sides of Karakoram highway is considered as an important agricultural area situated in the suburban of Gilgit city. The topography of the area is not uniform. The area of Sultanabad is consists between mountainous terrain and some parts of the area are considerably plain and some part contain with hilly slopes and also belong the double cropping zone area. Hunza River flows in to the west of the village.

The mountainous portion is covered dry and rocky, while hilly slope areas near the stream are mainly used for pastures and grasses for livestock. The main source of water in the study area is “Darband glacier” which is situated in the west of the village and moves northeast to the south towards Karakoram Range and Nagar valley. According to head of the village (*Nambardar*), the glacier is approximately 15 to 20 km long. It is the only source of water supply for irrigation and for drinking in entirely the year for the study area. The whole village is depending on this glacier for overall uses and melting water of the glacier is the main source of the Sultanabad and Danyore stream named “Mano gah”. The stream in turn joins the Hunza River first and then Indus River in summer seasons when there is enough water. The farmers have been using traditional irrigation for more than a half century which has caused tremendous losses in terms of the productive land due to waterlogging resulting from over-irrigation. However, now the government has started to improve the irrigation channels but still need to be done a lot in irrigation sector.

According to my observation the economy of Sultanabad is largely natural resource dependent. The settlement pattern in the area is also determined by the availability of water. The main source of water for irrigation as well as household uses is the mountain streams, which are fed by glacier melt. However, since water is not abundantly available throughout the year, its distribution and usage is closely monitored and regulated through a community based participation system. But the most important area that has remained to improve is that of water resource management, in which the traditional practices of water distribution and management are still being followed. Furthermore, despite the scarcity of water farmers are still using traditional irrigation channels, which reduced the frequency of irrigation. In this regard, poor community needs the support of government and development partners to adopt improved technologies for water management in the area.

However, in Sultanabad the criteria for a household are a family that pays the social dues or collections and attends collective works such as maintenance or cleaning of the irrigation channels. When a person or family is declared as a household they have to pay all social dues. In return this family or person gets all the benefits from the village such as new lands if they are dividing it among households or other collective benefits for the village. The Karakoram highway gives villagers relatively quick access to the main market from where they purchase the necessities of life as well as access to an expanded labor market.

2.5.3 Parri village

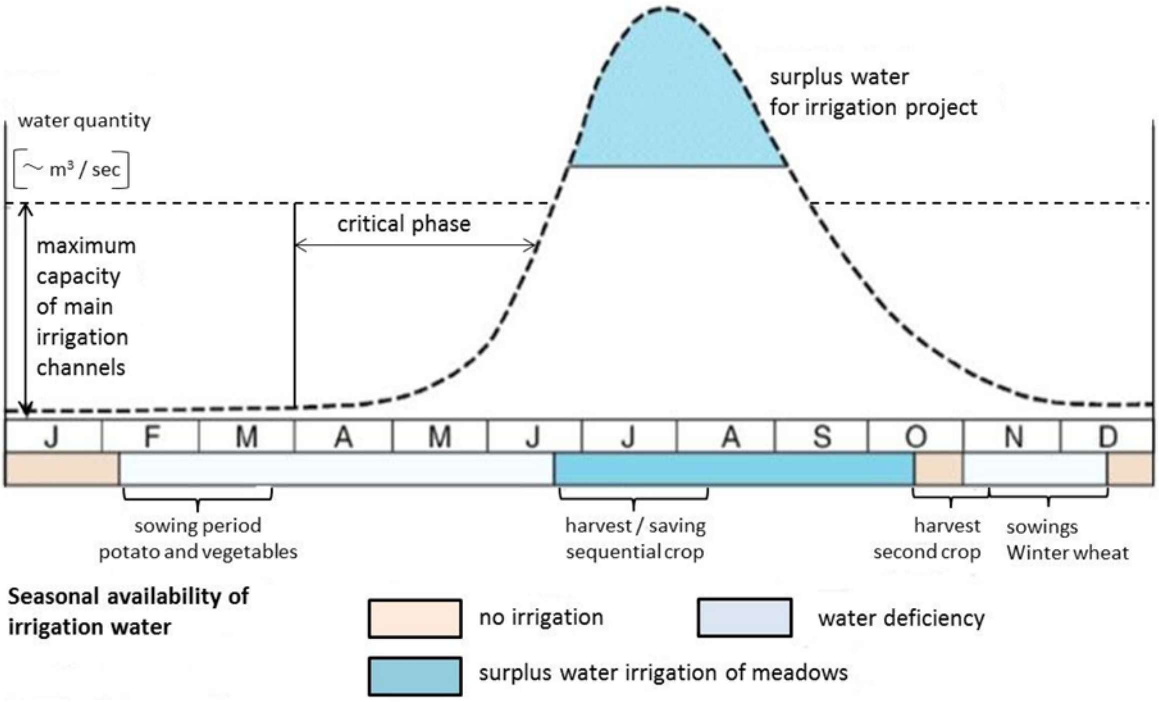
Parri is a small village 29 km from Gilgit city. The Karakoram Highway crosses Parri village and also connects it to Juglot town to the south. In the North it is connected to the Gilgit city. Parri has an intervening width of mountainous terrain. It is situated near the junction of three mighty mountain ranges the Karakoram, the Himalayas, and the Hindukush. The mainstay of the locals is mixed agriculture and livestock, heavily supplemented by cash income from laboring and public service. Vegetable, maize, potatoes, fodder and wheat are commonly grown in the village. The land of Parri is also rich in fruits like grapes, almond, apricot, capsicum, pomegranate and apples etc.

Most of the residence of Parri goes “Gashu and Pahote” valleys during summer season with their livestock, where rich alpine pastures provide sufficient fodder for large flocks, livestock herding, which contributes a significant share to household subsistence. However, only two percent of the population is involved in public services, according to the interviewed farmers. The valley’s proximity to Gilgit, where an increase in higher population growth rates, declining food subsistence, and increasing dependence on external food supply has resulted of growth in the commercial sector. Therefore, numerous shops have been set up using earnings from selling livestock meat and other daily life necessities. These people have migrated to from different upstream areas such as Balas valley, Sai Bala and Kohistan, etc. Despite migration, some of these households have not abandoned their native homes and agricultural land, where they still grow crops and travel back at sowing and harvesting time.

As the rainfall is low in all over NAs therefore, agriculture in the area is dependent on irrigation systems fed by glacial or snow melts. Parri channel 18 Km long is one of the long water channels in Gilgit district. In the British era, there was a good piece of uncultivated land along with Karakoram highway in the place of Parri. They decided to construct an irrigation channel with the help of local habitant from Chakarkot village on (*Sai Nallah*) stream to bring water for crop cultivation. However, later on 1994, Aga Khan Rural support Program (AKRSP), with the participation of the farmers has done viding and improved the channel. The distribution and use of irrigation water is a bit different still in Parri. The water is also considered to be a common property resource for a limited number of households who either have land under the command area of a channel or who are otherwise entitled to it. However, in case of Parri if someone buys the land he must buy the water in terms of time for his land, otherwise he is not allowed to use the water either for agriculture or other purpose.

2.6 Water availability in NAs Pakistan

Water availability during dry period (February to May) is very critical for crop production as shown in figure 2.4, in NAs of Pakistan. The climate is dry continental, characterized by a great variation in average temperatures from 40ºC between May and October to –4 ºC or less in November to April. The average annual rainfall in Gilgit and NAs is 150 mm. In NAs of Pakistan the irrigation schedule which is characterized by water scarcity (dry) and surplus (wet) seasons. The amount of surplus water is available only for a very short period compared to water scarcity season. The Figure 2.4 shows the maximum and minimum water availability and cropping patterns in NAs.



Source: Adopted from Kreutzmann, (2011)

Figure 2. 4: water availability and irrigation pattern in Gilgit district of Northern Pakistan

2.7 Water Rights in NAs of Pakistan

Water users in the villages have been managed water distribution by making water user association themselves on a rational and equitable basis, among the indigenous people. Where water availability is less, strict rules and regulations are applied and adhered to water rotation. Water right forms the basis for distribution of water inside the villages. Complex management strategies have been established in former times in order to operate the communal irrigation system effectively and sustainably, so that resources are still not depleted. Management of the canal network and water utilization is regulated by local institutions. Rules and customs on withdrawal of water and maintenance, as well as organizations that administrates and control. These rules are fixed in written form in the water rights documents and through oral arrangements. Traditional customs regarding water management originated in Pre-Dogra time and have been stipulated in written form in the legal documents on water rights (Revaj-eabpashi) during land settlement in Gilgit-Baltistan by the Administration of Jammu and Kashmir in 1901 and 1911 (Schmidt, 2004). These documents, defining water related rules and regulations are kept in original at the local administration department (Tehsil office). They describe rules for each village for example, water for the main channels, secondary channels, the distribution ratio, rotation system, and responsibilities for maintenance.

In couple of villages close to Gilgit water use rights are given only to those who own officially registered "settled land" which is agricultural land for which "*Malia*" (agricultural production tax) was paid before the 1970s. Other farmers cannot claim water for land but can only use excess water. People of "Jutial and Khomer" towns have joint right to the use of Jutial Nallah (stream). In the time of scarcity (March-May) this right is strictly enforced. Irrigation water to Zulfiqar colony is stopped, as this settlement does not have traditional user rights. Therefore, this colony relies on a river lift scheme for drinking and irrigation purposes from March to May (Hussain and Langendijk, 1995). However, over the time, water rights have been modified through mutual agreements between old and new settlers in the few town or villages in NAs. Nevertheless, there are still many villages in NAs where water is abundant, there are no water rights. Farmer can use water freely at any time for their crop cultivation. (Mizushima, 2009) found that in the Hussaini village (a village in NAs of Pakistan) had no particular custom regarding water rights. He found that the amount of water carried by the five irrigation ditches may be unstable, in the village with a strong sense of community bonding; the water is evenly distributed to all farmers or cropland. Therefore, the Hussaini village has sustained irrigation farming of wheat and bean crops by establishing a village specific distribution method.

2.8 Water Distribution System in NAs Gilgit

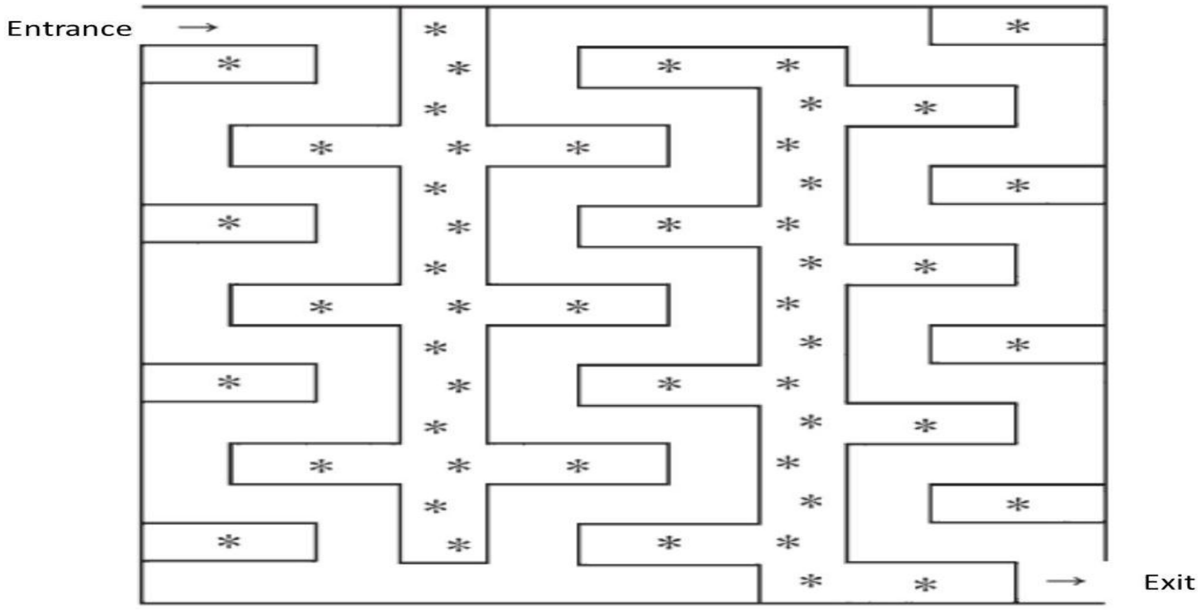
"*Warabandi*" the traditional practice of water sharing by turn, according to an established roster is followed in Sultanabad, Parri and many other parts of Gilgit District.

This management practice helps farmer to ensure that irrigation water is equitably allocated during periods of water scarcity, particularly between March and May. When the period of water scarcity is over or where water scarcity is not a problem, water distribution is generally more informal. Field observations confirm that Warabandi system remains a durable and not readily changed irrigation management practice in Gilgit. Under the *warabandi* system, each household in the *kuhl* command takes its irrigation turn on a specific day at a specified and equal period of time. Generally, food crops are given first priority in water use, followed in order by fodder crops, and finally by trees (fruits and orchads). Thus, where night irrigation is practiced, it is usually for trees and fodder crops (food and vegetable crops are commonly irrigated during the daylight hours). Amongst food crops, vegetables typically take priority over food grains; even to the point where an operating warabandi can be interrupted out of turn should a farmer plead the necessity of water for a vegetable plot.

Individual fields have an allotted share of water and receive it through field channels, which reach them through the opening and closing of individual field sluices (Kreutzmann, 2000). Additionally, farmers take their irrigation turns under the warabandi system in the water scarcity areas. Each farmer is given a particular day and time to take water for irrigation, but there may be informal exchange of turns between proximate farmers (Shahid Ahmed and Joyia, 2003). Kreutzmann (2000) describes water management in central Hunza and explain that the individual portions of the channel belong to certain groups only. Different kinship groups command the night and day cycles of irrigation whereby groups get to use the water during the day and some use it during the night. The first priority is given to cereal crops on irrigated terraces, then potatoes, vegetables and finally fodders. This sequence is relaxed only when sufficient water becomes available in the channels. At this time, the first watering of the orchards is allowed.

As mentioned previously, the irrigation water shortage was already known from the unstable supply of water from the glacier that runs normally through the water channels.

The farmers responded to this problem with the management and repair of water intake points and channels and by trying various measures including the construction of unique furrows in the potato fields as shown in Figure 2.5.



Source: Mizushima, (2009)

Figure 2. 5: Construction of unique furrows for potato and tomato cultivation (A schematic depiction).

Figure 2. 6 : Furrow irrigation system used for vegetables such as potato and tomato etc.

Source: Dieckhoff, (*2008*) *The Shigar Microcosm*

Figure 2. 7: Border irrigation system used for grain crop in NAs

Two different irrigation techniques are being used in all over NAs Pakistan. Root and tuber crops such as (potato and tomato etc.) are cultivated through furrow irrigated parcels and grain crops and some other vegetables through border irrigation (Figure 2.6 & Figure 2.7). In Gilgit district distribution systems are enforced in every season through the water user associations, however, some areas except summer when abundant water supplies are usually available. In some villages enforcement is only during the month of March to May when farmers need more water for wheat and vegetable crops and melt waters have not yet increased stream flow. Distribution patterns often reflect village settlement patterns. Early settlers enjoy slightly better distribution but over time agreements are reached to accommodate newcomers and population growth (Hussain and Langendijk, 1995).

2.9 Maintenance of Irrigation Channel

The maintenance in the NAs irrigation systems reflects their common property origins. Traditionally, the common portion of the irrigation channel maintained through an annual contribution from all farmers served, either in the form of labor or produce. This practice continues to be followed even now, in terms of cash or labor. General maintenance typically takes place in spring, before the first irrigation for the new crop year and when water flows are low or non-existent. On channels where silt loads are heavy, all the farmers may also participate in a one or two day mid-season de-silting the operation. Maintenance of lateral or field channels not common to the system is the responsibility of individual farmers.

Particular and occasional tasks are carried out collectively by all villagers along the main channels. In general, one male member of every household has to attend. If not complying with this rule the household will be sanctioned. Work includes cleaning and repairing the channels annually after winter constructing or improving the channel once in a while, and in case of natural hazards mobilizing helps. More regular activities such as maintaining the channel, checking that the discharge is not impaired and removing accumulated sediment load are mostly assigned to the last hamlets of the main channel. Here also, the respective households have to provide one male laborer. Only in case of emergency, such as heavy floods causing serious damage to the canal network (Said, 1998), more than one person per household from all hamlets has to help.

Some villages employ a watchman (chowkidar) during the irrigation season, who patrols the common portion of the channel and clears debris from the channel intake, plugs leaks, repairs small breaches, and otherwise monitors water supply conditions. On a daily basis, they do small repairing, regulate water flow to prevent damage and alert the community in case of emergency. In systems where watchman is not employed, farmers will take regular turns patrolling and maintaining the common channel, usually at the time of their irrigation turn. Whenever a major breach or other maintenance emergency occurs, all the farmers on the channel will participate in its repair.

2.10 Farming System in NAs of Pakistan

Farmers in the Northern Areas are primarily subsistence, whose main aim is to produce enough grain, meat and milk to satisfy household consumption demands. Agriculture systems are characterized by various types of transhumance, based upon the three board agro-ecological zones found in NAs. Livestock are integrated into the farming system and provide valuable manure to maintain the soil fertility of irrigated land; farmers insist that above all the other management factors under their control, it is the amount of manure they are able to apply the most influences their yields.

A typical geographical sequence of farming activities is as follows:

- Most of the lowest parts of the valleys (the river banks of the Indus) are not cultivated, because of flooding and difficulties in constructing irrigation channels;
- The main village farmlands are located on river fans in the valley bottoms and alluvial deposits on the hills of side valleys. In the lower parts of the valleys, double cropping allows for two staple food crops: wheat in winter (November-June) and maize in summer (June-October). In the single cropping zone, wheat, potatoes, barley and maize are the principal crops (June to October). In both the double and the single cropping zones, most vegetables for home consumption and fodder for winter feeding are grown. The land is irrigated with water supplied by diverting river tributaries or snow-milt through channels (kuhls) in the hillsides. During the winter, animals are free to graze on crop land, a tradition which makes the adoption of new practices (such as the introduction of winter fodder species) difficult;
- Above the farmland on the other lower side of the irrigation channels, water is released to irrigate a mixture of forest and fruit trees, shrubs and grassland. Grass is used to produce hay for winter feeding; tree foliage is used for animal feed in autumn and the trees provide fire-wood and timber;
- Above this village forest/pasture area, the mountain-sides rise steeply. High forests and alpine pastures provide summer grazing for sheep, goats and cattle, and thus play a crucial role in supporting valley farming. Farm households use these

pastures in two different ways: (i) Part of the family may move to the alpine pastures and stay there during the summer, while some family members remain in the village to tend the fields and any cattle that have not been taken to the high pasture; or (ii) Farmers may leave their animals with semi-nomadic tribes (gujars), who herd the livestock during the summer and are paid in the form of milk and wool while the animals are in their custody.

- Through this transhumant system, people are able to exploit many different components of the valley ecosystem. The irrigated farmland requires manure to remain productive and the alpine pastures make it possible to keep herds sufficiently large to supply meat and milk to the irrigated cropland and alpine pasture is made possible by the existence of the village forest/pasture area, which supplies winter fodder in addition to some cultivated annual or perennial irrigated fodder crops.

2.11 The Marketing System for the Cash Crops in NAs

The marketing system for fruits, potato and vegetable crops in the study area is the same as the usual system adopted in the rest of the villages in Northern Pakistan Figure 5.1.

Farmers market their horticultural produce in three different ways.

a. Selling the produce themselves in the village, in the local market or directly to the consumers. This method applies for 1 or 2 crops such as (potato and fruits) and 5-10% of their volumes (this channel is not shown in the figure).
b. Selling the produce themselves through a wholesale commission agent to different types of buyers in the wholesale market. This system applies for the majority of the crops and for more than 50% of their total production.
c. Selling the crop to local contractors *(Beopari)* at a time when it is still standing and has achieved a certain level of maturity, and does not require major husbandry care

anymore, or when it has been recently harvested and is lying in the store. The contractors then take the produce to the wholesale market and sell it through the wholesale commission agents.

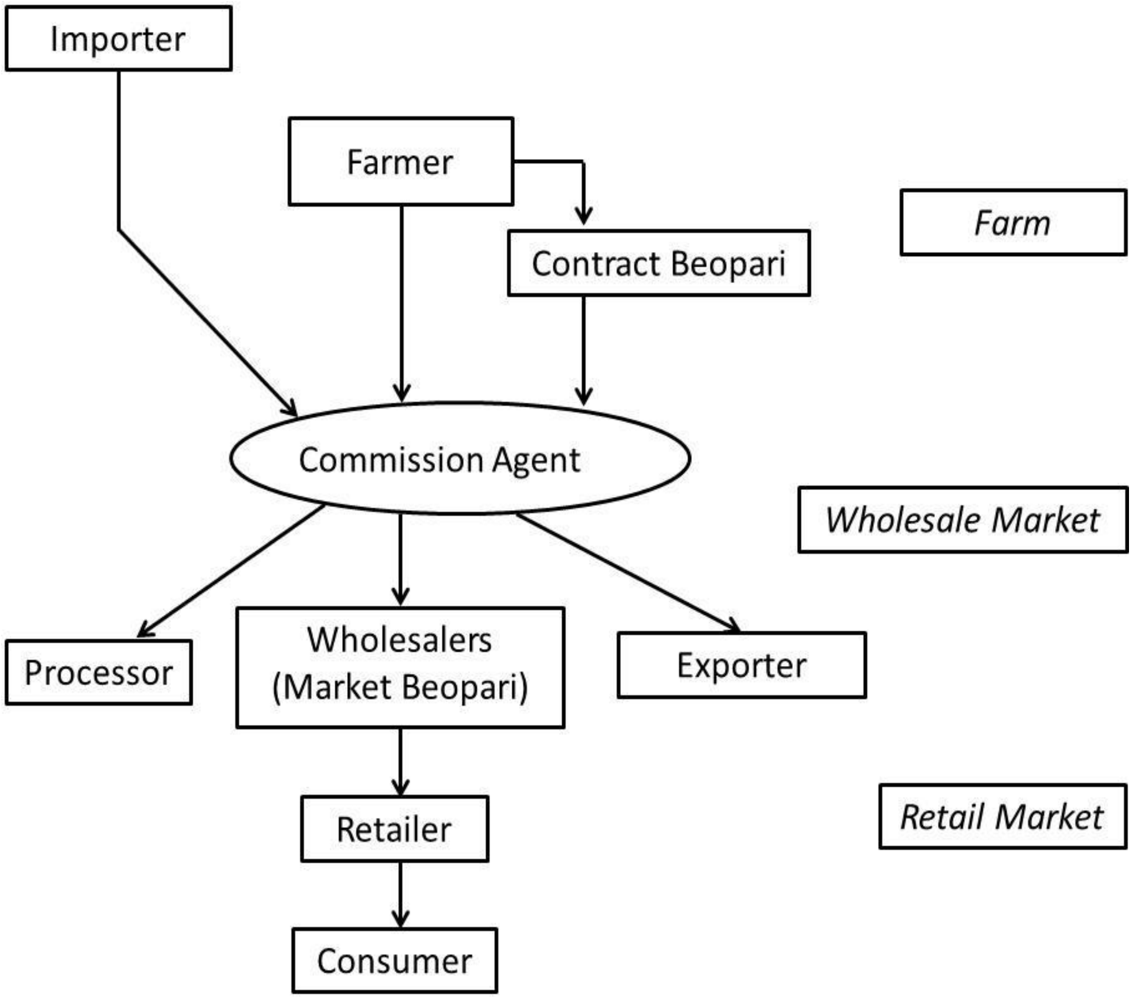


Figure 2. 8: Fruit and vegetable marketing channels in study area

Due to sales to outside markets, farmers get in contact with market commission agents. In this way, they develop good relations and may enter into long-term contracts with each other. The farmers have interest in getting good prices for their produce and occasionally some credit. By paying reasonable prices and providing credit to farmers, the commission agents ensure large number of suppliers get more commission and more power in the market. The important cereal crops are wheat and maize. These crops are grown mainly for home consumption. Since wheat is the most important daily staple, the government controls wheat marketing. Cross border import and export of wheat is not allowed to private sector. Every year government announces a support price, which is the minimum price at which the government guarantees to buy the produce.

2.12 Karakoram Highway and Economic Development in the NAs

The process of change in Northern Areas of Pakistan, which had been extremely slow due to geographic constraints, suddenly speeded up with the conversion of historical Silk route into Karakoram Highway (KKH) in early 1980s. An unprecedented influx of socio-cultural and economic change followed, which had a dramatic impact on the natural and human environment of the region. Various cultural and social habits earlier dictated by environmental constraints have changed; for instance, people in Gilgit, Hunza-Nagar and Baltistan region have given up their seasonal vegetables and potatoes as well as their raw fruit (trees) which they have followed for centuries to save on the firewood for winter. The impact of the Karakoram Highway is very conspicuous on the socio-economic life of the regions' people. Therefore is worthwhile to discuss the different aspects of KKH. However, our focus here is to give an overview on it.

The development of the Karakoram Highway, which has led to a dramatic improvement in access;

- The evolution of a development paradigm that places significant emphasis on the role of NGOs and civil society;
- The initiation of the Aga Khan Rural Support Programme and a range of other projects which address both livelihood and conservation issues, and also;
- Crops such as vegetables, potato and fruits turned into cash crops because of easy accessibility of the market area and can easily be transported to down country, thereby providing an important source of income.

- The highway has made it possible for the people to get all necessary items available in their own local market. Thus not only making them self-sufficient but also helping in the development of their own market which also serves the surrounding areas.
- Tourism is also growing in the area day by day and could become an important source of income.
- Impact on literacy rate is also becoming obvious with the fact that on the one hand more educational institutions are being opened and on the other, students from villages are able to go to Gilgit city or the down country for higher education.

2.13 Summary

The reality of locally designed irrigation systems within the harsh mountain environment especially NAs has been neglected over long periods due to the attribution of backwardness and limited growth orientation towards remote valley societies. Only within the last decade awareness has significantly grown and a deficiency on accessible information about their cultural and socio-economic foundations is present. In recent years development agencies implementing integrated rural development programs try to build on local knowledge and emphasize cooperation with farmers in order to serve their felt needs. In sum, there appears to be an increasing demand to understand the complexity of locally adapted irrigation systems and the connected societies which could serve as a center for regional development involving the projects for reorganized activities.

Irrigation in NAs proofs to be a well-established since long time ago as sophisticated system in the NAs as a whole and study areas particularly. However, during this study certain challenges are noticed faced by farmers mainly in Sultanabad and Parri recently:

- seasonal water shortage affecting villages at the lower parts of the main channels,
- seepage in the channels causing considerable water loss due to poor infrastructures,

- natural hazards, e.g. floods, landslides, causing damages mainly at channels heads,
- poor condition of water rights documents and lack of interest by government,
- lake of farmers participation in TIS in terms of O&M,
- and lack of monetary resources for development.

There remains the common error that water shortage does not occur in regionalized small irrigation systems in NAs where only 1.8 % of the available land (as shown above) is cultivated. In that case it is assumed that there are enough resources to irrigate these few terraces properly throughout the year. This assessment holds true especially for the Karakoram where the glacier cover is excellent. However, even there water scarcity is common and affects the selection of crops. Traditional crops well adapted to high mountain conditions include wheat, millet, peas and barley all of which require about 250 mm water on average; whereas crops such as maize need about 800 mm. Potatoes and beans are positioned in between (Kreutzmann, 2000).

The irrigation schedule in NAs is characterized by scarcity and surplus water periods. The system of cultivation can only be managed through collective effort of respective farmers if the vegetation growth period governed by climatic factors is taken into consideration. The existing irrigation system is a highly adapted strategy to improve water deficiency during the sowing seasons. The amount of water available in the growing season directs the development potential and increase of productivity.

There are many factors and social differentiation of water user groups, which is very important to understand. In NAs Pakistan they are the still most hidden features, but nevertheless very important. Netting Robert (1974) called it "the system nobody knows" in one of his famous contributions to irrigation studies. There is some paradox in his statement; basically it is a system known to everybody who is concerned with it and who is an actor in practice. But as it is nowhere written down and fixed, it is difficult for researchers, policymakers and development practitioners to grasp. We can find these features of irrigation societies globally in mountain irrigation networks and in Asia and the

Indus Basin Pakistan (cf. for more detailed evidence: Sidky, 1996).

The management of irrigated agriculture varies in the NAs as it depends much on the specific physical conditions of irrigation system as well as the respective social and historic background. However, the major common feature regarding irrigation practice is the sustainability of a system and long standing way of managing and operating the limited water resources as common effort through a sophisticated system of social institutions. This in turn contributes to strengthening the community based farmers organization by creating interdependence among water users to ensure the participation in irrigation management.

The utilization rights, including the water rights documents and customary laws, are for the people/farmers to rely on. Despite permanency of the legal documents and oral traditions, dynamism is noticeable in the organizational structure. This concerns particularly the increasing management of services in the irrigation sector, e.g. through government funding, wage work, and penalties in cash from farmers. Such kind of economic management of collective water resources may indicate the change in NAs irrigation system.

Management of the water resources for irrigation uses should incorporate a participatory approach by involving not only the governmental agencies (NPIW) but also the users' and other stakeholders, in an effective and decisive manner, in various aspects of planning, designing, development and management of the water resources schemes. Necessary legal and institutional changes should be made at various levels for this purpose. Appropriate role of WUAs and farmer organization should particularly be involved in the operation, maintenance and management of water infrastructures or facilities at appropriate levels progressively.

CHAPTER III

REVIEW OF LITERATURE

3.1 Introduction

The canal irrigation has been practiced in many countries, especially in arid and semi-arid regions of the world. During operation, the irrigation system is subjected to a variety of problems including seepage of water. The canal irrigation system especially, watercourses are facing a number of operational problems resulting in very high degree of losses of water during its conveyance. The lining of irrigation channels help to conserve water, reduces seepage and prevents the losses. The losses of water are not only economically undesirable but it would help on to adjacent land adding detrimental effect.

Several studies related to the impact evaluation of irrigation improvement projects such as water losses and saving, land and water productivity, participatory irrigation management, water markets and sustainability of irrigation schemes are done around the world including Pakistan. The present study is an attempt to measure the performance of the improved irrigation system in Northern Areas (NAs) of Pakistan. The study in hand is the first effort of its kind based on the primary as well as the secondary data. So far, in NAs Pakistan, not a single study has made an attempt to directly probe in to the problem. Therefore, there is no evidence of comparable results and no empirical literature available, which directly related to impact assessment of improved irrigation system (IIS). However, in national and international scenario, many studies were conducted to evaluate different issue and the performance of irrigation systems.

However, studies from the other parts of Pakistan and around the world related water losses from watercourses are described in section 3.2. Research studies related irrigation and agricultural productivity are summarized in section 3.3. Studies related to the impact of participatory irrigation management (PIM) on farm economy is discussed in section 3.4.

In section 3.5, described the studies related technical efficiency effect on crop production. The summary of the chapter is given in section 3.6.

3.2 Selected Studies Related Water Losses from Watercourses

Nazir (1990) reported that the water loss estimates given by Water Sector Investment Planning Study (WSIPS) for the irrigated fields were 25% of the water applied to the fields. These estimates were 1.5 times greater compared to the losses estimated in 1883, which were about 10% of the applied water.

Jacob (1990) carried out a research in northern areas of Pakistan and found one expects that a more precise control of water at the field inlet better leveling of the fields and appropriate intervention by the irrigator during the process of irrigation would lead to improved efficiencies at field level. Conveyance losses in supply and distribution channels are much as expected. He reported that the losses are no larger in the new channels than in the older ones, undoubtedly because of the sealing of channel beds by silt deposition, facilitated by the relatively flat slopes of the new Passu channels.

Irrigation Research Institute (1992) tested various lining materials to reduce seepage losses from the watercourses. About 12 watercourses located in different areas having varied soil textures and water table conditions were selected in addition to the 4 watercourses constructed at Field Research Station Niazbeg. This study revealed that water seepage losses from lined watercourses ranged from 8 to 19.8% of inflow.

Shahid et al., (1996) describe the efficient water saving can be achieved by keeping the conveyance losses to a minimum level. The seepage quantities from unlined irrigation channels as quoted from various technical sources ranges from 25% to 50% of transported water. While seepage losses in unlined conveyance systems of different countries in the world also varied from 25% to 50% of total diversion (Mashhadi, 1993).

Sarwar et al., (2001) estimated the conveyance losses had a remarkable effect on water distribution; as conveyance losses at the head sections were reduced, farmers were getting more discharge at their farm gates. It can be concluded that frequent maintenance and cleaning of earthen watercourses was necessary to maintain high conveyance efficiencies.

WAPDA (2004) undertook a water management research project at the Mona Reclamation Experiment Project (MREP) which determined that watercourse conveyance loss rate ranged from 31% to 57%, with the highest losses in SCARP areas.

OFWM (2005) has found that lining is a long term effective technique for reducing seeping losses from the watercourse, but on account of being costly; it is somehow provided only on 15-30% length at the head of watercourse.

Siyal (2007) reported that the OFWM program had developed as a technical approach for water conservation and its improved management at watercourse command level, OFWM program was now told recognized and enthusiastically supported by the farming community. A majority 86.5% of the farmers perceived that there was great improvement occurred in water delivery efficiency through watercourse renovation.

Arshad et al., (2009) absorbed that for the lined watercourses the irrigation water losses ranged from 35 to 52% and for the unlined these were from 64 to 68%. Arshad and Ahmad (2011) reported that lining has increased 25% conveyance efficiency and if we lined all other watercourses not only conveyance efficiency will be improved but will also help in equal water distribution among farmers and will increase the command area of that watercourse.

3.3 Studies on Irrigation and Agricultural Productivity

Under irrigation and agricultural productivity, there are very useful studies such as (Merry and Wolf, 1986; Chaudhry, 1986; Badruddin, 1987; Kumar and Mruthyunjaya, 1992; Byerly, 1994, Faruqee, 1995; Khan, 1997; Sivasubramayan, 2000; Iqbal and Ahmad, 2001; Bhattaria, et al., 2002) which focus on the role of irrigation in enhancing agricultural productivity.

Khan, Ali and Anania (1996), examined the factors behind low crop yield. Both the quantitative & qualitative analysis has been taken. The quantitative findings provide valuable in-sight into various sources of productivity in terms of acreage effects, capital input effect and irrigation water availability effect. All the indicators show that the results are statistically valid and that the model in its final estimated form is well specified, while the rests of variables are insignificant.

Hassan (1997) analyzed the trend of agricultural productivity in Pakistan since independence. He reported that the 1960 was a surge in the agricultural growth rate of 5% per annum, exceeding internationally by Malaysia and Thailand. The improvement was the result of significant investment in water resources. Agricultural production during this period was helped by large augmentation of irrigation water supplies from Tarbella Dam and the dramatic increase in the domestic production.

Molden et al., (1998) reported that to achieve sustainable production from irrigated agriculture, it is essential to improve the utilization of resources such as water infrastructure and land resources (Molden *et. al*, 1998). The crop production in this area is very dependent on irrigation derived from high altitude snow and ice melt (MacDonald, 1998).

Sivasubramaniyan (2000) discussed the irrigation impact in terms of cropping intensity, crop pattern & productivity of land in 1988-89 and 1991-92. A survey was conducted in 1992, from 210 farmers in two multi village tanks in KPT and DMT in Tamil Nadu. Analysis shows that access to well water and location of land have a significant bearing on cropping intensity.

Rosegrant et al., (2002) find out several factors which contribute to water scarcity such as average annual precipitation may be low or it may be highly variable. Moreover, population growth and an increasing consumption of water per capita have resulted in a rapid increase in the demand for water. This tendency is likely to continue as water consumption for most uses is projected to increase by at least 50% by 2025 compared to 1995 level. Since the annually renewable fresh water available in a particular location is typically constant, water scarcity is increasingly constraining food production.

Ma and Fang (2006) explain that world water crisis has already affected about one third of the world's population. Irrigation water is very important for agricultural production, as it is positively correlated with grain yield. It is very important for the policy makers to take measures to improve irrigation water use efficiency, especially in the water-scarce areas (Wang, 2010).

Afzal and Barbhuiya (2011) mentioned that the canal irrigation system of Pakistan is one of the largest irrigation systems in the world. This system is very old and needs major improvement to make it efficient and meet the present demand for irrigation. It can be managed well, if the farmers are involved in its operation and maintenance (O&M).

3.4 Assessment of the Impact of Participatory Irrigation Management (PIM) on Farm Economy

A wide range of participatory irrigation management studies have identified a multitude of reasons why local farmers have participated or not participated in irrigation management. These reasons include: livelihood dependency of irrigation schemes (Ostrom, 1999; Kim & Khiev, 2007), the presence of an efficient and reliable supply of water, the level of benefits that flowed from irrigation schemes (Maleza & Nishimura, 2007), peer pressure (Levi, 1988; Ostrom, 1994), trust in the leadership (Wade, 1988; Meinzen-Dick et al., 1997; Lopez-Gunn, 2003), local awareness of rules, rights and the importance of participation relative to livelihood and irrigation status (Tewari & Khanna, 2005), the improvement in scheme infrastructure and the community's sense of ownership of the scheme (Ostrom, 1990 and Hirschmann, 2003).

Salman (1997) made a comparative study of the legal framework of Water Users Associations (WUAs) in six countries namely Colombia, India, Mexico, Nepal, Philippines and Turkey. The study suggested that if farmers participate through WUAs in managing and operating parts of the irrigation system, including collecting water charges, the result would be an optimum use of water.

Mollinga et al., (2001) studied the implementation of participatory irrigation management in Andhra Pradesh. He reported on the impact of the introduction of participatory irrigation management in two secondary canals. The empirical findings revealed that the rural elite captured most of the seats in the WUAs managing committees and committee membership was strongly linked to party politics.

Wahaj (2001) studied the performance of irrigation system in Fordwah Irrigation system in Pakistan. Six water courses along the two distributaries at the tail of the system were selected for in-depth study. The study suggested that there was neither a standard set of water management activities nor the strict plan. Farmer’s actions were mostly subjected to their desires to match water demand with supply. However, one could still see some of the water management activities that were inevitable to operate the system.

Bagadion (2002) studied the role of water users associations for sustainable irrigation management. The paper drew from the experience of the Libanan-Cabusao Pump Irrigation System to identify the factors affecting the role of WUAs in participatory irrigation management in the Philippines. In general, the factors identified were: laws and policies of the country and its irrigation agency; physical condition of the irrigation system; size of irrigated farm holdings; farmers’ net income; capability and organizational arrangements of the WUA; and environmental problems

Karagiannis et al., (2003) mentioned that in Pakistan, poor irrigation water utilization has serious implications on agricultural development. However, during the last decade, considerable efforts were made to develop new policies aimed at increasing irrigation water efficiency based on the assertion that more could be achieved with less water.

Chandrasekaran et al., (2004) studied participatory irrigation management for efficient water use and enhanced rice productivity in Tamil Nadu. They reported the results of community based on-farm irrigation management trials; experiments were conducted during 1992-97 at two different sites of the Cauvery Delta Zone to determine the requirements and benefits of improved irrigation management. Improved irrigation management reduced water use at the head and middle reaches and spared more water for farmers at the tail-end compared with the control. Results indicated that farmers in an irrigation system could increase crop productivity through the judicious management of irrigation water and equal sharing of water from the head to the tail-end area.

Namboodiri et al., (2006) studied surface water institutions in India. He analyzed the performance of the local level water user associations and irrigation cooperatives. The study showed that the role of government dominated as regards to pricing of water and actual release of water for irrigation. On the other hand the institutions played a major role with respect to planning for capital investments, actual release of water for irrigation, collection of dues from farmer members and monitoring the use of water.

3.5 Studies Efficiency Effect on Crop Productivity from Pakistan

Battese and Coelli (1993) adopted two models of technical inefficiency with stochastic production frontier to wheat crop using data of four districts of Pakistan. The results indicated that frontier was shifting out over time. It was also found that technical inefficiency was declining in the districts of Faisalabad and Badin. Adoption of new technology and better extension services to wheat producers were the important factors in improving the efficiency.

Battese, et al., (1996) used a single stage stochastic frontier production function to estimate technical inefficiency and its determinants in wheat production in Pakistan. Only the coefficient of labor was found statistically insignificant and it was estimated that the older farmers with better education were less technically inefficient.

Battese and Broca (1997) adopted translog and Cobb Douglas production functions to determine technical efficiency for wheat farmers in four districts of Pakistan. Different hypotheses were tested and the Cobb Douglas was preferred over translog model. The mean technical efficiency ranged from 50 to 100%.

Battese and Hassan (1999) estimated technical efficiency of cotton growers using a stochastic frontier production function model. Technical inefficiency of cotton production tended to decrease for farmers who first irrigated their crops later and who performed rogging, but inefficiencies tended to increase with more inter-culture operations.

Ajibefun et al., (1999) mentioned that the technical efficiency is the ability of farms to produce the maximum output from its resources. Technical efficiency of an individual farm is defined as the ratio of observed output to corresponding frontier output and farm effects at the available technology. Hence, inefficiency arises, if there is a gap between production level at the frontier and that at the farm.

Hussain (1999) estimated the technical, allocative and cost efficiencies of the cotton-growing farmers in four districts of Punjab. Both parametric and non-parametric approaches were employed. The mean values of technical, allocative and cost efficiencies for stochastic frontier production function and DEA were approximately similar. Farmers' education, extension service and credit facilities were found to decrease technical inefficiency in cotton production.

Shafiq and Rehman (2000) applied data envelopment analysis (DEA) to study the relative technical and allocative efficiencies of individual farms in cotton production in Pakistani Punjab. The analysis pointed out the existence of a significant extent of resource use inefficiency. In many instances, it was found that farmers were using the quantities of inputs unjustifiably higher than what would be required to achieve their present levels of crop output.

Ahmad, et al., (2002) adopted a stochastic production frontier analysis to estimate wheat productivity, efficiency and sustainability in Pakistan. The results showed that the average technical efficiency was about 68% showing that an average farmer could increase wheat production by 32% with available resources. Farm size, credit and location of market were found causing decline in technical inefficiency.

Bastiaanssen et al., (2002) mentioned that, in Pakistan the gap between water demand

and supply has increased manifolds, due to increased agricultural activities. The gap generally widens in winter season as compared to summer season. It also widens towards the tail end of distributaries and watercourses.

Bakhsh (2002) worked out economics of growing winter vegetables in Multan district of Punjab, Pakistan. Vegetables included carrot, radish and turnip. Results showed that labor was the important constituent of total cost in vegetable cultivation. Higher share of labor in total cost was reported in cauliflower, followed by carrot and turnip.

Ahmad (2003) estimated different input elasticities of production for poor and non-poor farms using the stochastic frontier production function. The average cost of the existence of technical inefficiencies was about 43% in terms of loss in output, ranging from 17 to 62%. The salinity problem and the tail-end location of the plot adversely affected farm productivity and efficiency.

Ahmad et al., (2004) estimated economics of growing potato in two districts (Okara and Kasur) of Punjab, Pakistan using cross sectional data. The findings of the study indicated that per acre yield was higher in Okara than that in Kasur. Important factors influencing yield between two districts included seed, farmyard manure and inorganic nutrients, irrigation and labor used for weeding. Therefore, net returns were significantly higher in Okara compared to Kasur.

Udoh and Etim (2006) estimated farm-level, output-oriented technical efficiency indices using stochastic frontier production function for waterleaf producers in Ethiopia. Labour, organic manure and irrigation were the most important production factors. The mean efficiency of 65% showed that output could be increased with available technology and resources.

Athar and Bokhari (2006) examined ethno-botany and production constraints of traditional and commonly used vegetables in Pakistan. It was recorded that in spite of higher profitability less area was allocated to vegetable cultivation. Moreover, lack of physical and social infrastructures, irrigation water, absence of market intelligence, use of improper seed, high infestations of pests and diseases, post-harvest deterioration and lack of effective extension work were the most critical factors limiting vegetable production and profitability in Pakistan.

Gal et al., (2009) suggests that appropriate relationship between irrigated schemes, farms and agro food processors can be effective for improving food productivity. Ghumman et al., (2010) and Shakir et al., (2010) have investigated irrigation systems in Pakistan. There are several other studies, addressing irrigation and agricultural issues (Batt and Merkley 2010; Hye and Siddiqui 2010; Lecina et al. 2010; Frija et al. 2010). But depending on the nature of the issues involved, there are still several areas which need further work.

3.6 Summary

The review of literature is a blend of many studies. Most of the studies were directly or indirectly related with the study in hand. Each study has specific features on the basis of objectives and methodology adopted. The findings of these studies are quite revealing and provide insights for testable hypotheses. The development of infrastructure especially irrigation, family size and education have important bearing on agriculture productivity. The studies on farm productivity indicated considerable increase in per unit crop yields and cropping intensity which they safely attributed to the irrigation developments. Cropping pattern was also changed due to heavy investment in irrigation infrastructure. Cultivation of high value crops and increased crop productivity has added reasonable increase in the income of the rural population. Studies on irrigation improvement revealed that there is sufficient amount of water available for agriculture in different regions of the world. If proper water harvesting and management techniques are adopted along with the water resources development strategies, agricultural productivity could be increased considerably.

It was clearly reflected that equity in water distribution was achieved by the involvement of farmers in the decision process. However, it differed significantly from one setting to another depending on factors such as land and water distribution, the quality of irrigation and infrastructural management, the availability of inputs and support services, and water and irrigation policies.

An inspection on the above-mentioned studies points out that the frontier approach has been used for measuring efficiency of agricultural sector in Pakistan and around the world. But according to our knowledge, no study was found on technical efficiency in crop production from northern mountainous areas of Pakistan. The studies reviewed in the above sections revealed that technical inefficiency was a serious problem and it is, therefore, of prime importance to measure technical inefficiency and its causes. Main causes of technical inefficiency include poor managerial qualities of the producers. Agricultural productivity could be enhanced by improving managerial qualities (technical skill and knowledge) of the farmers (Ali and Flinn 1989). Therefore, this study will help in identifying various factors affecting productivity and ways to improve dry season crop production in Northern Areas of Pakistan.

The stochastic frontier production function approach, source of data, sampling and empirical models are discussed in the next chapter in detail.

CHAPTER IV

MATERIALS AND METHODS

4.1 Introduction

Analytical study comprises of systematic and appropriate techniques for analysis. The selection of sample, data source and methodology is important to analyze, verify and describe the relationships. The finding and analysis of data comprising qualitative and quantitative variables need in-depth interpretation. The first section of the chapter provides an overview of sampling framework and data sources. The second section explains different approaches such as single equation estimation: OLS approach, Yes's index of satisfaction (YIS) and participation, concept regarding production function and efficiency concepts and measurement along with basic definitions. This chapter also describes the historical background of stochastic frontier production function and the technical inefficiency effects model.

The data presentation and dissemination leads to successful completion of the study. Keeping in view the objectives of the study, following research methodology was adopted.

4.1.1 Sampling framework and sample size

Statistically well designed sampling procedure is of prime importance to drive the needed inferences. A systematic sampling procedure was adopted in selecting the samples from the two villages (Sultanabad and Parri) of Gilgit District in Northern Areas of Pakistan. The list of all schemes installed in these villages was received from the office of the Director Water Management Gilgit. Study areas were initially selected purposively on the ground that both improved and traditional irrigation systems are available. A representative sample of 78 farm households were selected for collecting primary information from the field and secondary information from the water management/irrigation department offices and other national and international sources.

4.1.2 Questionnaire development

A comprehensive questionnaire was constructed and pre-tested in order to make necessary changes regarding variation in situation across different selected watercourses. After necessary amendments, the final version of the questionnaire was developed with simple and easy questions for the respondents. The questionnaire consisted of different elements arranged as follows.

- **Basic household information**

This part was designed to gather information about the household, such as household members, their ages, education level, sources of income, employment, non-farm income, area owned, and area rented-in, area rented-out and land rent in the area.

- **Agricultural production**

This unit obtained information on the farming situation and experience, cultivated area, crop cultivated, crop production in each growing season, agriculture inputs and values of agricultural production and inputs were collected from the both irrigation system groups.

- **Irrigation infrastructure and management**

This section gathered information on sources of irrigation water, number of irrigations systems, operation and maintenance of irrigation infrastructure, water distribution and overall condition of the water channels, level of participation, satisfied or not satisfied with the present irrigation system were collected.

4.1.3 Pre-Testing of the questionnaire

Keeping in view the objectives of the study, information such as the clarity of the questions, length of time required completing a questionnaire, quality of the answers, relevancy of the questions and logistical requirements were gathered during the pre-testing period. A general review of the questionnaire was conducted and necessary changes based on pre-testing were incorporated.

4.1.4 Data sources and collections

Two types of data were collected.

- Primary data
- Secondary data

4.1.4.1 Primary data collection

For collection of primary data, we interviewed the respondents personally at their farms. Although questionnaire was constructed in English, yet the questions were asked in the local language (Shina) for the convenience of interviewees to get the required information with maximum accuracy. While interviewing, I tried my best to maintain informal and friendly atmosphere in order to obtain the data from the respondents. Data was mainly based on recall for up to the past one year, since respondents rarely had written records. Due to the lack of education in the region keeping records, especially data that were related to land use and inputs for individual crops were difficult task to collect. However, whenever possible, cross checking was done simultaneously with the help of individual farmers, head of the village and land record holder (the local government office or tehsil office), to minimize the straight forward recall error. Fieldwork in the community was the ultimate focus of study as farmers were the most important stakeholders in the process.

4.1.4.2 Secondary data collection

Various secondary data sets were also collected in order to support the results on primary data set. In this research, selected improved and traditional channels were examined and assessed for their physical and economic performance. The research work was based on:

i. Literature review,
ii. Interviews with different stakeholders including farmer organization (FO) representatives particularly president and members of management committee, water user associations (WUAs),
iii. Officials of Water Management Department (WMD) and irrigation management experts from different walks of life.

Literature review contributed towards the understanding of the existing irrigation system and the proposed institutional structure. The climate data was collected from the Gilgit Metrological Department (GMD). Interviews with the FO, WUA representatives and relevant people from the government and relevant institutions enhanced the understandings of the irrigation system management and broadened the vision regarding the irrigation improvement.

4.1.5 Data entry and data organization

For data entry, a format was prepared on the Microsoft Excel work sheet. It was also required to convert data recorded in different units in the questionnaire to standard units prior to entering in the database. All the data was carefully entered. Cleaning is the integral part of the data management process before using it in the final analysis. The entered data was examined for errors, missing values and zeros. Errors identified were corrected. The data were also examined cell by cell to detect any error.

4.2 Conceptual Framework

In this part, conceptual frameworks underlying the analytical techniques used in the study have been discussed. This part is divided in to four parts:

a) Single equation estimation: OLS approach
b) Yes's index of satisfaction and participation
c) Concept regarding production function

d) Efficiency concepts and measurement

4.2.1 Single equation estimation: OLS approach

In this study different single equation models have been estimated to capture the impact of improved irrigation system on farm income and farm productivity. Models were estimated by using Multiple Regression models through Ordinary Least Square (OLS) estimation procedures. Multiple regression was used to account (predict) for the variance in an interval dependent, based on linear combinations of interval, dichotomous, or dummy independent variables.

4.2.2 Yes's index of satisfaction (YIS) with index of participation

Level of satisfaction was analyzed using Yeh's Index of Satisfaction (YIS), (Yeh, 1975). The satisfaction index has been used widely to determine the satisfaction index of respondents in various income groups. The index was calculated by subtracting the number of respondents who were dissatisfied from the number of satisfied respondents and then dividing it by the total number of respondents. Putting it into a symbolic form, YIS, can be written into the following expression equation (1):

$$\text{YIS} = \frac{\text{S}-\text{D}}{\text{R}} \qquad \text{(i)}$$

Where,

S = the number of respondents satisfied with Present Irrigation System (PIS),

D = the number of respondents dissatisfied with PIS and

R = the total number of respondents.

To understand the level of farmers' participation in irrigation management a similar participation index was defined as follow in equation (2):

$$\text{IP} = \frac{\text{P}-\text{NP}}{\text{R}} \qquad \text{(ii)}$$

Where,

IP = Index of participation,

P = the number of respondents involved in Participatory Irrigation Management (PIM),

NP = the number of respondents never participate in PIM and

R = the total number of respondents.

The index ranges from +1 to –1. A positive value indicates that there are more respondents who are satisfied than those who are not satisfied or participation in PIM is higher than non-participation. The larger the value, the more intensive is the degree of satisfaction or participation and lower value shows the dissatisfaction or non-participation.

4.2.3 Concept of production function

Generally, production function shows how the factors of production such as land, labour, capital and entrepreneur are combined to produce output. Factors of production have derived demand because only factor of production does not provide utility to human being e.g. fertilizer provides no utility to human beings but it increases output when used in production process. According to Beattie and Taylor (1985), production function is the highest output that a farmer can get from a given set of inputs with the given technology. A production function in mathematical form is expressed as:

$$Y_i = f(X_i)\varepsilon_i \qquad (1)$$

Where Y_i denotes output of a farmer, X_i shows a vector of inputs used in the production process and (f) represents suitable functional form. ε_i represents deviation from ideal production level that ranges from zero to one but never negative. If ε_i is greater than zero, output is assumed to be subject to random error. There are two types of inputs which are used in the production process. They include variable inputs and fixed inputs. Variable inputs can be defined as the amounts, which can be changed during a production process whereas fixed inputs are those inputs whose amount does not change in a production process for certain of time. So we can say there are two time periods namely short run period and long run period. All inputs used in the production process are assumed as variable inputs in the long run time period. Whereas in the case of short run time period one input is assumed as variable input and all others remain fixed.

4.2.3.1 Technical efficiency

Economic performance of a firm, farm or organization is estimated by efficiency. It is defined as the economic or productive efficiency of a firm, farm or organization, meaning that it is thriving in producing as much output as feasible from a known set of inputs (Farrell, 1957).

According to Koopmans (1951) efficient producer is one who has to sacrifice at least one unit of any output to obtain at least one extra unit of other output or who could save at least one unit of any input at the cost of reduction in the quantity of at least one output. There are two components of efficiency such as technical and allocative efficiency. Technical efficiency means the capability of a farm to produce as much output as achievable with given sets of inputs (input oriented efficiency measure) or the capacity of a farm to use as least inputs as possible for a given level of output (output oriented measure). Farrell (1957) estimated the difference between technical and allocative efficiency. Technical inefficiency might be when maximum output is not achieved with given factors of production and the causes of technical inefficiency include mismanagement of timing and method of application of production inputs.

Allocative or price inefficiency arises when the ratio of marginal products of inputs is unequal to the ratio of market prices. According to Lovell (1993), allocatively efficient firms combine optimal combination of inputs and output while keeping in view the established prices. Economic efficiency is the product of technical and allocative efficiency.

4.2.3.2 Inputs oriented efficiency measures

Farrell (1957) used input oriented efficiency measures to explain the constant return to scale relation between multi-inputs and a single output. Using this approach, he illustrated the concepts of technical, allocative and economic efficiency. In Figure 4.1 input oriented efficiency measure has been explained in detail. Two input factors namely, X1 and X2 are used to produce a single output (Y). A fixed level of output produced by using different combination of two inputs is shown by the unit isoquant input IQIQ. Point B shows the technically output level on the efficient unit isoquant, IQIQ. A firm operating at point A produces the same level of output Y as produced on unit isoquant, IQIQ. A line drawn from the origin O, to the point A explains the technical efficiency of the given firm. This OA line passing through the point B indicates that the same level of output, Y, is produced with X1 and X2 inputs at the point B (Coelli et al. 1998) implying that the observed firm is technically inefficient. Thus, the technical efficiency of the observed firm is defined as the ratio of the distance from the point B to the origin over the distance of the point A from the origin.

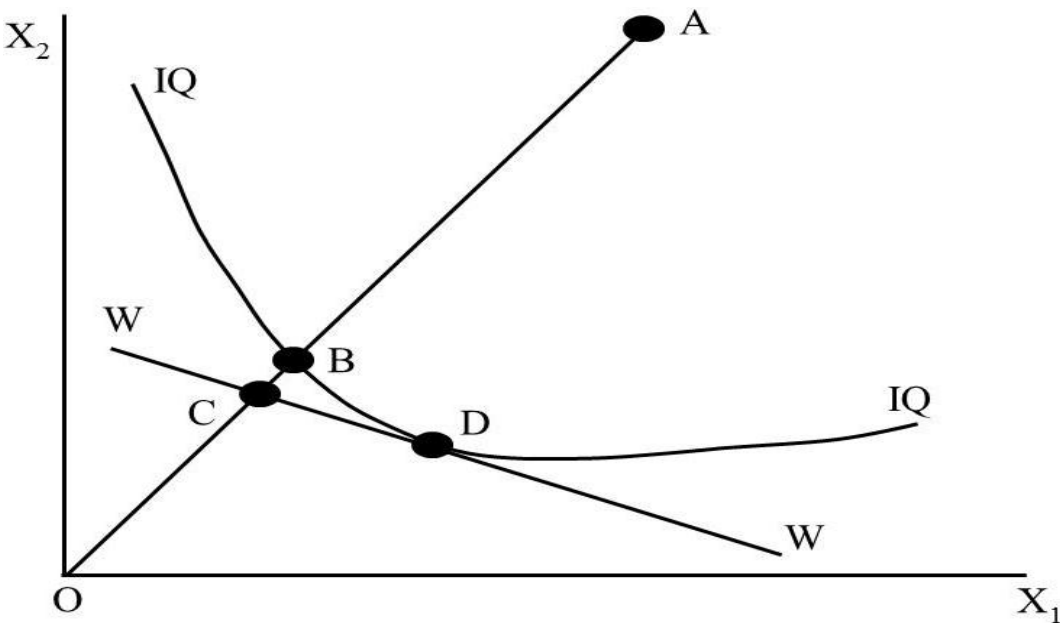


Figure 4. 1: Input-oriented measures for technical and allocative efficiency

(Reproduced from Coelli *et al.* (1998).

$$TE = OB / OA$$

We can estimate allocative efficiency in the presence of given input prices. In Figure 4.1 is “O” cost line is shown by (ww) which is tangent to the unit isoquant at the point D. The allocative efficiency is defined as: AE = OC / OB.

Both technically and allocative efficient output can be produced at the point D, but point B shows technically efficient production only (Coelli et al., 1998). Economic efficiency is defined as the product of technical and allocative efficiency. EE = TE* AE and EE = [(OB/OA) (OC/OB)] = OC/OA.

4.2.3.3 Concept of production frontier

Production frontier is defined as the relationship between input and output. It reflects the highest output that can be attained at each input level given the current state of technology in the industry (Coelli et al, 1998). The production frontier is used as a standard against which the technical efficiency of production of a firm, farm or organization is measured. Farrell (1957) referred the frontier as the best practice frontier. An average production function used to assess efficiency and optimum usage of inputs has been criticized on various bases. The production frontier function represents the utmost possible output reachable from a given level of inputs and the average production function represents the mean output for a given level of input and this is the important distinction between the production frontier and the average production function. Upton (1976) points out that the average production function is not an adequate representation of complex and dynamic farming system. Simultaneous equation bias and the problem of multicollinearity are raised by Yotopoulous and Nugents (1976) and Lau and Yotopoulous (1971). Ghatak and Ingersent (1984) are of the view that average production approach cannot distinguish between technical and allocative efficiency. It is possible that allocation of resources could be below the maximum technically efficient level, mainly due to the factors, such as lack of ability, knowledge and attitude.

On the basis of these drawbacks of average production function, production frontier has been chosen for the present study to determine technical efficiency of the farmers in the study area to analyze the impacts of improved irrigation system and other factors on the efficiency/inefficiency.

4.2.4 Measurement of technical efficiency

Two approaches namely frontier approach and non-frontier approach are used to estimate technical efficiency, which is also called non-statistical and statistical methods. Non-statistical methods comprise non-parametric and parametric approaches. The non-parametric approach is called deterministic approach as it has no fixed functional form for frontier including all observations in the model. It is also known as data envelopment analysis (DEA) method. The parametric approach is called probabilistic approach based on Cobb-Douglas or other forms. Statistical methods consist of non-stochastic and stochastic methods. Non-stochastic frontier approach estimates technical efficiency and it implies that all variation from frontier is due to presence of inefficiency. Stochastic frontier function (SF) shows that deviation from frontier is owing to two factors, random effect and inefficiency. Maximum Likelihood (ML) and corrected ordinary least squares (COLS) methods are used in statistical methods (Ali and Byerlee, 1991). However, in literature, both parametric and non-parametric approaches have been used to find out technical efficiency of various enterprises. Parametric approach makes use of econometric modeling and mathematical modeling is done in non-parametric (DEA) approach. There are certain advantages and disadvantages of these two approaches over each other which are discussed by Battese (1992), Bravo-Ureta and Pinheiro (1993), Forsund et al. (1980), Fried et al. (1993), Parikh and Shah, (1994); Parikh et al., (1995), Coelli (1996) and Coelli and Perclman (1999).

Schmidt (1986) argued that the results obtained by non-parametric approach are less precise because it makes less use of information compared to the parametric approach.

Further the DEA approach is sensitive to extreme observations and measurement error (Forsund et al. 1980). Another limitation of this approach is that it is difficult conceptually to separate the effects of uncontrollable environmental variables and measurement error from the effect of differences in farm management (Jaforrullah and Whiteman, 1999). Moreover, tests of hypothesis in relation to differences in technical efficiency cannot be performed statistically (Schmidt 1986, Jaforrullah and Whiteman 1999).

4.3 Parametric Frontier Production Function

DEA approach has not been used because of disadvantages of this approach as discussed above. Thus the parametric approach is used for the present study. Parametric approach has two types, deterministic and stochastic frontier production functions. Development in econometric frontier production function has been reviewed by Battese (1992) and Coelli, et al. (1998).

Following the work of Farrell (1957), we assumed that the production function of fully efficient firms is known. However, in practice the production function is not known. Farrell (1957) gave the solution to this problem. According to Farrell, the sample data could be used to estimate the production function by implying a non-parametric piece-wise linear technology or a parametric function, such as the Cobb-Douglas production function. In the production function (1), ε_i represents deviation from ideal production level that ranges from zero to one but never negative. If ε_i is greater than zero, output is assumed to be subject to random error, such that:

$$Y_i = f(X_i, \beta) + \varepsilon_i \exp(v_i) \quad (2)$$

Expressing equation (2) in the log form:

$$\ln Y_i = \ln f(X_i, \beta) + \ln \varepsilon_i + v_i \quad (3)$$

Where, $\ln\varepsilon_i$ is the TE term such that $\ln\varepsilon i \leq 0$ and v_i is the random error due to model specification [v_i ~ N (0, σ^2)].

The stochastic frontier production function takes account of firm's specific random shocks and technical efficiency separately into the analysis. Aigner et al. (1977) and Mceusen and Van den Broeck (1977) pointed out that deviations from the production frontiers are because of two types of factors, such as factors entirely outside the control of the firm or farmer and factors under the control of the firm or farmer. This signifies that deviations are not completely under the control of the firm or farmer, but some factors such as bad weather, measurement errors, etc. are totally outside the control of the firm or farmer.

4.3.1 The stochastic frontier production function

In order to overcome the deficiencies of traditional stochastic frontier production model, Aigner et al. (1977) and Mceusen and Van den Broeck (1977) gave independently the stochastic frontier production function, including both types of factors into the model. In such type of model, error term is decomposed into two components, factors outside the control of the firm or farmer and factors under the control of the firm or farmer. Therefore, this model is also called composed error model. This model shows that the firm's output can be affected by technical inefficiency along with measurement errors and other factors, such as effects of weather, luck, etc., combined effects of unspecified/omitted variables in the model (Coelli et al 1998). Simplifying equation (3) for j inputs and substituting u_i for –($ln\varepsilon_i$):

$$\ln Y_i = \beta_o + \sum_{j=1}^{x} \beta_j \ln X_j + v_j + u_i \qquad (4)$$

Where, β_0 and β_j are unknown parameters to be estimated, and u_i is the technical inefficiency term such that $u_i \leq 0$. It assumed that u_i ~ N ($0, \sigma_u^2$) or more specifically, u_i ~ |N ($0, \sigma_u^2$)|, which is independently and identically distributed. In addition, it is assumed that v_j and u_i are independently distributed over the input variables in the model (Battese and Coelli, 1988). Many assumption for u_i can be taken, however it is assumed to be half normally distributed, as it has been assumed in the majority of applications to date (Coelli, 1995). Here, u_i is obtained by truncation of the normal distribution at zero with mean $Z_i\ \delta$ and variance σ^2 (Battese and Coelli, 1995), given by: $u_i = Z_i\ \delta + W_i$, where, the random variable W_i is defined by the truncation of the normal distribution with zero mean and variance δ^2 such that the point of truncation is $-Z_i\ \delta$, that is, $W_i \geq -Z_i\ \delta$. For estimation, the functional form of u_i is considered to be:

$$u_i = \delta_o + \sum_{m=1}^{a} \delta_m Z_{mi} + e_i \qquad (5)$$

Where, δ_0 and δ_m are unknown parameters to be estimated, Z_{mi} is the variable affecting TE in the production, and e_i is the model specification error [$e_i \sim N\ (0,\ \sigma_e^2)$]. The stochastic frontier production function is detailed in Figure 4.2. The horizontal axis shows the inputs units used in the production process and outputs are represented on the vertical axis. The deterministic frontier production function in the figure assumes declining return to scale. Two firms, *i* and *j* are considered. Suppose firm *i* produces output Y_i, and firm *j* produces output Y_j. Firm *i* makes use of x_i units of inputs to produce output Y^*_i = exp ($x_i\beta$+v_i) and this output level lies above the deterministic output level, Y_i = exp ($x_i\beta$+v_i) because the v_i's are positive. Now consider the firm *j* using *j*-th units of inputs and generating output Y**j* =exp ($x_i\beta$+v_i).This output level lies below the deterministic output level, since v_i's are negative.

Thus we can say that the observed output may be higher than the deterministic frontier production function if the random errors are greater than the inefficiency effects Y^*_i >exp (xiβ) if $v_i > \mu_i$). However, the observed output would be smaller than that of the deterministic frontier production function if the random errors are less than the inefficiency effects (Y**j* >exp ($x_i\beta$) if v*j*>μ_i), (Coelli *et al.* 1998).

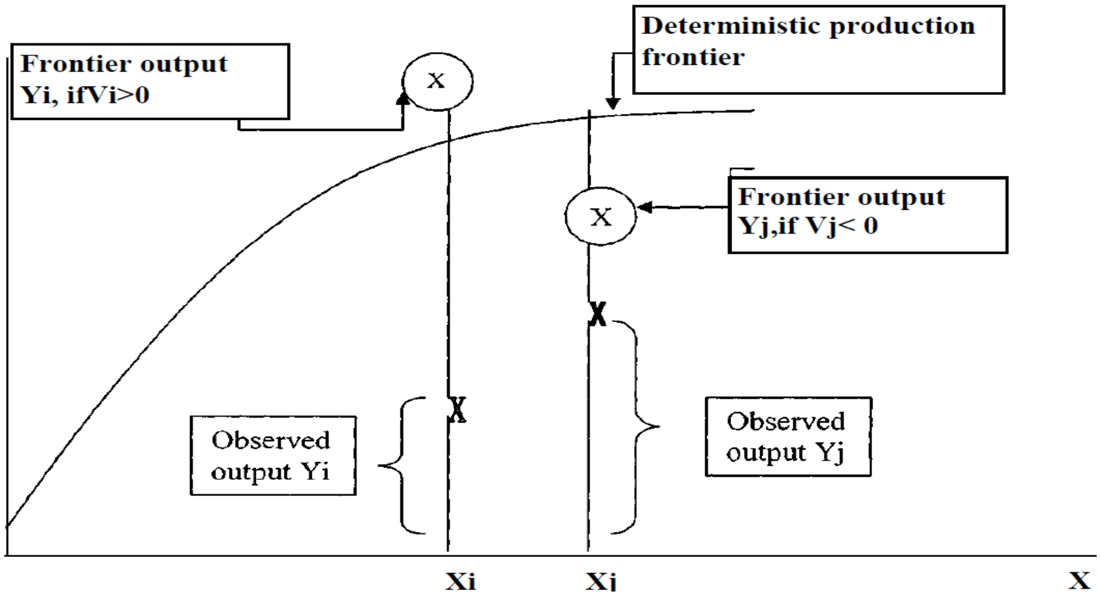


Figure 4. 2: Stochastic frontier outputs (Reproduced from Coelli *et al.* 1998).

4.3.2 Technical inefficiency effects model

A variety of factors, such as distinctiveness of firms, management, physical, institutional and environmental aspects can affect technical inefficiencies in the production process of the firms or farmers. Kalirajan (1981) and Pitt and Lee (1981) regressed the predicted technical inefficiency effects on various explanatory variables, such as firm size, age, education of the manager, etc. In the above studies two staged approach has been employed however, this approach has been criticized due to serious problems pertaining to assumptions made for the μi. In the first stage, the technical inefficiency effects are assumed to be independently and identically distributed using the approach of Jondrow *et al.* (1982) to estimate firm or farm level technical inefficiency. However, the predicted technical inefficiency effects are assumed to be a function of a number of firm-specific factors in the second stage, which implies that they are not identically distributed, unless all the coefficients of the factors are simultaneously equal to zero (Coelli *et al.* 1998).

Kumbhakar *et al.* (1991), Reifschneider and Stevenson (1991) and Battese and Coelli (1995) criticized the second stage used to estimate the determinants of technical efficiency. They specified stochastic frontier models in which the inefficiency effects are defined to be explicit functions of some firm-specific factors, and all parameters are estimated in a single-stage maximum likelihood procedure. Wang and Schmidt (2002) critically discussed biasness in two-step estimation of the effects of exogenous variables in technical efficiency levels by proposing a class of one-step models based on the scaling property that *u* equal a function of *z* time a one-sided error *u* whose distribution didn't depend on z.

Hung and Liu (1994) suggested a model for a stochastic frontier production function, in which the technical inefficiency effects are specified to be a function of some firm-specific factors, in conjunction with their interactions with the input variables of the frontier function. Bravo-Ureta and Pinheiro (1993) also studied the association between technical efficiencies and various socio-economic variables, such as age and level of education, firm size, access to credit and utilization of extension services. Battese and Coelli (1988, 1993 & 1995) proposed the technical inefficiency effects model for panel data. This model estimates stochastic frontier production function and inefficiency effects in a single step to avoid problems of two-step models. On the other hand, the suggested measure of technical efficiency is given by (Battese and Coelli, 1988), to begin with the stochastic frontier production function:

$$TE_i = \exp(-u_i) \qquad (6)$$

$$\frac{E(Y_i^* / u_i, X_{i)}}{E(Y_i / u_i = 0, X_i)} \qquad (7)$$

From this model the technical inefficiency effects are function of a set of explanatory variables, namely firm size, age, education of the manager and other socio-economic factors and vectors of unknown parameters to be estimated and a random error (Battese and Coelli 1995). It is assumed that the technical inefficiency effects are independently distributed non-negative random variables; however, these effects are not identically distributed random variables. The prediction of technical inefficiency is based on its conditional expectations, given the model assumptions (Battese and Coelli, 1995).

4.3.3 Estimation of stochastic frontier production

The maximum likelihood estimates (MLE) method or corrected ordinary least square (COLS) method can be used to estimate the parameters of the stochastic frontier production function. However, Coelli, (1995) concludes that the maximum likelihood estimator is asymptotically more efficient than the COLS estimator. Computer software such as LIMDEP econometrics packages (Greene, 1992) and the FRONTIER 4.1 program (Coelli, 1996) can be used to determine technical efficiency. The parameters for the stochastic production function model in equation (4) and those for technical inefficiency model in equation (5) are estimated simultaneously using maximum-likelihood estimation FRONTIER 4.1 Program developed by (Coelli, 1995) in this study. Which, estimates the variance parameter of the likelihood function in terms of: $\sigma^2 = \sigma_u{}^2 + \sigma_v{}^2$ and $\gamma = \sigma_u{}^2 / (\sigma_u{}^2 + \sigma_v{}^2)$.

In general, technical efficiency lies between 0 and 1. When technical efficiency is equal to one, it implies that the firm or farmer is producing on the production frontier with available resources and technology and it is the indication that the firm or farmer is technically efficient. When value of technical efficiency is less than zero, it implies that the firm or farmer is producing below the production frontier for given technology and resources and it is said that firm or farmer is technically inefficient.

4.3.4 Likelihood ratio test

To decide on the production functional form and to test the significance of the variance parameters in the stochastic frontier production function, and other null hypothesis, generalized likelihood ratio (LR) tests are used. These tests employ the following calculation (Greene, 1990):

$$\text{LR } \lambda = -2\,[\text{Ln }(H_0) - \text{Ln }(H_1)]$$

Where, $Ln(H_0)$ and $Ln(H_1)$ are the values of the likelihood function under the null and alternative hypothesis. In most situations this statistic has asymptotic chi-square distribution with degrees of freedom equal to the difference between the number of parameters in H_1 and H_0, if H_0 is true. When one or more of the restrictions involve a one sided alternative, then this statistic does not encompass a chi-square distribution. When the null hypothesis involves $\lambda = 0$, the alternative hypothesis can only involve positive values of γ. Coelli (1995) noted that the distribution of any likelihood-ratio statistic involving the γ parameter has distribution which is a mixture of chi-square distributions. The 5% critical value for the null hypothesis of $\gamma = 0$, When μi is assumed to have a half normal distribution (Coelli, 1996a).

4.4 Summary

This chapter was divided into three parts. In the first part, single equation models were estimated to capture the impact of irrigation improvements in terms of land use, productivity and profitability. Multiple Regression model was estimated by using Ordinary Least Square (OLS) estimation procedure. In the second part of chapter, Yeh's Index of satisfaction used to know the satisfaction or participation level of farmers in irrigation operation and management. The Cobb-Douglas model common among researchers, which is also found to be statistically powerful, is used to fit the production function in the third part of chapter along with frontier and technical efficiency model. An advantage of the Cobb-Douglas production model is that coefficient estimates can be interpreted as measures of elasticity, thus allowing an analysis of the responsiveness of output to each of the input variables used in the production process; hence it is adopted in this research. The previous studies showed that Cobb-Douglas production function was widely used to determine the input-output relationship in agriculture sector. It was instead developed because it had attractive mathematical characteristics, such as diminishing marginal returns to either factor of production.

Frontier production represents the maximum level of output that is possible with a given level of inputs, which enables us to analyze the gap between farm and frontier production levels with the determining factors. The concepts of efficiency input oriented efficiency measures and measures of technical efficiency were also discussed in this chapter. Frontier approach was used to measure the technical inefficiency and its determinants.

CHAPTER V

CROP PRODUCTION AND PROFITABILITY IN SULTANABAD

5.1 Introduction

To achieve the objectives of this study comparing an improved irrigation system (IIS) with a traditional irrigation system (TIS) in terms of land use, crop productivity and profitability, we conducted a field survey in a village of Gilgit District Northern Areas (NAs) of Pakistan. A farmer's profit from growing a given crop depends upon the price he receives for his output, the level of output he is able to produce, and the costs he incurs in producing it. In this study, one way of judging competitiveness is to compare those production costs from the both IIS and TIS in the study area. A comparative cost of production analysis was thus undertaken as the first step in this study. To a large extent, this comparative cost of production analysis is fairly indicative of further issues of comparative advantage.

This chapter begins by presenting results of the two irrigation systems IIS and TIS available in the study area as well as results of the cost production, profitability and cost benefit analysis of the IIS. The sensitivity analysis evaluates effects of five assumptions. The assumptions that are evaluated are land use, crop yield, farm income, crop profit and improved irrigation cost per unit basis. The results and discussion are followed by a farmer's characteristic that attempts to determine the importance of IIS and its impact on farm income of the farmers especially for the dry season crops.

The first part of this chapter will cover the socio-economic profile of the respondents. The second part is based on the cost production analysis, profitability and cost benefit analysis of improved channels along with multiple regression analysis. The marketing channel along with summary is presented in the last part of the chapter.

5.2 Socio-economic Profile of the Respondents in Sultanabad

Apart from the direct measurement of the variables in the Sultanabad village other basic characteristics like household head age, education level, family size, farming experience sources of income of the respondents, and farm income provides information on the impact of irrigation in the study area. Various indicators were analyzed under the following categories:

- Socio-economic indicators
- Agricultural indicators

5.2.1 Socio-economic indicators

5.2.1.1 Household head age, family size and family labor

The socio-economic characteristics of the sampled farmers are presented in Table 5.1. The average age of improved irrigation system (IIS) and traditional irrigation system (TIS) farm household head is 62 and 53 years respectively. Most of the farmers (household head) in Sultanabad were relatively older and fall in the age group of 45-60 years. Though in few cases even the household head don’t participate in the farm activities due to higher age or sickness, but, he still uses his power to take decisions related to agriculture and other routine actions. It is possible that the older farmers may take benefit of their experience to grow crops more efficiently.

Family size represents the number of total family members (male and female) of the respondent. The average family size (10.8) of the respondents was very high compared to the national average family size of 6.8 persons (PAP, 2002), implying the presence of a larger family structure and an integrated family system. It was observed that IIS farmer are more educated than TIS farmers. It shows that large family size with low education level in the both groups has more tendencies to work on the farmland as compared to an educated family of the same size.

Table 5. 1 : Characteristics of Farmers

Particulars	IIS	TIS	p-value
Average household head age (years)	62	53	0.003 ***
Average family size (person)	11.3	10.4	0.259
Average household head education level (Years)	7.5	4.5	0.026 **
Average full-time family workers (person)	0.8	0.6	0.044 **
Average part-time family workers (person)	4.0	2.7	0.000 ***
Average farming experience for cereal crops (years)	22.4	21.4	0.422
Total area (acre)[1)]	9.6	8.2	0.094 *
Cultivated area (acre)	7.8	5.0	0.000 ***
Pasture and grass area (acre)	1.3	1.3	0.470
Non-irrigated area (acre)	0.5	1.8	0.000 ***
Average agriculture income (Rs.)	171,243	91,133	0.000 ***
Household income (Rs.)[2)]	423,318	212,880	0.000 ***

Source: Author's survey (2009)

Note: (IIS) Improved irrigation system, (TIS) Traditional irrigation system,

i. ***: Significant at 1%, **: Significant at 5% and *: Significant at 10%

ii. [1)] Total area includes (cultivated area + pasture and grass area + non-irrigated area)

iii. [2)] Household income is crop income + non-farm income except (livestock) income

iv. n= 38

The average family size, which is an indicator of family labor availability, is not significantly different between both systems. Furthermore, average number of full-time and part-time farmers in the IIS is significantly higher than that of the TIS in Table 5.1.

5.2.1.2 Educational status of the respondents

It was found that most of the farmers in the study area were either illiterate or just completed primary level education (up to Class V). When the respondents were asked about their low level of education, they revealed that they got the household farming in inheritance from their forefathers and no middle or high schools were available for the study at that time. For such respondents, agriculture was the only source of income, and due to their limited resources they remained unable to get desired education. However, the level of education measured in terms of number of years of schooling is statistically significant, indicating that farmer household heads in IIS are better educated. On the other hand, it was observed that majority of the farmers (educated or uneducated) were also engaged in other economic activities at local level due to less farm income. Thus it is clear from the above discussion that most of the farmers in the study area were not equipped with education due to lack of schools. Similar pattern of educational qualification was found in farmers' organization (FOs) and water user associations (WUAs). While interviewing such farmers, it was observed that they straggle in adopting modern agricultural techniques.

5.2.1.3 Farming Experience

Experience of farm household in agriculture has also implications on agricultural productivity. The result shows that farmers from IIS and TIS had 22.4 years and 21.4 years of experience in farming, and there are no significant differences between the both systems Table 5.1. They were able to get more productivity of crops by timely sowing of crops, use of improved and traditional irrigation systems. Since saving and equally distribution of water, use of seeds, fertilizers and agro chemicals on account of their experience.

5.2.1.4 Land holdings

Land is unevenly distributed among the farmers in the study area. The number of farms in different farm household classes varied during different time intervals. Land is being fragmented into smaller units due to prevailing inherited land distribution system. Over-population has been one of the more apparent causes of this variation especially as the farm sizes were decreasing. The average total landholding per farm household is significantly different between the two groups as the IIS farmers own 9.6 acres and the TIS farmers own 8.2 acres Table 5.1. This is mainly due to early settlement of the IIS farmers as a result, they have been able to acquire more land. Moreover, since the IIS farmers are settled in upstream even before the settlement was improved they were able to cultivate a larger landholding due to greater water availability in the upstream. The average cultivated land which includes extent of cereals, vegetables and fruits in both seasons is relatively high and statistically significant between the IIS farmers (7.8 acres) and the TIS farmers (5.0 acres). This is obvious as the IIS farmers have access to more land and water. Non-irrigated land extent of the TIS farmers is significantly higher than the IIS farmers. Almost all households are engaged in agriculture and it is the major source of livelihood in the area.

5.2.1.5 Income and sources of income of the respondents

Farming is a profitable business if it is managed scientifically/technically using balanced inputs. In the study area, it was found that most of the farmers were growing major crops (wheat, potato, vegetables and fodder) as dry season crop and (maize, barley, vegetables) in wet season crop, while fruits are grown by farmers as perennials in the study area. Due to financial constraints, most of the poor farmers were unable to use the recommended level of inputs and due to that they could not get expected yields. It was also evident that for large proportion of farmers in the study area agriculture was the only source of income. However, there were many farmers who jointly managed farmland along with the other economic activities due to less farm income.

More than 85% of the farmers were engaged in agriculture for their livelihood. In terms of cereal crops such as wheat only few farmers can sell in the local market or to the local farmers, while most farmers grow it for self-consumption. However, Potato, vegetables and fruits are the main source of cash income. The agricultural income as well total income of the IIS farmer in study area is significantly higher than that of the TIS farmers. The higher agriculture income is mainly attributed to the availability of irrigation water. The share of agricultural income of the IIS farmer’s total income is higher than that of the TIS farmers i.e. 53% and 43% Table 5.1, respectively.

Moreover, the higher total income in IIS farmer is due to the early settlement of farmers, which allows them to engage in off-farm activities within the village or nearest cities along the villages such as some of the respondents were either doing government (mostly in army) or private sector service, labor along with agriculture, shopkeeper, carpenters in the small wooden industries etc. and also very few farmers were getting remittances from abroad.

5.2.2 Agriculture indicators

5.2.2.1 Comparison of land use and yields of crops between the both systems

Wheat, potato, vegetables and fodder are the dry season crops and maize, barley, vegetables and (fruits as perennial) are the wet season crops grown in the study area. Both IIS and the TIS farmers utilize significant amount of their farm produce for self-consumption. Nevertheless, the majority of commercial farmers belong to the IIS farmer group. The low agricultural income of TIS farmers can be attributed to low land productivity, constrained by factors such as a lack of water and also might be poor soil fertility. Table 5.2 summarizes the percentage and average cultivated land, and crop yield for both IIS and TIS households as well cost production of dry season crops. Land utilization for crops among IIS farmers is significantly higher than TIS farmers in the dry season except for fodder crop. Even in terms of the proportion of total arable land used for crop cultivation, IIS farmers use a higher proportion of their arable land for crop cultivation during dry season. It is evident that the IIS farmers cultivate more land in the dry season especially for cereal and cash crop i.e. wheat, potato and vegetables, due to availability of irrigation water. While, the TIS farmers cultivated more land for fodder crop due to the fact that fodder need less water to grow and is second priority compare to the food crops.

Result shows that all the crops cultivated by IIS farmers in dry season produce higher yields as shown in Table 5.2 and 5.3. However, in the wet season the productivity of crops is not significantly different between the two groups with the exception of maize. The higher productivity in maize crop cultivated by IIS farmers can be attributed to the use of especially purchased seeds and other higher amount of inputs. The better productivity of IIS farmers in dry season can be attributed to both availability of water and high input usage. The absence of significant difference in productivity of barley and vegetables in the wet season indicates that irrigation could be an important determinant of crop productivity in the area. This further confirms the fact that IIS farmers are at an advantage in dry season due to continuous availability of water for crop cultivation. While collecting data from the field, it was observed that some farmers were getting more yields of crops and others operate at low performance level. The difference in crop productivity between the systems and across the various categories of farmers was attributed to number of factors, such as location of farmers field with respect to main canal and location of the farm with respect to watercourse, farmers usage of inputs, education level and might be soil conditions. Overall, condition of the watercourse i.e. improved/lined or traditional/unlined, also significantly contributed towards surface water availability to the farmers.

Table 5. 2: Average Land Size, Crop Yield and Profitability of Crops in Dry Season

Items	Dry Season Crops							
	Wheat		Potato		Fodder		Vegetable	
	IIS	TIS	IIS	TIS	IIS	TIS	IIS	TIS
Area (acre, %)[1)]	3.16*** (26%)	0.86 (11%)	1.41*** (17%)	0.59 (7%)	1.59 (13%)	1.89 (23%)	1.93*** (16%)	0.95 (12%)
Yield (kg/acre)	433.0***	317.2	858.8***	544.6	1,353.8***	906.7	1,455.8***	1,175.0
A: Gross production each crop (Rs.)/acre	9,293***	6,312	19,255***	13,342	20,307***	13,600	33,702***	27,202
B: Farm management cost (Rs.)/acre								
Hired labor	1,280	1,179	3,139	4,058	1,402***	1,033	2,699	2,540
Fertilizer	870***	326	2,257***	569	489***	187	1,201***	585
Agrochemical	638***	279	2,606***	1,485	1,074***	508	1,207	1,212
Own seeds	945	2,224***	2,579	5,004***	1,745	1,642	576	1,065***
Purchased seeds	1,104***	613	2,527***	510	1,987	2,036	1,021	981
Machinery cost including (fuel, tractor and tools)	2,120	3,430***	2,951	3,549	1,424	1,360	1,774	1,918
Total Rupees (Rs.)	6,956	8,050	16,058	15,175	8,121**	6,765	8,478	8,301
C: Net profit (A-B) each crop/acre (Rs.)	2,337***	(-1738)	3,197***	(-1833)	12,186***	6,835	25,224***	18,901
Irrigation cost for dry season Rs./acre	69.8							
Net profit each crop/farm (Rs.)	7,373	(-1501)	4,493	(-1081)	19,402	12,896	48,722	18,005

Note: 1). Figures in parenthesis indicate percentage (%) of land utilization in dry and wet seasons

i. ***: Significant at 1% and ** at 5% and * at 10%.

ii. Farm management cost includes (Hired labor cost, fertilizer cost, agro chemical cost, seed cost (own + purchased seed) and machinery cost (all type of tool tractor and fuel cost).

Table 5. 3: Average Land Size, Crop Yield and Profitability of Crops in Wet Season

Items	Wet Season Crops							
	Maize		Barley		Vegetable		Fruits	
	IIS	TIS	IIS	TIS	IIS	TIS	IIS	TIS
Area (acre, %)[1)]	5.2*** (42%)	2.59 (32%)	0.35** (3%)	0.15 (2%)	1.36** (11%)	1.04 (13%)	1.42** (12%)	1.07 (13%)
Yield (kg/acre)	492.3**	425.0	356.3	338.6	835.4	805.4	1,777.3***	1,475.5
A: Gross production each crop (Rs)/acre	11,945**	9,946	5,702	5,417	21,094	20,337	47,100***	39,100
B: Farm management cost (Rs)/acre								
Hired labor	1,546	1,361	1,622	963	3,727	3,918	395	206
Fertilizer	1,204***	785	1,020	756.8	917	916	-	-
Agrochemical	1,631***	844	964	545	1,702	1296	1,793	1,453
Own seeds	704	939***	717	489	586***	413	-	-
Purchased seeds	1,727***	953	121	355	619	563	-	-
Machinery cost including (fuel, tractor and tools)	2,840***	2,037	2,070	1,086	2,362	1,986	-	-
Total Rupees (Rs)	9,651	6,919	4,288	2,483	9,912	9,093	2,187	1,659
C: Net profit (A-B) each crop/acre (Rs)	2,294	3,027	1,414	2,934	11,182	11,244	44,913***	37,441
Irrigation cost for dry season Rs./acre	69.8							
Net profit each crop/farm (Rs)	11,932	7,837	491	448	15,243	11,747	63,587	40,200

iii. ***: Significant at 1% and ** at 5% and * at 10%.

iv. Irrigation cost for dry and wet season (excluding cost borne by the government), but this cost is not included with in net profit for each crop Rs. /farm

v. Source: Author’s survey (2009)

Table 5. 4: Cost Benefit Analysis of Improved Irrigation System

Channels	Length (m)	Irrigated area (acre)	Ⓐ Government share cost Rs.	Ⓑ Farmers share cost Rs.	(Ⓐ+Ⓑ) ❶ Initial cost Rs.	❷ Maintenance cost Rs.	❸ Initial cost Rs./acre	❹ Initial cost/acre /10 years	❺ Maintenance cost Rs./acre	(❹+❺) Total one year cost Rs./acre
1	740	135	287,500	104,847	392,347	8,000	2,906.3	290.6	59.3	349.93
2	810	250	355,680	110,070	465,750	10,000	1,863.0	186.3	40.0	226.30
3	390	105	190,360	100,000	290,360	6,000	2,765.3	276.5	57.1	333.63
4	465	90	200,690	96,890	297,580	7,000	3,306.4	330.6	77.8	408.44
Average	601.3	145	258,557.5	102,951.8	361,509.3	7,750.0	2,710.3	271.0	58.6	329.6

Source: Author’s survey (2009)

Note: 1USD= $ 60.8 (Rupees) in 2007; Durability of project: 10 years;

Total one year cost/acre is calculated by (Initial cost/acre/10 +maintenance cost/acre)

5.2.2.2 Cost production of crops and profitability

Estimation of cost of production of a farm enterprise is a complex phenomenon. The cost of one enterprise cannot be determined precisely unless the cost of all other enterprises is determined simultaneously. This is due to the reason that the farm enterprises are interdependent and interrelated and cost of any one of them cannot be determined in isolation. The major cost items included in this analysis were fertilizer, chemicals, seeds, hired labor and machinery cost (fuel, tractor and tools).

Cost of production and profitability of crops were calculated for dry and wet season crops per acre of land for the IIS and the TIS farmers as shown in Table 5.2 and 5.3. In the dry season, wheat is the main food crop, potatoes and vegetables are main cash crops while fodder is cultivated for the livestock by both the IIS and the TIS farmer groups. It is evident from the results that the real cost of production of dry season crop in most of items included in the analysis are significantly higher in the IIS compare to the TIS with few exceptions. The cost of production and profitability analysis Table 5.2 shows that the farmers in IIS had obtained higher gross production and net profit from all the crops. The higher gross production and profitability obtained by farmers in IIS can be attributed mainly to higher yield and the higher input usage as the input use is statistically significant between the two groups. Moreover, it is also evident as indicated by the significant difference in the cost of purchased seeds used for wheat and potato. The IIS farmers are using better quality seeds than the TIS farmers. However, there is no significant difference in input usage for vegetables between the two groups. This could be due to vegetables being the main cash crop, the TIS farmers pay more attention and utilize their limited resources for cultivation of vegetables. The farmers made judicious use of all the inputs along with the major production input. It also clearly depicted that the IIS farmers were able to get more quantity of irrigation water after improvement of irrigation in the study area.

Overall, analysis indicates that farmers in the IIS are obtaining higher profit by investing more on inputs as there is less risk due to continuous water availability. Maize is the second main food crop in NAs of Pakistan, vegetable is the main cash crop and barley is grown as a livestock crop in the wet season by both the IIS and the TIS farmers. The analysis presented in Table 5.3 shows that the IIS farmers use more inputs for maize compared to the TIS farmers. As a result, the gross production is significantly higher; however, the net profit is not significantly different between the two groups. Moreover, there is no significant difference in the gross production or net profits in case of barley and vegetables between the two systems. These results imply that availability of water in the wet season encouraged both groups of farmer to use more agriculture inputs thereby obtained net profits which are not significantly different between the two groups. However, the TIS farmers do not use the significant inputs in the wet season due to the effects of input usage for dry season crops. Fruits are grown as perennials by both farmer groups and the net profit of IIS farmers is significantly higher despite no significant difference in input use. This could be attributed to continuous availability of water for IIS farmers particularly during spring season when trees bloom.

5.2.2.3 Cost benefit analysis of improved irrigation channels

Cost benefit analysis (CBA) is a technique for evaluating a project or investment by comparing the economic benefits with the economic costs of the activity. Benefit-cost analysis has several objectives. First, CBA can be used to evaluate the economic merit of a project. Second, the results from a series of CBA can be used to compare competing projects. CBA can be used to assess business decisions, to examine the worth of public investments, or to assess the wisdom of using natural resources or altering environmental conditions. Ultimately, CBA aims to examine potential actions with the objective of increasing social welfare. Without a doubt, results from a CBA can be used to raise the level of public debate surrounding a project.

Operation and maintenance of the system is an important aspect for the sustainability of irrigation system. Table 5.4 shows the performance of the IIS under study in respect to operation and maintenance (O&M) expenditures. O&M expenditures include general O&M expenditures incurred on the water channels. Another interesting fact is that in the IIS reforms, 20% of the total cost for the purpose of O&M from each channel will be collected from the respective farmers through FOs in terms of cash or labor. The study showed that average per acre O&M expenditures in study area is 69.8 Rs./acre per season, which is 0.19% of gross agriculture income of farm households per year. The cost of capital, O&M of the IIS are not high and thus makes it more affordable for farmers to pay the annual operations and maintenance costs. It is clear from results that O&M expenditures incurred by the irrigation department were not uniformly spent in all the channels.

5.2.2.4 Factor influencing on dry and wet seasons crop productivity

To further confirm the impact of water on crop productivity we carried out a multiple regression analysis for the two main crops wheat in dry season and maize in wet season by using “ordinary least square” method. As the multiple regression analysis, yield measured in kg/acre was considered as the dependent variable, while the independent variables consisted of inputs (cost/acre), a dummy to represent IIS and TIS input and dummy interactions for the IIS.

The results presented in Table 5.5 shows that the dry season (wheat), the dummy is statistically significant at 10% and purchased seed usage is significant. However, in the wet season (maize) none of the variables except constant and the interaction between purchased seeds and IIS dummy is significant implying that there is a significant impact of IIS on yield of wheat in the dry season. The results from the regression show that some of the subjective variables are significant, suggesting that the results would be biased without taking them into account. In general, irrigation, fertilizer and purchased seeds positively affect higher yield of dry season wheat.

Table 5. 5 : Results of Regression Among Inputs Against Yield

Crops		Coefficients	Standard Error	t-stat	p-value
Wheat (Dry Season)	Constant	391.141	37.179	10.5204	0.000
	IIS dummy	-249.241	146.64	-1.699	0.100
	Fertilizer cost	-0.071	0.071	-1.009	0.321
	Agro chemical	0.026	0.059	0.446	0.659
	Purchased seed	-0.094	0.040	-2.361	0.025
	Fertilizer cost* IIS dummy	0.309	0.166	1.863	0.072
	Agro chemical*IIS dummy	-0.071	0.126	-0.568	0.574
	Purchased seed*IIS dummy	0.197	0.080	2.482	0.019
			Adjusted R Square= 0.346, F-value= 0.004		
Maize (Wet season)	Constant	348.678	129.154	2.700	0.011
	IIS dummy	121.716	143.413	0.849	0.403
	Fertilizer cost	0.063	0.236	0.268	0.791
	Agro chemical	0.133	0.151	0.880	0.386
	Purchased seed	-0.089	0.069	-1.294	0.205
	Fertilizer cost* IIS dummy	-0.311	0.253	-1.224	0.230
	Agro chemical*IIS dummy	-0.109	0.167	-0.651	0.520
	Purchased seed*IIS dummy	0.252	0.087	2.901	0.007
			Adjusted R Square=0.319, F-value= 0.007		

Source: Author's survey (2009)

Note: Dummy value indicates IIS and TIS. (1= IIS, and 0 = TIS),

n= 38, ***: Significant at 1%, ** : Significant at 5% and *: Significant at 10%

The result is not surprising because irrigation water enable farmers to use more inputs such as fertilizer, agrochemicals and purchased seeds etc. thus farmers face lower risks when applying the input more intensively. The negative sign for the fertilizer and purchased seeds are might be overuse of inputs. This suggests that farmers in the study area received very little or no institutional support on inputs application and essentially make decisions on their own. The absence of guidance in determining appropriate levels of inputs for their land may have led to high levels of input application. However interaction variables for the wheat show a positive affect while for the maize it shows negative except purchased seeds.

Value of adjusted R^2 was 0.35 in wheat and 0.32 in maize indicating that the independent variables included in the production function explained about 35 and 32% of their effect respectively, of the variations in the dependent variable of the wheat and maize crops. Reasonable F-value also depicted that the overall model was significant in the both cases. The estimated coefficients (βs) of the explanatory variables showed the percentage change in dependent variable with one percent change in explanatory variable.

5.3 Summary

To reach the objective of the study, the benefits derived by farmers from improved irrigation system in terms of land use, crop productivity and profitability, collected data from the farmers of the study area was average land use, yield of major crops, cost of production, and profitability of crops. The study reveals that the use of improved irrigation system in the region had beneficial effects on farming communities in terms of better land utilization and improved productivity leading to higher farm income. This study also shows that farmers are willing to invest more on agricultural inputs in terms of using purchase seeds, fertilizer and agro chemicals when continuous water availability is assured. This could be discussed thus: as the income level of the farmers' increases, the quantity of inputs utilized also increases. When farmers have enough funds at their disposal, there is the possibility that they purchase more of the inputs and hence increase agricultural productivity. When the income of the farmers is high, the farmers would not mind buying the input at any price.

It was found that irrigation improvement had positive impact on the above mentioned variables. Average yield increased due to availability of irrigation water and input usage in the study area. Moreover, the cost of improving traditional irrigation channels and operation and maintenance costs are not considerably high. Therefore, it is suggested to further extend the improvement of TIS channels, thereby uplifting the living standards of the farming community in Gilgit-Baltistan.

CHAPTER VI

ESTIMATION OF FARM LEVEL TECHNICAL EFFICIENCY OF WHEAT, VEGETABLE AND POTATO PRODUCTION IN NAS OF PAKISTAN: A Stochastic Frontier Approach

6.1 Introduction

In Northern Pakistan, agriculture is the mainstay of the people. More than 90% of the population depends upon agriculture. The climate is ideally suited for the cultivation of crops like wheat, vegetables, potatoes and fodder for the dry season and maize, barley and vegetables for the wet season and fruits are grown as perennials by both farmer. Wheat is staple food in Northern Areas (NAs) of Pakistan and fluctuations in its production substantially due to considerable problems, affect food security. Rice, pulses, fruits and vegetables are of prime importance after wheat. Domestic production of wheat, maize and other food crops is not sufficient to fulfil the dietary demand of the people of NAs. Mostly, people get nutrient requirement from rice and wheat which is not sufficient to fully meet the dietary needs of the population.

The crop productivity is very low despite having surplus labour in the rural areas of the country. For example, per hectare potato yield is 17.7 ton as compared to the rest of the country's potato yield of 23.6 ton. The yield is declining over the period of time in Northern Areas (NAs) due to lack of water in growing season, crop rotation, lack of proper technology, timely availability of inputs and rising production costs (Socio-economic Survey of Northern Areas, PARC, 2002-03).

A pertinent question is how to increase crop production in developing countries like Pakistan? There are three possible ways to increase the production a) by allocating more land, b) by developing and adopting new technologies and c) by utilizing the available resources more efficiently. The third option of using available resources more efficiently is the most viable approach. This implies that increased crop production lies in improvement of productivity i.e. yield per unit area. Since additional areas and development and adoption of new technology are not at hand, therefore, the ample scope exists for improving productivity. It is generally believed that resources in the agricultural sector, especially in developing countries are being utilized inefficiently.

Therefore, this chapter aimed to compare the productive performance of the improved irrigation system (IIS) with the traditional irrigation system (TIS) to estimate farm level technical inefficiency using a stochastic frontier production technique involving a model for technical inefficiency effects of (wheat and vegetable) and potato crops separately.

Wheat is the main traditional crop in the region and vegetables are the main cash crop grown as dry season crop. Potatoes are one of the most important vegetable and cash crops of the Gilgit and entire NAs of Pakistan. Potatoes were grown by the farmers for centuries as for self-consumption but during the recent few decades farmers were growing potato as a separate (vegetable) crop for commercial purposes. The Aga Khan Rural Support Program (AKRSP, a local NGO, is working in the region since eighties) encourages the cultivation of potato in NAs by introducing improved seed varieties. Due to this encouragement normally each household has devoted a part of his land for potato cultivation in dry season.

This chapter presents the findings of maximum likelihood estimates (MLE) and technical efficiency analysis for the (wheat and vegetables) and potato. In section 6.2 a short overview on empirical model, which was briefly explained in chapter 4. In section 6.3 we discuss the maximum likelihood estimates (MLE) and technical efficiency analysis of wheat and vegetables. Where, description of variables such as details about output and inputs of crop, hypothesis test, MLE and technical efficiency of wheat and vegetables are discussed. Section 6.4 described the MLE and technical efficiency analysis of potato along with description of variables and hypothesis test. Summary of the finding are given in the last part of the chapter.

6.2 Empirical Model and Efficiency Analysis

The results can be considerably affected by the choice of functional form in an empirical study. Most commonly used forms in empirical studies are Cobb-Douglas and translog production functions. However, translog or flexible functional form causes serious problem of multicolinearity whereas Cobb-Douglas function is easy to estimate and interpret and is commonly used to determine technical inefficiency studies. Therefore, for the present study, Cobb Douglas form has been used to estimate stochastic frontier production function and inefficiency effect model.

Crops grow in the study areas are wheat, potato, vegetables and fodder, by both IIS and TIS farmers' in dry season. Each crop requires wide-ranging levels of inputs during different growth stages such as fertilizers being utilized by the farmers, different kinds of plant protection measures (agrochemicals), and different kinds of labor such as family labor or hired labor and variety of other inputs. Keeping all these facts in view, it is more logical to determine technical efficiency of all crops separately. Therefore, this study was designed to determine technical efficiency of selected dry season crops such as wheat, vegetables and potato.

However, the Cobb-Douglas functional form is used even with its well-known limitations because it is easy to estimate and mathematically manipulate. The parameters for the stochastic production function (as explain in chapter 4 methods and material) equation (4) and those for technical efficiency model in equation (5) are estimated simultaneously using maximum likelihood estimation.

$$\ln Y_i = \beta_o + \sum_{ij=1}^{x} \beta_{ij} \ln X_{ij} + v_{ij} - u_{ij}$$ *and* i = 1, 2……..n

j = 1, 2…..... n

$$\mu_i = \delta_o + \delta_1 Z_{1i} + ... + \delta_8 Z_{8i} + \omega\iota$$

Where, *Yi* is the dependent variable in the production function showing gross value production Rs. per acre for i-th farm growing j-th crop. *ln* represents natural logarithm. Xij is a vector of k inputs used in the production of j-th crop.

It is assumed that some farmers produce their production on the frontier and others do not. Therefore, the need arises to find out factors causing technical inefficiency. The technical inefficiency model has been developed for this study to concentrate on this issue. The technical inefficiency effects model incorporates farm and farmers specific characteristics, institutional and environmental factors. The above-mentioned variables included in the technical inefficiency effects model are detailed with their expected effects on technical inefficiency in Table 6.1 for wheat and vegetable crops.

6.3 Stochastic Frontier Analysis of Wheat and Vegetables

As discussed above the majority of the households grew several crops in dry (Rabi) the wet (Kharif) seasons. However, in this study/section we only consider the dry season wheat as main cereal crop and vegetables as cash crop except potato. Potatoes are grow as a separate crop in the region. The reason behind the selection of the two important dry season crops is that water is a limiting factor in the dry season and to know the technical efficiency of crop.

6.3.1 Description of variables for wheat and vegetables

A basic summary of the values of the key variables, which are defined in the econometric model in the previous section, is given in Table 6.1. The values are described on the basis of per unit. In regression, all the independent variables for frontier model are in logarithm form along with dependent variable, whereas, variables in the technical inefficiency model are in absolute values. The technical inefficiency model comprises of several variables which might affect the decisions and hence technical efficiency of the farming households.

The dependent variable is the total production of wheat and vegetables measured in rupees. The value of each crop was estimated using sale price for sold products. Inputs were categorized into four variables: capital; labor, machinery cost and number of irrigations applied to crop production. For wheat and vegetables, they were categorized: capital; labor, machinery cost and number of irrigations applied to crops production.

Table 6. 1: Description of Output, Inputs, and Farm Specific Variables for (Wheat and Vegetables)

Variable Name	*Unit*	*Description*
	Crop specific variables for (Wheat and Vegetables)	
Output (Y_i)	*Log of Rs.*	Gross value production (GVP) of each crop (Rs./acre)
Capital (X_1)	*Log of Rs.*	Total value of inputs used for each crop (Rs./acre)
Hired labor (X_2)	*Log of Rs.*	Costs of hired labor (Rs./acre)[a]
Machinery cost (X_3)	*Log of Rs.*	Cost of hired machinery (Rs./acre)
Irrigation (X_4)	*Nos.*	Number of irrigation applied to each crop (Numbers)[b]
	Farm specific variables	
Farm size (δ_1)	*Acres*	Cultivated area per crop[c]
Age (δ_2)	*Years*	Age of household head in years
Level of education (δ_3)	*Years*	Years of schooling of household head
Household size (δ_4)	*Persons*	Number of all household members
Irrigation system (δ_5)	*Dummy*	Value "1" if improved irrigation system (IIS) and "0" in case of traditional irrigation system (TIS)
Location of farms (δ_6)	*Dummy*	Distance of farms from the main channel, value "1" if head and "0" tail[d]
Quality of soil (δ_7)	*Dummy*	value "1" if good and "0" others
Village (δ_8)	*Dummy*	value "1" if Sultanabad

Note: n= 77

Note**:** PRS = Pakistani Rupees (PRS 65 = 1 US Dollar approximately, as of 2007);
a). In this study we use only hired labor. Family labor is excluded due to using particular crop data. Though the mean household size was 12 persons, but most of the family members are not actively participating in farm work due to schooling and off farm activities.
b). A more appropriate measure would be the amount of water (such as cm^3 or m^3) delivered to the crops field rather than the number of irrigations. Because of conveyance losses, farmers located at the lower ends of the system would receive less water even if the frequency of irrigation is uniform for all farmers.
c). As wheat and vegetable cultivation area is considerably smaller compared to total land holding. The total holding was not taken for the analysis due to individual crops.
d). Both villages are located along with Karakoram Highway and it is passing approximately from the middle of the villages. Farmers located above the road considered as “head” and located below the road considered as “tail”

We aggregated capital in monetary value of each crop inputs such as fertilizer, seeds and agrochemicals. This is due to unavailability of kg per acre data especially in agrochemical for wheat and vegetables. Hired labor was measured in terms of monetary value due to unavailability of person per day data in a few cases, due to hiring of labor on contract basis. Family labor wages were not included because of the subsistence nature of agriculture in the area for wheat and vegetable. Machinery cost was measured as monetary value of hired machinery, working hours in the individual crop for plowing and threshing. Generally all farmers did not have their own machinery such as tractor and thresher etc. except the agricultural basic tools.

6.3.2 Summary statistics of output and inputs of selected crops

Summary statistics of the mean value of gross production, input use and farm specific variables involved in the stochastic frontier production and technical inefficiency index for crop production in wheat and vegetables are presented in Table 6.2. The mean value of gross production crop per acre was higher in vegetables (Rs. 26,738) followed by wheat (Rs. 7,458). The use of fertilizer, agrochemicals, own and purchased seeds and hired labor were higher for the vegetables, followed by wheat, except machinery cost. However, there is no significance difference for the irrigation water inputs. In the stochastic model, the sign of the coefficient directly shows the direction of effect.

All the values of crop specific variables are expected to have positive signs depicting a positive relationship between irrigation water and the corresponding variable since they increased agricultural productivity. On the other hand, it is important to show a negative sign for the estimated parameters of the technical inefficiency analysis, which indicates a positive relationship. All the inputs were valued by the quantities used per acre at their prevailing market price in the study area. The irrigation frequency of each crop is presented frequency of irrigation delivered to the crops field, and expected to have positive signs.

6.3.3 MLE results of stochastic frontier analysis for wheat and vegetable crops

The overall technical inefficiency effects are evaluated in terms of the parameters associated with σ^2 and γ. The estimate for the variance parameters σ is significantly different from zero at one percent. This indicates statistical confirmation of our presumption that there are differences in technical efficiency in the two systems. The share of one sided error in total variance γ is 29% and 59% of the two variances of wheat and vegetable respectively, Table 3.

Table 6. 2: Summary Statistics of Output and Inputs

	Variable Name	*Mean*	*S.D*	*Minimum*	*Maximum*
	Crop specific variables				
Wheat	Output (Y_i)	7,458.0	2,387.3	3,582.0	12,100.0
	Capital (X_1)	3,101.4	958.6	1,689.0	7,280.0
	Hired labor (X_2)	1,299.4	465.3	400.0	3,600.0
	Machinery (X_3)	2,184.2	1,164.8	1,166.7	5,600.0
	Irrigation (X_4)	18.7	4.6	14.0	29.0
	Farm size (δ_1)	1.29	1.28	0.20	5.10
Vegetables	Output (Y_i)	26,738.0	6,395.8	14,662.0	45,004.0
	Capital (X_1)	3,642.2	790.0	1,973.0	6,410.0
	Hired labor (X_2)	2,384.8	656.0	1,406.3	5,250.0
	Machinery (X_3)	1,630.6	447.6	1,166.7	3,360.0
	Irrigation (X_4)	18.3	4.9	13.0	29.0
	Farm size (δ_1)	1.26	0.61	0.50	4.00
	Farm specific variables				
Age of household head (δ_2)		58.40	9.06	42.00	72.00
Level of education (δ_3)		5.42	3.85	0.00	16.00
Household size (δ_4)		12.00	3.97	5.00	24.00
Irrigation system (δ_5)		0.51	0.50	0.00	1.00
Distance of farms (δ_6)		0.56	0.50	0.00	1.00
Quality of soil (δ_7)		0.64	0.48	0.00	1.00
Village δ_8)		0.49	0.50	0.00	1.00

Note: SD = Standard Deviation

These results indicate that the technical efficiency effects are significant in the production of crops. The estimated value for the variance parameter, γ, is significant at one percent, which indicates that the random component of the inefficiency effects does have a significant contribution in determining the level and variability of output of the farm households. The overall results of the stochastic frontier production function estimates are presented in Table 3.

The production elasticities of wheat and vegetables are positive and significant as expected. According to the findings, it was clear that the increasing capital investment at one percent, the production of wheat and vegetables could be increased by 0.20% and 0.61%, respectively. Timely availability of agricultural inputs within a reasonable price is an important factor for improving crop productivity in the area. Positive and significant elasticities for capital in case of the two important cash crops in the selected villages of Gilgit-Baltistan indicate the potential to increase productivity by increasing input use. The labor elasticity for wheat and vegetables are as expected positive and implies that one percent increase in expenditure on hired labor will increase production of wheat and vegetables by 0.18% and 0.15%, respectively. The derived production elasticities for irrigation with respect to wheat and vegetables farms are 0.31% and 0.45 % respectively. These positive and significant elasticities indicate one percent increase in irrigation frequency will increase production of wheat and vegetables by 0.31% and 0.45%, respectively. The estimated coefficients of the explanatory variables in the model for technical inefficiency effects are of interest and have important implications as shown in Table 3.

Results of the study indicate that the variable of farm size for wheat is positive and negative for vegetables but not statistically significant. It shows that farmers who grow wheat operate small landholding and are more technically efficient, while, vegetable growers can become more efficient by increasing scale of operation. Age of the household head is included as a proxy for farming experience to assess the effects of experience on technical inefficiency. The impact of age on efficiency is negative for wheat and

Table 6. 3 : Stochastic Frontier Production Function Analysis of Determinants of Farm Productivity and Technical Efficiency

Variables	*Wheat*		*Vegetables*	
	Coefficient	*t-ratio*	*Coefficient*	*t-ratio*
Stochastic frontier model				
Constant	2.976	7.15***	0.797	0.92
Capital	0.197	1.97*	0.612	4.33***
Hired labor	0.184	3.02***	0.152	2.10**
Machinery cost	0.242	0.970	0.128	1.16
Irrigation	0.314	3.69***	0.449	3.72***
Technical inefficiency model				
Constant	0.485	4.73***	-0.167	-1.02
Farm size (each crop)	0.029	0.45	-0.164	-0.75
Age of household head	-0.004	-2.98***	0.002	0.65
Level of education	-0.002	-0.75	-0.005	-5.57***
Household size	0.009	1.42	0.006	0.21
Irrigation system	-0.39	-8.84***	-0.237	-3.07***
Distance from main channel (head & tail)	-0.033	-5.53***	-0.121	-0.48
Quality of soil	0.025	0.27	0.158	0.6
Village dummy	-0.079	-0.95	-0.023	-0.53
Variance parameters				
Sigma-square (σ^2)	0.005	5.52***	0.035	6.24***
Gamma (γ)	0.286	7.19***	0.593	9.71***
Ln Likelihood	109.96		141.17	

Note: ***, **, *, significant at 1%, 5% and 10%, respectively

significant at one percent indicating that older farmers are more efficient; however, in case of vegetable it is positive but not significant. Age has an inverse impact on efficiency of vegetable. Older farmers may take benefit of their experience to use inputs more efficiently for wheat. It is possible that the older farmers could be more traditional and conservative, so they preferred to grow cereal crops as compared to cash crops.

Different studies indicated that age had mixed impact on the efficiency which depends on the type of crop and studied area. The coefficient of education is negative and statistically significant for vegetable, while, for wheat it is not significant but negative. This result indicates that higher the level of education, higher the TE, this could be due to better access to information and good farm planning. The coefficient of household size is positive for the growers of wheat and vegetables, but not significant. This does not imply that large family size is technically less efficient than the small families. However, insignificant could be due to family members not actively participating in farm work.

Of particular interest in this study are the coefficients associated with irrigation system dummy in the technical inefficiency model ($\delta 5$). The negative and significant coefficient of irrigation system dummy associated with wheat and vegetables implies that IIS farmers are technically more efficient than those farmers belonging to TIS. It shows that there is a positive relationship and significant differences between IIS and TIS. This could be attributed to substantial saving of water losses by improved watercourses in the study area. Khan (1986) reported that the watercourse improvement has enabled to reduce water losses by 53%, in Pakistan. World Bank (1992) proposed to improve watercourses by lining to control excessive seepage, water logging and salinity. However, given that this conclusion is reached from a purely technical analysis, the economic viability of such irrigation investment needs to be evaluated in the light of costs of irrigation development and the relative prices of inputs and outputs. An additional dummy variable to represent farmers belonging to head and tail of the irrigation channel was included to examine the distribution equity.

The coefficients of the distance dummies are negative and significant signs for both wheat and vegetables. This implies that the farmers located at the head of the water channel are more efficient because of the easy access and availability of irrigation water in dry season. We further examined the differences in efficiency between head and tail by undertaking a t-test. In Gilgit-Baltistan, the shortage of water at tail-end of watercourses arises from water loss due to seepage and rat-holes. However, in practice, either because of the stealing of water by farmers close to the water source or conveyance losses, farmers located at the tail reaches of the system generally get disproportionately less water as compared to those located at the head. As a result, often there is a significant difference in the income levels of farmers in the head and tail reaches of a water channel. The coefficients of soil dummies are positive for wheat and vegetables, but not significant. Investments in soil improvements do generate short and long-term economic gains to the farmers. However, the linkage between farm revenue and soil improvement has not been properly studied in Gilgit-Baltistan region. Therefore, a research on soil quality is further necessary. The village dummy for wheat and vegetables were negative but insignificant.

6.3.4 Hypothesis tests for the wheat and vegetables

Hypothesis tests on the suitability and validity of the efficiency model are conducted by employing the log likelihood ratio test where the suitability of the restricted model is tested against unrestricted model in Table 6.4. The test is defined as $\lambda = -2$ [Ln (H0) – Ln (H1)], Where, Ln (H_0) and Ln (H_1) are the log likelihood values obtained from running the restricted and unrestricted models, respectively. From this table it is evident that the traditional average production function does not represent adequately the production

Table 6. 4 : Test of Hypothesis for the Stochastic Frontier and Inefficiency Effects Models for Wheat and Vegetables Growers.

Null Hypothesis	Log Likelihood	LR Statistics λ	Critical value	Decision
Wheat				
$H_o : \gamma = 0$	103.92	12.08	11.07	Reject H_0
$H_o: \gamma = \delta_0 = \delta_1 \ldots \delta_9$	79.14	61.64	22.36	Reject H_0
$H_o: = \delta_0 = \delta_1 \ldots \delta_9$	79.12	61.68	9.49	Reject H_0
$H_o: = \delta_1 \ldots \delta_9$	72.53	74.86	11.07	Reject H_0
Vegetables				
$H_o : \gamma = 0$	134.92	12.50	11.07	Reject H_0
$H_o: \gamma = \delta_0 = \delta_1 \ldots \delta_9$	117.47	47.40	22.36	Reject H_0
$H_o: = \delta_0 = \delta_1 \ldots \delta_9$	117.46	47.42	9.49	Reject H_0
$H_o: = \delta_1 \ldots \delta_9$	107.06	68.22	11.07	Reject H_0

structure of wheat and vegetable cultivating farms in the sample as the null hypothesis that $\gamma = 0$ is rejected at 5% level of significance.

Thus, the technical inefficiency effects are in fact stochastic and a significant part of output variability is explained by the existing differences in the degree of output oriented technical efficiency. In addition, the hypothesis that the inefficiency effects are absent (i.e., $\gamma = \delta_0 = \ldots \delta_7$) is also rejected at 5% level of significance. This indicates that the majority of farms in the sample operate below the output oriented technically efficient frontier. The third hypothesis test assesses no constant and farmer specific effects in the error component. The test result rejects the null hypothesis in favor of the inclusion of these variables. Finally, the fourth hypothesis test, imply the joint significance of the determinants of inefficiency, rejection of the null hypothesis indicates that the included explanatory variables jointly influence on farm efficiency even though when taken individually some may not be significant.

6.3.5 Technical efficiencies in crops production

The estimated technical efficiencies of individual growers of wheat and vegetables are presented in Tables 6.6 and 6.7 while frequency distribution of technical efficiency levels in IIS, TIS and overall are given in Table 6.5. Details regarding farm specific technical efficiencies are important as they provide detailed information to policymakers on the nature of production technology used in farms. The estimations of frequency distribution of wheat and vegetable technical efficiency are given in Table 5. Estimated efficiency score for wheat indicate that 50% farms are relatively less than 75% technically less efficient. The average overall level of technical efficiency is 76.6% ranging from a minimum of 58.6% to a maximum of 96.1%. It indicates that farmers in overall samples are producing on average at 76.6% of their potential with the given present state of technology and input levels. However, the average level of TE has been estimated in TIS as 71.5% with their score ranging from 58.6% to 85.5%, where 84% farmers are in the range of 0 to 75%. This implies that most of the farms in the sample faced severe technical inefficiency problems. It indicates that on an average the sample farmers tend to realize around 71% of their technical abilities.

Hence, 29% of the technical potentials are not realized for wheat crop in TIS. Therefore, it is possible to improve the production level of farms by 29%, following efficient crop management practices without increasing the level of input application. While, in IIS mean efficiency score is 81.6% within a range of 70.3% to 96.1%. It indicates that farmers operating under IIS are more efficient compared to TIS; hence, improving productivity requires introduction of new technologies.

Table 6. 5: Distribution of Wheat and Vegetable Farms for Different Levels of Technical Efficiency

Efficiency rating	IIS		TIS		Overall	
	N	%	N	%	N	%
Wheat						
00-75	7	18.0	32	84.3	39	50.7
76-80	13	33.3	4	10.5	17	22.1
81-85	8	20.5	2	5.3	10	13.0
86-90	7	18.0	0	0.0	7	9.1
91-95	3	7.7	0	0.0	2	2.6
More than 96	1	2.6	0	0.0	2	2.6
Total	39	100	38	100	77	100
Mean Efficiency	81.66		71.50		76.64	
Minimum	70.30		58.61		58.61	
Maximum	96.10		85.49		96.10	
Vegetable						
00-75	0	0.0	9	23.7	9	11.7
76-80	5	12.8	11	28.9	16	20.8
81-85	8	20.5	7	18.4	16	20.8
86-90	10	25.6	6	15.8	16	20.8
91-95	13	33.3	5	13.2	17	22.1
More than 96	3	7.7	0	0.0	3	3.9
Total	39	100	38	100	77	100
Mean Efficiency	88.06		81.79		84.97	
Minimum	76.56		69.14		69.14	
Maximum	98.19		94.42		98.19	

Note: N indicates number of respondents

Table 6. 6 : Technical Efficiencies of Wheat Growers

Farmers Number	Technical Efficiency	Farmers Number	Technical Efficiency	Farmers Number	Technical Efficiency
1	0.961	27	0.883	53	0.734
2	0.942	28	0.855	54	0.750
3	0.820	29	0.831	55	0.748
4	0.903	30	0.776	56	0.753
5	0.950	31	0.754	57	0.722
6	0.845	32	0.711	58	0.718
7	0.919	33	0.729	59	0.676
8	0.895	34	0.706	60	0.725
9	0.896	35	0.796	61	0.676
10	0.887	36	0.839	62	0.686
11	0.881	37	0.732	63	0.691
12	0.822	38	0.791	64	0.686
13	0.796	39	0.703	65	0.675
14	0.791	40	0.855	66	0.694
15	0.810	41	0.824	67	0.707
16	0.805	42	0.758	68	0.687
17	0.798	43	0.646	69	0.693
18	0.797	44	0.761	70	0.640
19	0.793	45	0.695	71	0.683
20	0.808	46	0.714	72	0.724
21	0.784	47	0.741	73	0.723
22	0.796	48	0.712	74	0.676
23	0.763	49	0.762	75	0.731
24	0.774	50	0.716	76	0.586
25	0.763	51	0.761	77	0.620
26	0.745	52	0.754		

Mean technical efficiency= 76.6

Table 6. 7: Technical Efficiencies of Vegetables Growers

Farmers Number	Technical Efficiency	Farmers Number	Technical Efficiency	Farmers Number	Technical Efficiency
1	0.982	27	0.892	53	0.803
2	0.965	28	0.843	54	0.787
3	0.955	29	0.845	55	0.892
4	0.954	30	0.908	56	0.844
5	0.916	31	0.927	57	0.781
6	0.941	32	0.766	58	0.743
7	0.914	33	0.772	59	0.781
8	0.939	34	0.827	60	0.807
9	0.963	35	0.829	61	0.785
10	0.891	36	0.794	62	0.844
11	0.945	37	0.842	63	0.806
12	0.927	38	0.777	64	0.794
13	0.890	39	0.789	65	0.797
14	0.872	40	0.920	66	0.696
15	0.868	41	0.887	67	0.793
16	0.931	42	0.891	68	0.798
17	0.917	43	0.889	69	0.740
18	0.821	44	0.899	70	0.776
19	0.895	45	0.905	71	0.727
20	0.840	46	0.935	72	0.696
21	0.872	47	0.944	73	0.792
22	0.861	48	0.941	74	0.746
23	0.850	49	0.852	75	0.708
24	0.900	50	0.940	76	0.754
25	0.851	51	0.851	77	0.691
26	0.876	52	0.841		

Mean technical efficiency= 84.9

On the other hand, farmers producing wheat under traditional irrigation system are less efficient implying that the productivity of these farmers can be raised through improving the irrigation system. The main cause of inefficiency in wheat production can be attributed to poor irrigation. It also indicates that further potential exists to improve overall productive efficiency of the resources allocated to wheat production in Gilgit-Baltistan North region of Pakistan.

Estimated technical efficiency scores for vegetables revealed that nearly 22% of the farms are achieving efficiency levels ranging from 91% to 95%, and 21% from 76% to 80%, 81% to 85% and 86% to 90% respectively, with the mean efficiency of all the farms slightly above 69% in TIS. However, in IIS 33% of the farms get efficiency from the range of 91% to 95% with the mean efficiency of 88%. But overall technical efficiency of vegetable is 85%.

This means that farms are performing on average 15% below their potential level. With little changes in the production process like better use and allocation of resources and efficient farming decisions, technical efficiency and the production level of the farms can be increased by around 15%. Since most of the farms are operating well below the frontier level in TIS, which shows there is ample space for improvements. The strategy for agricultural as well as economic development of Gilgit-Baltistan thus, could be based on the background of the country's unexploited potential in the agriculture sector. The estimated results of mean TE is in line with the studies conducted by (Abedullah et al. 2006) for wheat (84%) and (Bakhsh, et al. 2006) for wheat (76%). Both these studies conducted in Pakistan, revealed that the average efficiency of farms to be well below the frontier. Thus, most of the analysis revealed that farmers are still behind potential production levels and some kind of technical inefficiency exists in the real world situation.

6.4 Stochastic Frontier Analysis for Potato Production

Potatoes are one of the most important vegetable and cash crops of the Gilgit and entire NAs of Pakistan. Potato was growing by the farmers for centuries as for self-consumption but during the recent few decades farmers were growing potato as a separate (vegetable) crop for commercial purposes. The Aga Khan Rural Support Program (AKRSP, a local NGO working in the region since eighties) encourages the cultivation of potato in NAs by introducing improved seed varieties. Due to this encouragement normally each household has devoted a part of his land for potato cultivation in dry season.

The lack of irrigation water on growing season, market access, cold storage facilities and the non-familiarity of the growers with modern farming methods are some of the factors discouraging the cultivation of this valuable vegetable on a large scale. The other major factor is that the growers are not satisfied with the return they get from this crop. Although, potato is major cash crop and the only source of income of many farmers however, still not taking serious measures by the stakeholders to overcome the problems. The reason for selecting the potato crop for this analysis was that potato is a high value crop with a higher yield compare to cereal crop in the region and is an important source of cash income.

6.4.1 Description of variables for potato

A basic summary of the values of the key variables, which are defined in the model for potato production, is given in Table 6.8. In regression, dependent and all the independent variables for frontier model are in logarithm form along with dependent variable as per unit basis, whereas, variables in the technical inefficiency model are in original values Table 6.9.

The dependent variable is the total production of potato measured in rupees (Rs./acre). The value of potato crop was estimated based on sales revenue. The independent variables are defined as X_{1i} to X_{6i} as follow in Table 6.8: X_{1i} indicate the log of potato cultivated area in acres, X_{2i} shows monetary value of fertilizer and agro chemicals cost per acre. We aggregated fertilizer and agrochemical monetary values due to unavailability of per acre data especially for agrochemicals. However, after aggregation we divided by cultivated area. X_{3i} is value of purchased seeds per acre. X_{4i} shows hired labor cost per acre, which is measured in terms of monetary value due to unavailability of man day data for few cases due to hiring of labor on contract basis. X_{5i} represents machinery cost per acre, it was also measured as monetary value of working hours used for plowing, leveling and planting or simply as tractor hours applied for preparing one acre of land for potato cultivation. X_{6i} shows the number of irrigations applied to potato per unit area of production.

Table 6. 8 : Description of Output, Inputs, and Farm Specific Variables for Potato

Variable Name	*Unit*	*Description*
Crop specific variables (Wheat and Vegetables)		
Output (Y_i)	*Log of Rs.*	Gross value production of potato crop (Rs./acre)
Cultivated area (X_1)	*Log of Rs.*	Cultivated area of potato in acres
Fertilizer & agrochemicals (X_2)	*Log of Rs.*	Cost incurred on fertilizers and agrochemicals (Rs./acre) on the potato production
Purchase seed (X_3)	*Log of Rs.*	Cost of purchased seeds (Rs./acre) used on the i-th farms
Hired labor (X_4)	*Log of Rs.*	Cost of hired labor incurred (Rs./acre)
Machinery cost (X_5)	*Log of Rs.*	Hired machinery cost (Rs. Per acre)
Irrigation (X_6)	*Nos.*	Number of irrigation applied to potato crop
Farm specific variables		
Total cultivated area (δ_1)	*Acres*	Cultivated area in acres
Age of household head (δ_2)	*Years*	Age of farmers in years
Level of education (δ_3)	*Years*	Years of schooling of household head
Family labour (δ_4)	*Persons*	Number of household members works in farm activities
Irrigation system (δ_5)	*Dummy*	Value "1" if improved irrigation system (IIS) and "0" in case of traditional irrigation system (TIS)
Location of farms (δ_6)	*Dummy*	Distance of farms from the main channel, value "1" if head and "0" tail
Quality of soil (δ_7)	*Dummy*	value "1" if good and "0" others
Distance village to city (δ_8)	*Km*	A variable showing distance in (km) from village to main market (Gilgit city)

Note: n= 76

6.4.2 Average output and inputs of potato

Summary statistics of the mean value of output, inputs use and farm specific variables involved in the stochastic frontier production function and technical efficiency index for crop production in potato is presented in Table 6.9. The mean value of output per unit area of potato was (Rs. 13,654). The use of hired labor cost (Rs. 3,023) was higher among all other input cost. It implies that potato production is more labor intensive crop. In the stochastic model, the sign of the coefficient directly shows the direction of the effect. On the other hand, it is important to show a negative sign for the estimated parameters of the technical inefficiency model, which indicates a positive relationship. All the inputs were valued by the

Table 6. 9 : Summary Statistics of Output and Inputs and Farm Specific Variables for Potato

Variable name	*Mean*	*S.D*	*Minimum*	*Maximum*
Crop specific variables				
Output (Y_i)	13,654.0	4,740.4	6,400.00	25,920.0
Potato cult. area (X_1)	0.7	0.6	0.1	3.0
Fertilizer & agroch. (X_2)	2,624.4	1,718.5	506.7	8,680.0
Purchased seed (X_3)	2,589.3	1,954.0	461.5	7,360.0
Hired labour (X_4)	3,023.3	1,466.3	800.0	8,400.0
Machinery cost (X_5)	2,576.2	1,311.0	933.3	4,000.0
Irrigation (X_6)	19.3	6.0	13.0	30.0
Farm specific variables				
Total cultivated area (δ_1)	5.2	3.6	2	13
Age of household head (δ_2)	58.2	9	42	71
Level of education (δ_3)	5.4	3.9	0	16
Family labour (δ_4)	3.6	1.5	1	8
Irrigation system (δ_5)	0.5	0.5	0	1
Location of farms dummy (δ_6)	0.6	0.5	0	1
Quality of soil dummy (δ_7)	0.6	0.5	0	1
Distance from village to city (δ_8)	18	11.3	5.75	34

Note: SD = Standard Deviation

quantities used per acre at their prevailing market price in the study area. The irrigation frequency of each crop is presented frequency of irrigation delivered to the crops field, and expected to have positive signs.

6.4.3 MLE estimates of stochastic frontier analysis for potato

The estimates of the parameters of the ordinary least squares (OLS) and maximum likelihood estimate (MLE) methods for the potato growers are given in Table 6.10. It is evident that five MLE coefficients of the inputs are associated with the output for the data set of potato growers is statistically significant and different from zero. Only two variables are significantly different when parameters are estimated using OLS method. Therefore, the MLE model is well representative of the data set for the potato growers compared to OLS method.

The Cobb-Douglas production function parameters can be interpreted directly as output elasticities. All the input parameters in MLE method have positive signs and statistically significant except machinery cost Table 6.10. This implies that these inputs are playing a major role in potato production. Results indicate that the highest output elasticity for the hired labor cost (0.31) followed by irrigation (0.20). Both variables are highly significant and positively related to potato productivity. The higher elasticity of irrigation and higher labor cost implying the contribution of total factor productivity is dominant. A one percent increase in the use of hired labor cost and irrigation numbers leads to a 0.31 and 0.20% increase in potato output, respectively. The increase in productivity is the result of availability of irrigation water on time, better weeding and cultivation practices.

Another important input in terms of its effect on the potato production is potato cultivated area and purchased seed followed by fertilizer and agrochemicals. An addition of one percent input potato cultivated area and purchased seed increases output by 0.19 and 0.12%, respectively. The results further indicate that increasing the farm size has a positive effect upon the technical efficiency of potato production. The findings of Ogundele and Okoruwa (2004) shows, that farm size significantly determines levels of

Table 6. 10: Ordinary Least Square (OLS) and MLE of Potato

Variables	OLS estimates		ML estimates	
	Coefficient	t-ratio	Coefficient	t-ratio
Stochastic frontier model				
Constant	1.071	8.25***	2.893	13.28***
Potato cultivated area	0.129	2.68***	0.189	3.05***
Fertilizer & Agrochemicals	-0.067	-1.48	0.091	2.16**
Purchased seed	0.082	1.86	0.122	2.75***
Hired labor	0.068	0.91	0.307	4.20***
Machinery cost	0.073	1.67	0.024	0.62
Irrigation	0.147	2.27**	0.200	3.33***
Technical inefficiency model				
Constant			-0.106	-0.84
Total cultivated area			0.006	0.95
Age of household head			0.001	0.61
Level of education			-0.199	-2.39**
Family labor			0.010	1.19
Irrigation system			-0.143	-4.35***
Distance from main channel			-0.066	-2.07*
Quality of soil			0.004	0.04
Distance from village to city			-0.032	-2.48**
Variance parameters				
Sigma-square (σ^2)	0.270		0.408	4.27***
Gamma (γ)			0.792	8.41***
Ln Likelihood	88.569		103.111	

Note: ***, **, *, significant at 1%, 5% and 10%, respectively.

technical efficiency. However, it might not be true to correlate the farm holding with inefficiency, especially in the case of potato where farmers have large farm holdings, but the area allocated to potato cultivation is only a part of total area available for cultivation. The greater use of purchased seed increases the plant population in the field and thus increases productivity. Fertilizer and agrochemical are important inputs used for potato production as one percent increase in fertilizer and agrochemical usage results in 0.09% increases in the productivity of potato. Machine cost, which is monetary value of working hours of tractor applied for preparing one acre of land for potato cultivation, has a positive coefficient but not significant. The insignificant might be due to irregular and small size of terraced fields in the study area.

The estimates for the variance parameters σ^2 and γ are significantly different from zero in the MLE model. This indicates statistical confirmation of our presumption that there are differences in technical efficiency among farmers. The share of one-sided error in total variance (γ) is 0.79% of the two variances. This result indicates that the technical inefficiency effects are significant in potato production.

The production efficiency at farm level depends on a number of socio-economic and demographic factors. The factors in this study identified as contributing positively towards improving farmers' efficiency for potato production include: level of education, irrigation system, distance from the main channel (head and tail) and distance from the village to city, in Table 6.10. In the empirical analysis, age of the household head is included as a proxy for farming experience of potato growers to assess the effects of age on the level of technical inefficiency. Results show that, as the age of the potato growers increases, technical inefficiency increase. Although elder farmers have more experience in farming, they are likely to be less adaptive to new technology. The household head's age could be interpreted as a proxy variable for adaptability to (or preference for) newly introduced technology. It means that the younger farmers are more technically efficient in potato production than the older farmers. This might be due to the fact that potato was recently introduced as a cash crop to the mountain region of northern Pakistan. The positive but not significant coefficient was found for total cultivated area. It implies that the total cultivated area increase technical inefficiency increase but not significantly.

The coefficient of education is negative and significant indicating that the farmers with more years of formal schooling tend to be more technically efficient. This shows that the farmers with more education respond more readily to uptake new technology and produce closer to the frontier output. The negative and significant coefficient of irrigation system dummy implies that IIS farmers are technically more efficient than those farmers belonging to TIS. Technical inefficiency of potato and vegetables farmers can be decreased by improving irrigation system to control excessive seepage, water logging and salinity.

To know the technical efficiency effect of location (head and tail) of potato growing farmers in irrigation channels a dummy variable was included. The negative and significant coefficient of the dummy variable indicates that the farmers located at the head of the water channel are more efficient. The distance from village to city is negative and significant implying that the technical efficiency of potato production decreases significantly with increase distance. This is because Sultanabad is located closer to the city (market) and farmers have better access to markets compared to farmers belonging to Parri village, which is 29 (km) from the city.

6.4.4 Hypothesis test

We tested the hypothesis that, whether the Cobb-Douglas production function is an adequate representation of the data using equation $\lambda = -2\,[ln\,(H_o) - ln\,(H_1)]$, given the specifications of the translog model. The null hypothesis, $\beta_1 = \beta_2 = 0$ tests the joint significance of input parameters. Null hypothesis is strongly rejected Table 6.11. Null hypothesis *i*), which specifies that inefficiency effects are not stochastic, is strongly rejected. Rejection of the hypothesis suggests that traditional mean response function is not adequate representation for the production function. Null hypothesis *ii*), specifies that

Table 6. 11: Likelihood Ratio Tests for Potato

Null Hypothesis	Log likelihood	LR statistics	Critical value	Decision
$H_o : \gamma = 0$	103.11	29.08	14.07	Reject H_0
$H_o: \gamma = \delta_0 = \delta_1 \ldots \delta_8$	113.26	49.38	25	Reject H_0
$H_o: = \delta_0 = \delta_1 \ldots \delta_8$	78.65	19.84	12.59	Reject H_0
$H_o: = \delta_1 \ldots \delta_8$	74.08	28.98	14.07	Reject H_0

inefficiency effects are absent from the model. The hypothesis is again strongly rejected. Null hypothesis *iii*), specifies that coefficients of all the variables included in the inefficiency effect model are equal to zero. The null hypothesis is strongly rejected Table 6.11.

Rejection of the hypothesis suggest that although individual coefficients of some variables included in the inefficiency effect model are not significant, jointly they are explaining variations in inefficiency among farmers. As mentioned above generalized likelihood ratio tests of hypothesis are generally preferred to the a symptotic t-tests in maximum likelihood estimation, the null hypotheses that individual effects of the explanatory variables in the model for the technical inefficiency effects are zeros were tested as well.

6.4.5 Technical efficiency in potato production

Frequency distribution of technical efficiency levels for potato growers in terms of IIS, TIS and overall basis is given in Table 6.12, while the individual technical efficiency of potato growers are presented in Table 6.13.

Table 6. 12: Frequency Distribution of Technical Efficiency Estimates.

Efficiency rating	IIS		TIS		Overall	
	N	%	N	%	N	%
< -75	0	0	21	55	21	27.6
76-80	5	13	8	21	13	17.1
81-85	9	24	5	13	14	18.4
86-90	15	39	4	11	19	25.0
91-95	6	16	0	0	6	7.9
> - 96	3	8	0	0	3	3.9
Total	38	100	38	100	76	100
Mean Efficiency	87.06		75.42		81.24	
Minimum	76.72		56.28		56.28	
Maximum	98.96		90.28		98.96	

Note: N indicates number of the respondents

Table 6. 13: Technical Efficiencies of Potato Growers

Farmers Number	Technical Efficiency	Farmers Number	Technical Efficiency	Farmers Number	Technical Efficiency
1	0.900	27	0.844	53	0.780
2	0.887	28	0.812	54	0.647
3	0.829	29	0.767	55	0.868
4	0.848	30	0.789	56	0.809
5	0.902	31	0.779	57	0.683
6	0.863	32	0.887	58	0.749
7	0.887	33	0.857	59	0.563
8	0.865	34	0.901	60	0.688
9	0.907	35	0.797	61	0.825
10	0.988	36	0.863	62	0.699
11	0.860	37	0.897	63	0.746
12	0.915	38	0.940	64	0.710
13	0.820	39	0.819	65	0.679
14	0.909	40	0.776	66	0.726
15	0.851	41	0.766	67	0.737
16	0.869	42	0.674	68	0.744
17	0.990	43	0.903	69	0.753
18	0.887	44	0.861	70	0.770
19	0.909	45	0.771	71	0.764
20	0.836	46	0.738	72	0.722
21	0.821	47	0.812	73	0.798
22	0.977	48	0.713	74	0.773
23	0.913	49	0.815	75	0.667
24	0.871	50	0.751	76	0.748
25	0.848	51	0.744		
26	0.798	52	0.869		

Mean technical efficiency= 81.2

The mean overall estimated technical efficiency of potato growers is 81.2 implies that still there exist a great potential to increase per acre output of potato. It shows that a large number of potato farms in the sample faced severe technical inefficiency problems. The mean technical efficiency estimated for this study is in line with Amara, et. al. (1999) for potato 80.3% and above than Bakhsh, et. al. (2006) for wheat 76.0% in Pakistan.

It is important to explain about the individual technical efficiencies of IIS and TIS to know the effect of the irrigation system. The average level of technical efficiency has been estimated in IIS as 87.1% with the scores ranging from 76.7% to 98.9%, where more than 87% farmers found to be having technical efficiency scores above 80%. This implies that most of the farms in the sample are near to the frontier level and having less technical efficiency problems. It indicates that on average sample farmers tend to realize around 87% of their technical abilities. Hence, 13% farms are not realizing their technical potentials for potato production.

On the other hand, the average predicted technical efficiency for potato in TIS ranges from 56.3 to 90.3% with a mean of 75.4% suggesting that there exist a great potential to increase per unit output of potato. It shows that around 75% of potato farms in TIS having severe technical inefficiency problems. These findings imply that farmers operating under IIS are more efficient compared to TIS. Farmers producing potato under TIS are less efficient due to the poor irrigation system. Therefore, productivity of these farmers can be raised through improving the irrigation system.

6.5 **Summary**

This chapter aimed to compare the productive performance of the improved irrigation system (IIS) with that of a traditional irrigation system (TIS) in order to estimate farm level technical inefficiency using a stochastic frontier production technique involving a model for technical inefficiency effects for the selected dry season crops (wheat and vegetable) and potato separately. The results of the MLE indicated that fertilizer, agrochemicals, purchased seeds, irrigation and labor used to perform various farming activities significantly contributed to wheat, vegetable and potato productivity. The results further indicate that increasing the farm size has a positive effect upon the technical efficiency of potato production. However, it is not fact that the farm holding with inefficiency, especially in the case of cash crops where farmers have large farm holdings, but the area allocated to crop cultivation is only a part of total cultivated land.

Considering determinants of technical efficiency, it was found that with an increase in age of the vegetable and potato growers' level of technical efficiency declined except in wheat production where it was positively related to respondents' age. Education was positively related to technical efficiency except wheat crop implying that the highly educated vegetable and potato growers were using available resources more efficiently. Family size was not related with technical efficiency in cultivation of all wheat, vegetables and potato; this is due to family members not actively participating in agriculture activities.

One of the important findings of the study was the impact of the irrigation system dummy in the technical inefficiency model. The negative and significant coefficient associated with wheat, vegetables and potato implies that IIS farmers are technically more efficient than those farmers belonging to TIS users. It shows that there is a positive relationship and significant differences between IIS and TIS. This could be attributed to substantial saving of water losses by improved watercourses in the study area. The coefficient of location (head & tail) of water channels is negative and significant, indicating that the farmers located at the head of the water channel are more efficient. The distance from village to city is negative and significant for the potato production implying that the technical inefficiency increases significantly with the increase in the distance but not for wheat and vegetables. Mean level of technical efficiency was 77% for wheat, 85% for vegetable, and 81% for potato implying potentials to increase crop production by using existing resources more efficiently.

CHAPTER VII

IRRIGATION MANAGEMENT AND FARMERS PARTICIPATION IN NORTHERN AREAS OF PAKISTAN

7.1 Introduction

Pakistan agriculture is almost completely dependent on irrigation. The majority of population is directly or indirectly dependent on agriculture as a source of livelihood. Water is very essential for agriculture and it is being provided to farmers through canal irrigation system. The purpose of this study is to understand how the level of satisfaction with improved irrigation system (IIS) and traditional irrigation systems (TIS) influences the level of participation in participatory irrigation management (PIM). And also find out that how the level of satisfaction enables farmer to participate more in irrigation operation and maintenance (O&M).

Irrigation management can be managed well if the farmers are involved in irrigations' O&M. Recently, planners and administrators in Pakistan have realized that the farmers' participation is very important and many projects of such nature are being implemented in different irrigation zones. Moreover, the Provincial Irrigation and Drainage Authorities (PIDA) have been established by legislation in each province and these authorities have formally initiated PIM in the country.

PIM refers to the involvement of stakeholders in planning, designing, policy and decision making, construction and supervision, operation and maintenance and evaluation of irrigation systems. Involvement of farmers in all aspects of irrigation management enhances farmers' satisfaction with the irrigation system. Participation is considered a key factor contributing to the long term sustainability of water user associations (WUAs) in Pakistan. It has been recognized widely that unless the farmers are involved in an organized way in the operation, management and maintenance, the objectives of irrigation projects cannot be realized to the full extent. Participation is crucial for agriculture and rural development and is one of the critical components for success of natural resource management.

This chapter consists in three parts. In the first part we discussed about the water availability and institutional structure of irrigation setup in the study area. In the second part results regarding farmers' participation, their satisfaction and the factors influence on their participation are presented. Finally, a summary of the finding are given in the last part of the chapter.

7.2 Water Availability and Source of Water

In Pakistan, water availability during the wet season July to September is very high but shortfalls are more frequent during the winter (dry) season. Such water scarcity is also common in NAs of Pakistan and affects the selection of crops and production. During the winter season temperature reach to -10 ºC, due to less temperature glaciers and snow melt is very slow. This situation leads to continue water shortage till the end of spring season. However, in the summer season higher temperatures would lead to more melting of snow and glaciers and may lead to a change in the seasonality and magnitude of the flood. For example, in the high altitude glacier-fed Shyok River, Fowler and Archer (2004) have found that a 10 ºC rise in temperature produces a 17% increase in runoff.

Glaciers and snow deposits are the principal sources of water in the Northern Areas. The water from melted snow and ice enters streams, which subsequently feed man-made water channels locally known as (*kuhls*). Irrigation is the single largest 'consumer' of water in the NAs, approximately 97% of the total cultivated area is under irrigation, highlighting the critical role of irrigation in the region's food security. Though, there is very little information about snowfall or glaciers, despite the fact that these are the principal sources of water in the region. Current water availability is unreliable because of the large variations in stream flows this leads to seasonal water shortages and means that irrigation systems cannot be operated on a demand basis. The situation is exacerbated by the fact that large quantities of water are lost in transits in extreme cases. These losses may be as high as 70 percent. Water resource management and development face a considerable number of challenges in the NAs. The management of water resources will need to be significantly enhanced and new water development schemes initiated, if the NAs future water requirements are to be fulfilled. Though, since the construction of new water channels and irrigation schemes is more capital intensive and time consuming, so the main strategy in irrigation sector for near future should be to improve the management and maintenance of existing systems.

Due to the present water crises and reduced river flows, farmers are getting less water for crop cultivation. To overcome these problems, National Program for Improvement of Watercourses (NPIW) setup in NAs with the aim of improving irrigation infrastructure. Lining of watercourses is one of the main water management measures. The improvement of water channels enable to reduce the seepage and water logging. Therefore, improvements of few hundreds of water channels in different villages of NAs were completed but still many efforts need to be done in irrigation sector. National government funded through Local government, 80% of the capital outlay for watercourse improvement through the NPIW, while the remaining 20% share in terms of cash or labor are gathered from the respective farmers as farmer share.

7.3 Institutional Structure

The irrigation system in study area involves different stakeholders from the local community such as water users, farmers' organization, WUAs, sub WUAs, watchmen and the local government. All stakeholders play their role in the areas where improvement has been done or in the way. However, national government and also NGOs are playing supportive roles in the management of irrigation. One of the local NGO Aga Khan Rural Support Programme (AKRSP) established in eighties with the aim to reduce poverty in

NAs through rural development in terms of health, education and rural infrastructure (irrigation channels and roads) etc. They constructed some of new irrigation channels in the region as well also helped farmers (in specific areas) to improve the irrigation system and still they are in the way to the development.

Figure 7.1 shows the main relationships between specific stakeholders and their interaction with the physical irrigation management system in the study area. The NPIW is providing guidance to the IIS user related irrigation operation and management through WUAs.

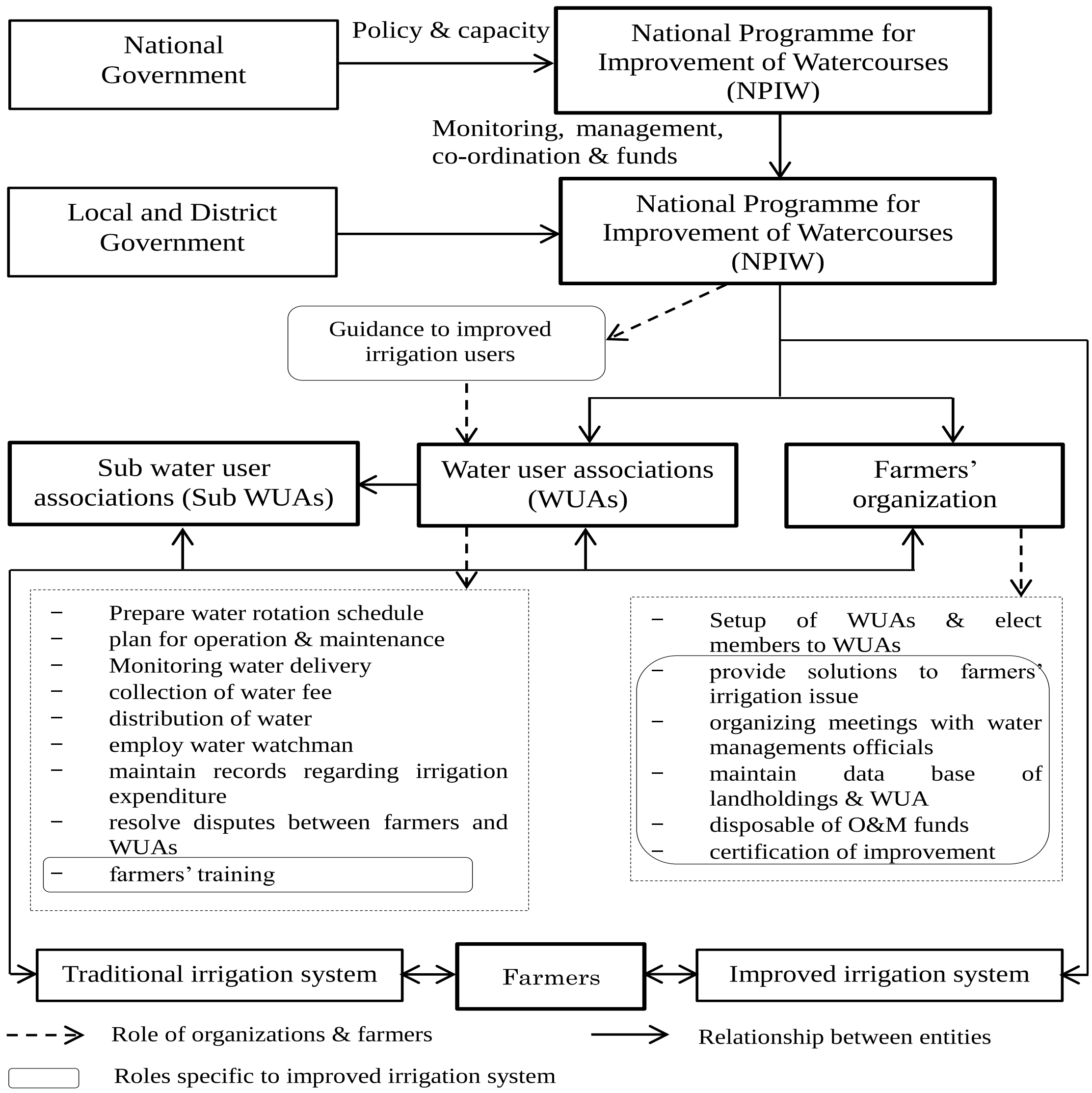


Figure 7. 1: Structure of water management in irrigation systems in Gilgit-Baltistan

Farmers' organization participation in irrigation management provides an important opportunity for improvement through working with WUAs in a more systematic way. These farmer organizations in the study area contribute to participatory management in numerous ways such as decision-making and planning, resource mobilization and management, communication and coordination and conflict resolution. In the IIS, farmer organization is responsible to provide all information about irrigation channels to the officials such as total area under irrigation channel, WUAs and farmers perceptions regarding farmers share etc.

In the both improved and TIS, WUAs play an important role to encourage more farmer's participation in irrigation management. WUAs contribute to design and construction; O&M fee collections, water distribution and record keeping, etc. There are few differences between the two systems such as in the IIS guidance related O&M and farmers training comes from NPIW through WUAs, which enhance farmers' level of understanding related to irrigation management and enable farmers to participate in PIM.

7.4 Farm Household Characteristics

The age of the selected respondents in the study area are 52 years for improved irrigation system (IIS) farmers and average 57 years for the TIS, Table 7.1. The level of education measured in terms of number of years of schooling is statistically significant, indicating that farmer household heads in IIS are better educated. Relatively better level of education is an advantage as it can form the basis for motivating farmers to participate in irrigation management. All the farmers cultivate own land. The average cultivated land which includes extent of cereals, vegetables, fodder crop and fruits in both seasons. The IIS farmers own more land compared to the TIS farmers, which implies that farmers in the IIS needs more water compared to the TIS farmers.

Almost all households are engaged in agriculture and it is the major source of livelihood in the area. The agricultural income of IIS farmer is significantly higher than that of TIS farmers. Moreover, the share of agricultural income of the IIS farmer's total income is higher than that of the TIS farmers i.e. 40% and 23%, respectively.

Table 7. 1: Characteristics of Surveyed Farmers

Particulars	IIS	TIS	p-value
Age of household head (years)	52.0	57.0	0.063
Education level of household head (years)	6.0	4.1	0.030
Family size of households (person)	10.8	11.6	0.145
Cultivated area (acres)	6.1	4.2	0.000
Average agriculture income (rupees)[1)]	157,180.1	86,879.1	0.000
Household income (rupees)[2)]	392,749.2	374,891.3	0.152

Source: Own estimated; author's field survey (2009)

Note: 1) Agriculture income is crop income - farm management cost

2) Household income is crop income + non-farm income except (livestock) income, n= 78

7.4.1 Satisfaction with present irrigation system

Satisfaction with the present irrigation systems was measured using three point likert scale (highly satisfied, satisfied and dissatisfied). According to Table 7.2, 69% of respondents are satisfied and 31% of them are dissatisfied with the present condition of the IIS. However in the TIS, 74% of respondents are dissatisfied, 15% are satisfied and only 10% of them are highly satisfied with the TIS. It is clear that the satisfaction level of the IIS farmers is higher than the TIS farmers. It is mainly due to the poor performance of the TIS in terms of condition of irrigation channels, and less water availability in dry season. Water availability has been found to be the cardinal factor influencing farmer's participation in community irrigation projects (Madhava and Chackacherry, 2004).

Satisfaction with water adequacy shows that in the IIS, 13% of the respondents are highly satisfied with adequacy of irrigation water. While, 44% of the respondents are satisfied and 44% are dissatisfied in the IIS. On the other hand, in the TIS, 90% of the respondents are dissatisfied due to water scarcity problems. Therefore, there is a significant difference between the IIS and the TIS. It is mainly because farmers in the TIS located at tail reach of watercourses are receiving less water. This implies that some

Table 7. 2: Level of Satisfaction with Present Irrigation System

Variables		Categories and number of samples		
Overall satisfaction level with present irrigation system		**Highly satisfied**	**Satisfied**	**Dissatisfied**
	IIS	27 (69)	0	12 (31)
	TIS	4 (10)	6 (15)	29 (74)
Adequacy of irrigation Water		**Highly satisfied**	**Satisfied**	**Dissatisfied**
	IIS	5 (13)	17 (44)	17 (44)
	TIS	0	4 (10)	35 (90)
Availability of water on fixed turns		**Highly satisfied**	**Satisfied**	**Dissatisfied**
	IIS	9 (23)	15 (38)	15 (38)
	TIS	0	5 (13)	34 (87)
Condition of present irrigation system		**Highly satisfied**	**Satisfied**	**Dissatisfied**
	IIS	27 (69)	9 (23)	3 (8)
	TIS	3 (8)	5 (13)	31 (79)

Note: Values in parenthesis are %,
Source: own estimated based on authors field survey 2009

farmers in the IIS, at head and tail of the water channels are having access to sufficient water.

However, in practice either because of the seepage or stealing of water by farmers close to the water source or conveyance losses, farmers located at the tail reaches of both systems generally get disproportionately less water. The results from the IIS users indicate that 23% farmers are highly satisfied with availability of water on their fixed turns, 38% of them are satisfied and 38% of respondents are dissatisfied. However, in the TIS 13% of the respondents' is satisfied receiving water on fixed turns, while 87% of them are dissatisfied with water turns particularly in water scarce (dry) seasons Table 7.2.

Water distribution depends on the water availability in the main irrigation channels. All the farmers are given their share of water according to the size of their landholding, which is decided by the WUAs. Water is distributed to the fields on a continuous flow basis during the water abundance period. When the water is abundant in quantity, the main gate or structure at the intake is regulated to provide water to all the watercourses. When the water is scarce in dry season, it is distributed on a rotational basis. Under the rotation system which is locally called (*warabandi*) system, each household in the channels takes its irrigation turn on a specific day at a specified and equal period of time. However, the number of gates to be opened or closed at the watercourses depends on the volume of water available at the main channel rather than on the farmers' requirements. This type of rotation does not seem to work well since the length of the watercourses and the volume of water channeled differ largely. Water theft is quite a common offence during periods of scarcity or drought in the region. Physical condition of PIS in the area directly affects the efficiency of the irrigation system. According to farmers in the IIS, the structures are satisfactory. As 69% farmers expressed that the present condition is highly satisfied, 23% of them are satisfied and 8% respondents are dissatisfied. However, 79% farmers in the TIS reported the physical condition is dissatisfactory, 13% and 8% of them said satisfied and highly satisfied, respectively Table 7.2.

7.4.2 Indices of satisfaction with present system

To compare the degree of satisfaction between the two systems composite satisfaction indices were computed. Table 7.3 present the indices of farmers' level of satisfaction with various elements of the present irrigation system in the study area. The overall result in Table 7.3 shows that the indices of farmers in the IIS is positive and mean values are better compared to the TIS and mostly highly statistically significant. However, the overall satisfaction of farmers in the IIS is moderate and the highest level of satisfaction is

Table 7. 3: Indices of Satisfaction

Index of satisfaction	IIS	TIS	t-stat
Overall satisfaction with present irrigation system	0.38 (1.38)	-0.49 (0.40)	7.041***
Adequacy of irrigation water	0.13 (0.92)	-0.79 (0.12)	4.838***
Availability of water on the fixed turns	0.23 (1.00)	-0.74 (0.20)	4.496***
Condition of present irrigation system	0.85 (1.50)	-0.01 (0.36)	7.020***

Note: Values in parenthesis are mean

*** significant at 1%, ** significant at 5% and *** significant at 10%, reported at the condition of present irrigation system.

Furthermore, the water availability on fixed turns and adequacy of irrigation water in IIS are showing low indices. This is due to the fact that during dry season water availability in the stream is very low and very difficult to tackle the water scarcity situation for the farmers. In the other hand, overall satisfaction, adequacy of water, water turns and condition of TIS shows a negative indices. These negative indices for all elements in the TIS reflect dissatisfaction with the irrigation system totally.

7.4.3 Participation in irrigation management

Farmers through WUAs and farmers organization participate in irrigation management. The activities mainly include maintenance of the common portion of the channels (cutting grasses, reconstruction of damage portion, removal of silt and cleaning channels etc.), which is an annual contribution from all farmers, either in the form of labor or cash. Spring is the time for general annual maintenance before the first irrigation for the new crop year. Maintenance of field channels are not common to the system, it is the responsibility of individual farmers. Main irrigation channel in study areas are common property of all villagers and it is maintained collectively through the farmer organization and WUAs.

All stakeholders are participating in O&M of irrigation channels in different levels. The result shows that all the respondents participate in watercourse level, while 54% and 41% of the respondents participating in main channel and branch level in the IIS, respectively. While, participation of the TIS farmers at watercourse level is 100%, field branch level is 33% and for main channel is 36%. The overall participation in irrigation management by farmers in the IIS is higher compared to the TIS, Table 7.4. This is probably because farmers in the IIS are comparatively satisfied with the IIS which motivates them to participate in PIM.

The cleaning of watercourses is very common activity among the farmers' in the study

Table 7. 4: Level of Participation in Present Irrigation System

Variables		Categories and number of samples		
Level of participation		**Main channel level**	**Watercourse level**	**Field branch level**
in irrigation	IIS	21 (54)	39 (100)	16 (41)
Management	TIS	14 (36)	39 (100)	13 (33)
Frequency of		**Often**	**Twice a year**	**Once a year**
watercourses	IIS	8 (21)	21(54)	10 (26)
Cleaning	TIS	9 (23)	19 (49)	11 (28)

Note: Values in parenthesis are %

Table 7. 5: Indices of Participation

Index of participation	IIS	TIS	t-stat
Farmers level of participation in main channel	0.29 (1.08)	-0.03 (0.72)	1.703*
Farmers level of participation in water course	1 (2.00)	1 (2.00)	-
Farmers level of participation in field branch	0.03 (0.82)	-0.18 (0.66)	0.753

Note: Values in parenthesis are mean, Source: own estimated based on authors field survey 2009

*** significant at 1%, ** significant at 5% and *** significant at 10%

area. The results indicate that 21% of farmers in the IIS participate often, 54% twice a year and 26% once a year.

However, 23%, 49% and 28% of the respondents participate in the TIS often, twice a year and once a year respectively, shown in Table 7.4. Improved channels were designed with slopes and sections in regime to minimize scouring and silt deposits. Water from glacier and snow melt carry a substantial amount of silt, which is loaded in channels and deposited on irrigated lands. These silt accumulation reduces channel cross-sectional area, which means that operating water levels must be raised to maintain flows. Major silt cleaning efforts are required each year in several times minimum once a year at the both systems. All stakeholders have to participate in this activity affording labor or maintenance fee (in cash).

7.4.4 Indices of participation in PIM

To determine the level of participation in both the IIS and the TIS index score were calculated. Results shown in Table 7.5 indicate that the level of participation in main channel was statistically significant while, field branch level was not statistically significant. The index scores of participation in main channel were positive and moderate, while participation level for field branches were low in the IIS. The negative indices of participation in main channel and field branch level in the TIS indicates that the participation of farmer in the TIS is comparatively low than those farmer in the IIS.

7.4.5 Factors influencing farmers' participation in PIM

A multiple regression analysis was performed to determine the factors influencing farmers' participation in PIM. According to the results presented in Table 7.6 satisfaction, family size, part time family labors, agricultural income, irrigation system dummy and village distance to the main market are main factors, influencing farmer's participation. This results imply that higher the overall satisfaction with the present irrigation system farmers are more likely to participate in irrigation management.

Table 7. 6: Results of Multiple Regression Analysis

Variables	Coefficients	t-stat
Satisfaction level of farmers	1.767	8.055***
Age of household head	0.008	0.715
Family size	0.068	3.193***
Part time family labour	0.031	2.178**
Cultivated area	-0.010	-0.240
Agriculture income	0.001	4.060***
Location of farmers[1)]	0.232	1.513
Irrigation system dummy[2)]	0.482	2.956***
Distance (km)[3)]	0.054	5.830***

Note: Adjusted R^2 value = 0.823, F-value = 41.025, n = 78
Dummies [1)] (Head=1 and Tail=0), [2)] (IIS=1 and TIS=0) and [3)] (Sultanabad=1 and Parri=2)
*** significant at 1%, ** significant at 5% and * significant at 10%

Higher the agricultural income higher the participation, this finding is consistent with Maleza & Nishimura (2007) who reports that farmers obtaining higher returns from agriculture are more likely to participate in irrigation management. Moreover, the irrigation system dummy is significant implying that farmers in the IIS participate more in irrigation management since their satisfaction level is higher with the improved irrigation system.

Family size shows a significant relationship with participation. It indicates that the larger family size encourage farmers to participate in irrigation management. The variable distance village to city is significant implying that farmers in Sultanabad are more inclined to participate in PIM than Parri village. This is because Sultanabad is located closer to the city center and farmers have better access to markets. This confirms the findings of Bandeth (2010), where farmers with better economic status are more inclined to participate in PIM.

7.5 Summary

This study examined the farmers' satisfaction level with various aspects of two irrigation systems; improved and traditional irrigation system to understand how the level of satisfaction influences farmer participation in PIM in Gilgit district of NAs Pakistan. Data related to farmers' satisfaction and participation obtained from the two systems were analyzed using Yeh's index of satisfaction and participation. Moreover, to determine the factors influencing farmers' participation in PIM multiple regressions analysis was performed. The estimated indices of satisfaction shows that four important variables adequacy of irrigation water, water availability on fixed turns and condition of present irrigation systems are significantly different between the two systems. However, level of participation except at main channel is not significantly different in both systems. The indices of participation in main channel and field channel in the IIS are positive, while in the TIS indices are negative implying that the level of participation of the TIS famers is lower.

Findings from regression analysis show that farmers' satisfaction, family size, part time family labor, agricultural income, status of the irrigation system and the distance from village to city are significant factors influencing farmers' participation in PIM. Overall this study establishes that the level of satisfaction with irrigation system is an important determinant of farmers' participation in PIM. Therefore, these findings imply that improvement of irrigation system in terms of developing physical infrastructure and efficient distribution of water can enhance farmers' participation in PIM. Moreover, farmer training and guidance provided to IIS farmer by NPIW through WUA as well as the active role of the farmer organizations contribute to enhance IIS farmers' participation in PIM. Therefore, strengthening the institutional arrangements in both systems can enhance farmers' participation in PIM.

Management of the water resources for irrigation uses should incorporate a participatory approach by involving not only the governmental agencies (NPIW) but also the users' and other stakeholders, in an effective and decisive manner, in various aspects of planning, designing, development and management of the water resources schemes. Necessary legal and institutional changes should be made at various levels for this purpose. Appropriate role of WUAs and farmer organization should particularly be involved in the operation, maintenance and management of water infrastructures or facilities at appropriate levels progressively.

CHAPTER VIII

CONCLUSION AND POLICY RECOMMENDATIONS

This chapter aims at summarizing and discussing the major finding of the current research and drawing up strategies toward improvements and development of the irrigation system in the region. It is divided into three sections. The first section elaborates general findings of the study, the second section describes the limitations and policy recommendations are given in the last part of the chapter.

8.1 Overall Discussion of Findings

The broad objective of this study was to compare an improved irrigation system (IIS) with a traditional irrigation system (TIS) in terms of overall management of irrigation system including level of participation and satisfaction, land use, profitability and to determine the factors influencing on technical efficiency, to find out the productive performance of IIS in Northern Areas (NAs) of Pakistan. In order to achieve the objective of this study we followed a systematic technique which was based on primary and secondary data. The primary data was collected from two villages (Sultanabad and Parri) in Gilgit District of NAs Pakistan by using a comprehensive questionnaire and secondary data obtained from the local, national and international sources. The traditional irrigation channels in NAs were constructed without proper designed by hand dug with stone and mud (cutting the rocks) which leads to considerable water losses. The crop production in the region is completely dependent on irrigation derived from high altitude snow and ice melt through irrigation channels.

The studies in previous chapters determined the impact of an IIS comparing with TIS. An evaluation of farmers' perception their satisfaction level with the present irrigation system and level of participation were also conducted. The chapters also analyzed the significance as well as the effect of demographic variables and other factors which influence farmers' participation in irrigation operation and management. An analysis of technical efficiency effect and its determinants in dry season crop such as wheat (as main cereal crop), vegetable and potato (as main cash crops) were also carried out to find out how the irrigation improvement has favorable impact on crop production in NAs of Pakistan. The conclusions drawn from the farmers' survey conducted to the appraisal of an improved irrigation system for the current socio-economic conditions, impact of the system and farmers' livelihood are outlined below as follow:

Firstly, a comparative study between IIS and TIS covers the land use, crop production, cost production and profitability of dry and wet season crops. It was found that the rate of land utilization for crops among IIS farmers is significantly higher than TIS farmers in the dry season with few exceptions. It is clear that IIS farmers cultivate more land in the dry season due to availability of irrigation water. All the crops cultivated by IIS farmers in dry season produce higher yields. However, in the wet season the productivity of other crops is not significantly different between the two groups with the exception of maize. The higher productivity in maize crop cultivated by IIS farmers can be attributed to the use of higher amount of inputs. The better productivity of IIS farmers in dry season can be attributed to both availability of water and high input usage. This further confirms the fact that IIS farmers are at an advantage in dry season due to continuous availability of water for crop cultivation.

Secondly, cost of production and profitability analysis shows that the farmers in IIS had obtained higher gross production and net profit from all the crops. The profit obtained by farmers in IIS can be attributed mainly to the higher input usage and availability of water as the inputs use is statistically significant between the both groups. This study also shows that farmers are willing to invest more on agricultural inputs when continuous water availability is assured. Wheat is traditional basic cereal crop mostly growing for self-consumption while, vegetables, fodder and fruits are grown for the both self and commercial purposes. One of the interesting finding of this study is that the wheat production is very low in the study area (433 kg/acre) compare to the national average yield of 1,055 kg/acre (Baloch, 2010), despite using significant amounts of inputs. However, on the other hand profit earns from cash crops by the farmers are very high compare to cereal crops. Thus, most of farmers might be growing cash crops in future due to high profit. Therefore, it is suggested that government should enhance the knowledge in the practices done by farmers for wheat cultivation in the case of input use. As it was confirmed by the regression analysis which shows negative coefficient for the fertilizer and purchased seeds.

Thirdly, the study aimed to compare the productive performance of the IIS and TIS, to estimate farm level technical inefficiency using a stochastic frontier production technique involving a model for technical inefficiency effects for the (wheat and vegetable) and potato crops separately. Initially, we compared wheat (main cereal crop) and vegetables (main cash crop) in terms of technical efficiency in productions and found that the vegetable growers are more efficient than wheat growers. Therefore, it was necessary to undertake a study on the technical efficiency effect of potato production, which is growing as separate vegetable crop in the region since few decades for commercial purposes as one of the dry season crop.

The finding of production elasticity estimates indicated that fertilizer, agrochemicals, purchased seeds, irrigation and labor used to perform various farming activities significantly contributed to wheat, vegetable and potato productivity. This shows that one percent increase in expenditure on the mentioned inputs will increase production of selected crops maximum frontier level. The results supported our hypothesis which specifies that inefficiency effects are not stochastic, is strongly rejected. Fertilizer, agrochemical, good quality/purchased seeds and more irrigation water are necessary for high crop production. The results further indicate that increasing the farm size has a positive effect upon the technical efficiency of potato production. However, it might not be true to correlate the cultivated area with inefficiency, especially in the case of potato where farmers have large farm holdings but the area allocated to potato cultivation is only a part of total cultivated land available for cultivation.

Fourthly, considering determinants of technical efficiency of age, it was found that with an increase in age of the vegetable and potato growers, level of technical efficiency declined except in wheat production where it was positively related to respondents' age. Education was positively related to the technical efficiency except for wheat crop grower, implying that the highly educated vegetable and potato growers were using available resources more efficiently. Family size was not related with technical efficiency in cultivation of all wheat, vegetables and potatoes. This is due to family members not actively participating in farm work. One of the important findings of the study was the impact of the irrigation system dummy in the technical inefficiency model. The negative and significant coefficient of irrigation system dummy associated with wheat, vegetables and potato implies that IIS farmers are technically more efficient than those farmers belonging to TIS.

Fifthly, we found that there is a positive relationship and significant differences between IIS and TIS in terms of crop productivity. This could be attributed to substantial saving of water losses by improved watercourses in the study area. The coefficient of location (head & tail) of water channels is negative and significant indicating that the farmers located at the head of the water channel are more efficient. The distance from village to city is negative and significant for the potato production implying that the technical inefficiency increases significantly with the increase in the distance but not for wheat and vegetables. Mean level of technical efficiency was 77% for wheat, 85% for vegetable, and 81% for potato implying potential to increase crop production by using existing resources more efficiently. Second hypothesis of the model is that efficiency determinants of crops is likely to be affected by the demographic and socioeconomic variables. The MLE results indicate strong evidence that farm size, level of education, irrigation system, distance from the main channel (head and tail) and distance from the village to city are important factors for improving technical efficiency level of crop production.

Sixthly, the study identified the level of satisfaction with the IIS and TIS influences on the level of participation in participatory irrigation management (PIM). Furthermore, we described how the level of satisfaction enables farmer to participate more in irrigation operation and maintenance (O&M). The result shows a statistically significant difference between the agricultural income earned by improved and TIS farmers. The higher income enhanced farmers' participation as well their level of satisfaction. The estimated results of satisfaction show that four important variables adequacy of irrigation water, water availability on fixed turns and condition of present irrigation systems are significantly different between the two systems. These factors could be considered for the satisfaction of IIS farmers. The indices of participation in main channel and field channel in IIS are positive while negative for the TIS. The negative indices implying that the level of participation of the TIS famers is low. The regression analysis shows that farmers' satisfaction, family size, part time family labor, agricultural income, status of the irrigation system and the distance from village to city are significant factors influencing farmers' participation in PIM. These findings imply that improvement of irrigation system in terms of developing physical infrastructure and efficient distribution of water can enhance farmers' participation in PIM. Additionally, it was found (in chapter 5) that per unit cost of improving traditional irrigation channels, operation and maintenance costs are not considerably high. The total cost of irrigation is 0.19% of gross agriculture income of farm households per year and thus makes it more affordable for farmers to pay the annual operations and maintenance costs.

Moreover, farmer training and guidance provided to IIS farmers by NPIW through WUA as well as the active role of the farmer organizations contribute to enhance IIS farmers' participation in PIM. Therefore, strengthening of the institutional arrangements in both systems can enhance farmers' participation in PIM, which leads to higher satisfaction of farmers.

In conclusion, this study further confirms the importance of IIS in the region to farming communities in terms of better land utilization and improved productivity leading to higher farm income. The empirical results obtained from the sampled farmers indicate that fertilizer and agrochemical, purchased seed, hired labor and irrigation numbers applied to crop significantly influenced on productivity of crops. In view of the increased environmental problems associated with more intensive use of inputs such as fertilizer, agrochemicals and good quality seeds in crops cultivation, the potential for production growth by increased intensification will be exhausted. Due to limitation of resources and poor management system, in the long run, increase per unit crop production can be achieved from the improvement in technical efficiency. Issues of water scarcity could be handled in a better way with carrying out investment in irrigation infrastructures.

However, to enhance farmers' participation in overall irrigation operation and management; farm income, family labor, status of irrigation system, farmer's training and guidance provided to IIS farmer by NPIW through WUAs are noticeable. Furthermore, the active role of the farmers' organizations contributes to enhance IIS farmers' participation in PIM. The strengthening of the institutional arrangements in both systems also can enhance farmers' participation in PIM.

8.2 Policy Recommendations

The following practical recommendations are made for technical, managerial and institutional improvements of the new initiated system as well as for the livelihood of the farmers.

1) Results of the study revealed that improvement in irrigation has positive impacts on the yield and profitability of all the major crops in the dry and wet seasons. However, many irrigation channels in the region are still not been improved.

Therefore, it is suggested that the Irrigation Department and NPIW project should be further extended to improve all TIS channels, thereby uplifting the living standards of the farming community in Northern mountain regions of Pakistan. Furthermore, the government should allocate more funds to improve irrigation infrastructure in NAs of Pakistan as a whole and in the study area particularly.

2) It is also evident that improvements of irrigation have positive impacts on the farmers locating at the tail clusters of the channels. But location of the farm still has negative impact on the efficiency of the farmers as evident by inefficiency effect model. So there is a need of a strong water management strategy to distribute water on equal basis for improving tail end farmers' crop productivity and higher income.
3) Available water rights and farmer participation in water resources management could help prevent problems and facilitate smoother, more equitable and efficient processes to improve water use efficiency. Therefore, it is necessary to ensure farmers involvement in planning, policy and decision making, construction and supervision, O&M and evaluation of irrigation systems.
4) It was found that the irrigation operation and maintenance cost for the improved irrigation was not considerably high. So, there is need after the irrigation services improvements in the region, the irrigation charges in terms of operation and maintenance should be revised.
5) Farmers should be informed about their entitlement of water and the expected quantities and timings. This information can enable them to plan the cropping patterns, farming operations and use of other non-water inputs for optimization. Farmers' participation can provide useful guidelines and feedback in evolving effective policy framework which in turn can be helpful in improving irrigation efficiencies.

6) The education level of the respondents is quite low compare with other parts of the country. As our result shows the higher level of education has an advantage, which can form better access to information, good farm planning and motivate farmers to involving in the farm management practices. Therefore, to face new challenges and transfer the latest technologies to the farmers' effective education programs through farmers training should be improve by given better education facilities.
7) Irrigation Department and On-farm water management have to promote better water management through WUAs, and give improvement priority to the area where water scarcity is high in dry season, in order to achieve increased and optimum crop production.
8) Further study of improved irrigation system is called for to more accurately determine the long-term sustainability. This continued monitoring would also add to the currently limited knowledge base and help indicate what effect the improvement of the system have on the livelihoods of the farmers. The conclusions drawn should be carefully used in other studies where more criteria were to be considered.

8.3 Future Areas of Research

To evaluate the performance of improved irrigation system in NAs of Pakistan still lot of work is required. Performance measurement of initiated system should concentrate on economic, institutional and technical efficiency issues. There is need to evaluate empirically the extent of maintenance and improvement activities, the distribution and productivity of water and changes in the size and distribution of farm incomes before and after irrigation improvement. It is suggested that further empirical research should be conducted taking into account "before and after" improvement approach.

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A Comparative Study of Improved and Traditional Irrigation System in the Gilgit District of Northern Areas of Pakistan: From the Farm Management Perspectives

ABSTRACT

Pakistan is one of the world's most arid countries with an annual average rainfall of under 240mm. In the northern parts of the country, Himalaya, Karakorum and Hindukush together make the largest mountain chain on the earth. The Northern Areas (NAs) of Pakistan recently known as (Gilgit-Baltistan) bordering with China, Afghanistan and India. As a result of the regions' politically sensitive location, the area has been accorded special territorial status and is administered directly by the Federal Government of Pakistan. It is a known fact that most people of the region are poor and depends on agriculture, growing traditional crops and water is supplied through irrigation channels. However, after completion of Karakorum Highway in 1986s, isolation came to the end with rapid social and ecological transformation, i.e. potato and vegetables turned into cash crops because of easy access to the market while on the other hand, demand for water increased due to growing population and cropping pattern.

NAs are considered as water stressed region in the country. It is mainly due to low rainfall (annually 150mm to 240mm) and river flows used for irrigation are derived from glacial snowmelt. Vast amounts of water are lost due to deteriorating watercourses, uneven fields and poorly designed irrigation channels in the region. Therefore, farmers in the region are facing severe water scarcity for agricultural activities. To overcome these problems, National Program for Improvement of the Watercourses (NPIW) was setup in Gilgit-Baltistan during 2003/2004 with the aim of improving irrigation infrastructure by converting irrigation system from traditional to lined/improved (channels made by cement concrete and stone). A total of 600 watercourses were constructed in 2009/2010 and lining of around 1,200 are underway. Given these developments in the irrigation sector, the

broad objective of this study is to determine the benefits of the improved irrigation system to the farmers' economy. This is achieved by comparing an improved irrigation system (IIS) with a traditional irrigation system (TIS) in terms of overall management of irrigation system, land use, productivity, profitability and technical efficiency of crop production.

The study is based on primary data collected from two villages (Sultanabad and Parri) in Gilgit District of NAs Pakistan by using a comprehensive questionnaire. The secondary data was obtained from the local, national and international sources. Using multiple regressions a comparative economic analysis encompassing land use, productivity, cost of production and profitability were examined. To test empirically the perception, satisfaction and participation in irrigation management Yeh's Index of Satisfaction (YIS) was used. Moreover, stochastic frontier production function was employed to ascertain the impact of irrigation on crop production. Technical inefficiency model was estimated to determine the level of technical efficiency and its determinants.

The content in the chapter five examines the benefits of IIS in terms of land use, crop productivity and profitability. The result shows that the land utilization by IIS farmers is significantly higher than TIS farmers in the dry season due to availability of irrigation water. All the crops cultivated by IIS farmers in dry season produce higher yields. However, in wet season except maize other crops productivity is not significantly different. The higher productivity in maize crop in IIS can be attributed to the use of higher amount of inputs. The higher productivity of IIS farmers in dry season is due to both availability of water and high input usage. The cost of production and profitability analysis shows that the farmers in IIS had obtained higher gross production and net profit in all crops. This is mainly due to the higher input usage and availability of water as the input use is statistically significant between the two groups. This study also shows that farmers are willing to invest more on agricultural inputs if continuous water availability is assured.

The results presented in chapter six are based on estimation of technical efficiency of selected crops and its determinants. The production elasticity estimates indicated that fertilizer, agrochemicals, purchased seeds, irrigation and labor used to perform various farming activities significantly contributed to wheat, vegetable and potato productivity. The results further indicate that increasing the farm size has a positive effect upon the technical efficiency of potato production. However, it might not be true to correlate the farm holding with inefficiency, especially in the case of potato where farmers have large farm holdings, but the area allocated to potato cultivation is only a part of total cultivated land.

Considering determinants of technical efficiency it was found that with an increase in age of the vegetable and potato growers level of technical efficiency declined except in wheat production where it was positively related to respondents' age. Education was positively related to technical efficiency except wheat crop implying that the highly educated vegetable and potato growers were using available resources more efficiently. Family size was not related with technical efficiency in cultivation of all crops. One of the important findings of the study was the statistical significance of the IIS dummy in the technical inefficiency model implying that the IIS farmers are technically more efficient than those farmers in TIS. It shows that there is a positive relationship and significant differences between IIS and TIS. This could be attributed to substantial saving of water losses by IIS in study area. The coefficient of location (head & tail) of water channels is also significant indicating that the farmers located at the head are more efficient. The distance from village to city is significant in potato crop but not for wheat and vegetables. Mean level of technical efficiency was 77% for wheat, 85% for vegetable, and 81% for potato implying that potential to increase crop production by using existing resources more efficiently.

The chapter seven examines IIS and TIS to understand how the level of satisfaction with irrigation system influences the level of participation. This study identified a statistically significant difference between the two systems in terms of farmers' satisfaction, participation and agricultural income. The higher farm income, developing physical infrastructure, family size and efficient distribution of water enhances farmers' participation as well their level of satisfaction. Furthermore, it was found that per acre cost of improving traditional channels are not considerably high. The total operations and maintenance (O&M) cost of irrigation is 0.19% of gross agriculture income of farm households per year, and thus makes it more affordable for farmers to pay the annual O&M costs.

The overall results of this study confirm the importance of IIS in terms of its beneficial effects such as enhancing farmers' participation in overall irrigation management, better land utilization and improved productivity leading to higher farm income. In the long run, increase in per unit production can be achieved by improving technical efficiency. Most issues related to water scarcity can be solved by investing in irrigation infrastructures. Moreover, to face new challenges and transfer the latest technology to the farmers' effective education programs through farmers training should be provided. The government should allocate more funds to improve irrigation infrastructure and farmers' education in NAs of Pakistan as a whole and in particular, in the study area.

パキスタン北部ギルギット地域における改良型/伝統型灌漑システムの比較研究
－農業経営学の視点から－

要旨

パキスタンは年平均降水量が 240mm 以下の世界で最も乾燥した国のひとつである。その中でも、パキスタン北部ギルギット・バルティスタン州は国内でも水不足が深刻な地域であり、同時に農村の貧困問題を抱えている。同地域は、ヒマラヤ、カラコルム、ヒンズークシ山脈が連なる山岳地帯であり、氷河や冬期の積雪の融雪水を主要な水源とする小規模灌漑を利用して麦類を中心とした自給的農業が展開していた。しかし、1986 年に中国とパキスタンを結ぶカラコルムハイウェイが開通して以降、水需要の多いジャガイモや野菜等の商品作物の生産が増加したため、水不足が深刻化している。パキスタン北部はアフガニスタン、中国、インドに隣接しており、政治的にもパキスタンに取って重要な意味を持つ。同地域の政治的安定のためにも、水不足の解消と商品作物生産による農家の貧困問題の解決が重要な課題となっている。

同地域で一般的にみられる小規模灌漑システムは、頭首口から圃場までの距離が長く、用水路の大部分が土や岩で構築されているため、送水中の大量の漏水解決が課題となっている。このような損失を制御し、農業用水の作物への適用効率を高めるために、同州では 2003/04 年に NPIW（国家水路改修プログラム）を設立し、伝統的な灌漑施設を漏水の少ないコンクリート製の水路に改良することを目指している。2009/10 年には合計 600 の用水路が改良されており、急速に灌漑施設の改良が進んでいる。しかし、改良型灌漑システム（IIS)の導入が農家経済にどのような影響を及ぼすのか、また効率的な作物生産に寄与しているのかについては、十分な研究がなされていない。

このような状況認識に立脚し、本研究ではパキスタン北部における灌漑施設の改良が農家経済に及ぼす影響を経営・経済学的視点から考察することを目的とし

た。そのために、灌漑施設の管理、土地利用、生産性、収益性、作物生産の技術効率性の観点から IIS と伝統型灌漑システム（TIS)を利用する農家の比較分析を行った。

本研究では、ふたつの村で実施した実態調査の結果を第一次資料として用いた。第二次資料としては、地元、パキスタン国内、そして海外の資料を使用した。本研究では、最初に二次データに依拠して、パキスタン及び同国北部ギルギット・バルティスタン州における農業生産の概況についての整理を行った。

最初に、IIS の利用が農家経済に及ぼす影響を明らかにするために作物の生産性、収益性の観点から IIS 利用者と TIS 利用者の比較分析を行った。分析の結果、乾期の水利用が可能になったことにより、IIS 利用者は TIS 利用者よりも土地利用率が高いこと、同時に、IIS 利用者は乾期の作物収量は TIS よりも高いこと、一方、相対的に水の供給量が多くなる湿潤期にはトウモロコシを除いて IIS と TIS 利用者の間に収量の有意な差が無いことが確認された。さらに、作物別に生産性と収益性を分析した結果、IIS 利用者は全ての作物で、高い生産性と所得を得ていること、水路の改良により水の利用が容易になった農家は、高収量品種や肥料、農薬等の投入財の利用を増やす行動を取っていることが示された。また、改良型灌漑システム導入に係る費用便益分析を行い、現行の政府等の補助と受益者である農家の農業所得を前提とすれば、受益者である農家が負担する水路改修費用は少額であり、小規模農家であっても十分に投資が可能な金額であることを明らかにした。

続いて、水の利用が生産に規定的な影響を及ぼす乾期の主要作物（小麦、野菜、ジャガイモ）を対象として、確率的フロンティア生産関数を用いた技術的非効率性の測定を行い、作物別に生産の技術的効率とその決定要因を推定した。その結果、灌漑方式別に作物別の技術的効率性をみると、いずれの作物においても IIS 利用者は TIS 利用者よりも効率的であった。TIS 利用者は、小麦、ジャガイモにおいて特に技術的効率性が低い農家が多い。また、灌漑水路に対する農家圃場の立地別にみると、幹線水路に近い支線水路上流に立地する圃場を耕作する農家の

効率性が高い。また、調査村から町までの距離では、ジャガイモの生産については町までの距離が近い村の生産効率が高い。灌漑方式以外の技術的効率性の決定要因としては、商品作物である野菜、ジャガイモでは、経営主の年齢が若いほど、また教育水準が高くなるほど技術的効率性は高くなっていた。一方、伝統的作物である小麦では経営主の年齢が高いほど、技術的効率性は高くなっていた。

以上、述べてきたように、パキスタン北部における改良型灌漑システムの導入により、適切な投入財と水利用により生産の効率性を高め、受益者である農家は生産性、所得の向上を実現している。このようなメリットを持つ改良型灌漑システムを持続的に利用するためには、適切な管理を適宜行うことが必要となる。灌漑システムのようなインフラストラクチャを維持していくためには、利用者の灌漑施設管理への参加が必要であり、国・州政府の指導の下、当該地域では参加型灌漑管理（PIM）が推進されている。そこで、Yeh の満足度指標を用いた分析、PIM への参加程度を被説明変数、満足度指標、農家属性、農業収入、立地属性、灌漑システムダミーを説明変数とする重回帰分析を行い、灌漑システムに対する満足度が PIM の参加程度に及ぼす影響を検討した。

その結果、農民の満足度、参加程度、農業所得の点で、IIS 利用者と TIS 利用者の間には統計的に有意な差が確認できた。高い農業収入、物理的なインフラの改良、家族員数、効率的な水の分配は、利用する灌漑システムに対する農民の満足度を高めるだけでなく、PIM への農民の参加程度を強めると考えられる。

これらの知見を元に、最後に今後望まれる政策的支援について指摘した。