Farming System Analysis of Irrigated Farms in Faisalabad, Pakistan

by

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Abstract

This research was related to water inequality assessment at canal and watercourse level in the head, middle and tail farms irrigated by Canal Rakh Branch, Faisalabad, Pakistan. The main objectives of the research were to assess the inequalities in irrigation water supply, farmers' decision about cropping patterns based on available water and the constraints faced in different areas. This study was carried out to assess the status of water availability in the year 2012-13.

The data analysis was performed in order to find out the differences in designed and actual water discharge in head, middle and tail areas based on the data provided by Punjab Irrigation Department. The analysis also aimed to study the farmers' adaptation to given water supply based on selected indicators such as area under each crop, number of crops in a year and purpose of production.

The research found out that the water inequality existed at canal level, distributary level and watercourse level. Tail distributaries were getting less water than designed discharge while in the head distributaries the condition was opposite i.e. they were getting more volume of water than their allocated share. However, in middle distributaries the water supply was equal to designed discharge. The reasons of inequality were based on physical design of canals, management of water flow in canal/water course and roles of informal institutional in water allocation. The research also found out that farmers decided the cropping area of high water demanding crops like sugarcane and low water demanding crops like fodder according to canal water availability. The area under high water demanding crops decreased from head to middle and further decreased in tail areas. The income of head farmers was the highest and it gradually decreased toward downstream areas, which implied the needs to focus on income diversification in downstream areas.

Keywords: Irrigation Water, Irrigated Farming Systems, Sugarcane Farming System, Rakh Branch Canal, Faisalabad, Wheat Farming system, Mixed Farming System.

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Chapter 1

Introduction

1.1 Background of Study

The population of world is increasing and developing countries have larger role in this increase than developed countries. Pakistan being a developing country is not any exception. In the past five decades from 1960, the number of inhabitants in Pakistan has grown more than three folds (170 million now) and this number is projected to increase two folds till 2025 (Qasim and Knerr, 2010). This geometric growth in population has raised the demand for food, as more masses need to feed; this increased demand of food implies exploitation of new cropland or more productive crop techniques for large scale as well as subsistence agriculture. Research institutes have put lot of effort to develop new varieties of many crops that are more yielding than previous ones, but the yield gap is still very large in Pakistan. One of the reasons of low yields is insufficient water availability coupled with inefficient use of water in fields (Ahmad et al., 2010).

Irrigation plays an important role in agriculture production. The irrigation system of Pakistan is praised for having an extensive and intricate canal network facilitating the water supply from far-off rivers to every field. This canal network was constructed after Indus Water Treaty in order to divert rivers for irrigation. This system was developed for 75% cropping intensity and its design was effective for said cropping intensity. However, with the passing years a drastic increase has been observed in the cropping intensity from a mere 75% to 200% and even more in some areas. This immense pressure on water system has malformed the efficiency of this system. Whole irrigation system has been run by traditional means, the lack of up gradation of system and its flexibility to adjust with the needs has arisen many issues on sustainability of irrigation system of Pakistan especially Punjab. Furthermore, the irrigation system of Pakistan has been proved inefficient in fulfilling the modern world crop needs (Bandaragoda and Saeed-ur-Rehman, 1995).

Due to high food demands, increased cropping intensities i.e. the number of crops grown in one year on a plot and climate change, water demand for agriculture has been projected to increase 70% from 1990-2025 (GOP, 2001). This situation is becoming more gruesome as the population growth is setting up the competition among demands of water for household, industrial and leisure uses and reducing its availability to agriculture sector. The volume of surface water supply to agriculture sector i.e. 107189.57 million m^3 as compared to average water demand that is 133216.04 million m^3 (GOP, 2012).

It is a common observation that those farmers whose farms are at the head of surface water source e.g. canal or water channel they use more than required volume of irrigation water as there is no or less conveyance losses in start. However, as the distance, increases the conveyance losses also increase and tail farmers could not get their fair share of canal water so they have to take support of tubewell water (Nakashima, 2000). The upstream farmers have no incentive to save water or leave it for downstream farmers if it is more than their requirement, because the extra water usage does not cost them anything the water expenses only count 5% of total crop expenses.

1.2 Problem Statement

The fixed nature of *Warabandi* system (the rotational system of water distribution, in which each farmer gets fixed amount of water after every 7 days or 10 days) and lack of proper infrastructure have caused water stress in tail areas. The farmers at tail suffer canal water shortage and employ tubewell water as a substitute, which causes salinity, water logging and lowering water tables. The difference in water availability has also changed the cropping systems on tail and head farms.

Although water supply has been limiting and the shortage is getting more severe, it has not tempted farmers to use new water efficient irrigation methods instead of old practices. By employing old irrigation practices farmers, leave major portion of water to get waste. Most of the farmers are smallholding farmers with large family size, which increase the demand for subsistence agriculture. In subsistence agriculture, lack of funds and skills favour the use of conventional irrigation methods. Examples of conventional irrigation methods include flood irrigation and furrow irrigation etc. However, conventional methods need more water as compared to pressurized irrigation methods like drip irrigation and sprinkler irrigation. These methods need more water, therefore, when canal water is not sufficient to fulfil irrigation needs, the water demand is fulfilled by using groundwater that is obtained from tubewells. However, this is putting pressure on groundwater resources in form of lowering water levels. Moreover, the use of tubewells also increases the cost of production due to higher prices of diesel and electricity (Iqbal et al., 2005). Further adding to aforementioned problems, conventional irrigation methods have raised many problems e.g. lower yield per unit of water used, nitrogen pollution, increased runoff, erosion of upper layer of soil, bending of plant stem and deterioration of water quality after drainage from fields (Fahong et al., 2004).

To assure enough supply of water, in past, government has focused only on supply side of irrigation that is why large projects were carried out to increase the water supply, to decrease the conveyance losses and to spread irrigation to more farms. How farmers are using the water and the role of irrigation in creating heterogeneity among farming systems has gained less attention (Nakashima, 2000).

The most common threats to the sustainability of irrigated agricultural system are build-up of salts and increased water saturation level in fields; reduction and contamination of water resources; alteration in soil nutrients, nutrient insufficiency and degradation of soil; higher level of pest attacks, yield losses to pests and related costs of increased pesticide application. Irrigated agriculture is confronting the pressure to grow more food with decreased water supply. The worsening situation can only be reverted if water is managed more efficiently and judiciously (Ahmad et al., 2004).

1.3 Objectives

1. To assess the spatial variability in irrigation water supply of Canal Rakh Branch
2. To classify current agricultural production systems in the study area with respect to water availability and access
3. To identify different constraining factors in each type of farming system

1.4 Research Questions

For objective 1

i. What is the volume of water in main and secondary canal system?
ii. How the water is distributed among farmers?
iii. Which areas get more water and which areas get less water?

For objective 2

i. Are the cropping systems same or different?
ii. What is the current water sources used?
iii. What are the cropping patterns?
iv. What is the share of high water demanding crops in each farming type?

For objective 3

i. What are the different factors that influence farmers' production practices?
ii. What are farmers' perceptions about water availability?
iii. What are the limitations faced by farmers that constraints the efficient use of water resources?

1.5 Rationale of Study

When it comes to agricultural production, there is a discrepancy in farmers' production technology (input/water use, temporal and spatial applications of inputs and mechanisation methods) even under same resource endowments, institutional and political stipulation. So there is a need to look into the internal variables (variables that are under farmers' own control) that lead to differences in the production technologies and follow-on outcomes. In Pakistan, the fixed rotational system of irrigation does not cater to the differences among farmers who operate on more or less similar scale but at different location with respect to water source. This study will help understand how farmers have adapted to different motivations or goals regarding a particular economic or social benefit from agricultural production with given water supply. Because those farmers who usually grow crops from commercial point of view, they try to increase profit by growing water intensive crops like sugarcane on larger portion of land than other crops like wheat that are important for food but offer less monetary benefit. Also this study takes into account the multifaceted effects of water use for irrigation, as it will analyse socio-economic as well as livelihood impacts of crop production (livelihood not only include income and wealth but also access to basic needs and freedom etc.). In previous studies, the analysis of different irrigation techniques only focused on technical/agronomic aspect i.e. yield per unit of water, efficiency of water use etc. (Ahmad et al., 2010; Naheed and Mahmood, 2009). There is a need of integrated approach, which incorporates not only technical or agronomic impacts but also the subsequent effects on farmers' income, social life and livelihood.

1.6 Scope and Limitation

This study was done on farm level. It was focused on finding the differences in production patterns that were caused by variations in water availability. First the focus had been put on cropping patterns in different areas along the water source chosen to be studied i.e. Canal Rakh Branch. Then subsequently it was assessed how these cropping decisions were embedded in wider matrix of household decisions. This study comprised the analysis of farming systems in terms of water availability accordingly the production and consumption decisions. The irrigation decision was not only based on water but also funds available for other sources of water, labour supply and access to information. It not only affected the yield of a crop but also it had a significant effect on development of area in terms of markets and infrastructure construction for crop transportation. Therefore, this study engulfed all of the above-mentioned spectres of irrigation decision on farm. It will help bridge the gap between agronomic and social aspects by looking at farm decisions and household decisions.

The limitations faced during the study were; firstly, shortage of time, due to which a large study area was not possible to be studied. Secondly, the farm size was very small in area that constrained the research largely to small and medium landholders. The third limitation was direct quantification of water use at farm level, as there was no data available for volume of water that each water channel and farm got. This limitation was addressed by using secondary data for canal water availability and using it for calculating approximate quantities of water available to each water channel and subsequently to each farm. Fourth limitation was the acquisition of personal data of farmers’ family especially female family members that is why the study did not differentiate between male and female population in the area.

Chapter 2

Literature Review

2.1 Irrigation Management System of Pakistan

The increased growing shortage of rainwater has made irrigation more advent. Irrigation can be defined as the non-natural application of water to the land and soil. Mainly it is used to fulfil water needs of a crop, but it is not the sole purpose of irrigation. It is also applied for upholding the landscapes, preservation of moisture in disturbed soils of dry areas, protection of plants from frost, curbing the weeds, and to fulfil water demand in days of scarce rainfall. The form of cultivation that relies more on irrigation or completely use irrigation water is called irrigated farming, on the contrary, the agricultural production that is done only by using rainwater is called rain-fed farming or dryland agriculture. Another term that is often used with irrigation is “drainage”. Irrigation cannot be dealt exclusive of drainage. Drainage is the term used for both natural and non-natural subtraction of water from the ground surface and sub-surface (Hargreaves and Merkley, 1998)

An irrigation system is a method of delivering water to an area where it is needed for irrigation. The key to an effective irrigation system is to get maximum volume of required water to the plants, or into the soil, as possible. While this may seems like an easy thing to do, it is not. There are many sources of irrigation water, it can be obtained from underground wells, springs and can be retrieved from rivers, lakes and ponds. Another water source that is getting popular is use of wastewater (Upchurch et al., 2000).

Pakistan is an agricultural country and most of its agricultural production is dependent on use of irrigation water. Irrigated agriculture will remain the backbone of Pakistan’s economy. Nature has provided Pakistan with adequate surface and underground water resources. These resources had been used for agricultural, household, and production purposes. Pakistan possessed one of the biggest irrigation systems in the world. Almost, 75% of cultivated land is under irrigated agriculture in Pakistan (GOP, 2011). In Pakistan, currently three large dams along with 12 barrages and seven head works are in operation to fulfil the water needs of the country. From these dams and barrages 45 irrigation canals (major plus minor) and 12 interlink canals have been made to supply water to the farmers’ fields. There has been 0.7 million tubewells installed to draw subsurface water. The most significant method of irrigation water supply is through canals, because canals can carry a plentiful volume of water and cost less (GOP, 2009). The total length of canals in Pakistan is 58,500 Km that helps to supply water throughout the country for irrigation and other purposes (Akhtar, 2003).

2.1.1 Indus river basin system

Indus River is the main river, which irrigates large proportion of cultivated land in Pakistan. However, Indus River does not do it exclusively; there are many tributaries of Indus River, which spreads it across the whole country. Out of these tributaries five major one are Jhelum, Chenab, Ravi, Beas and Sutlej. Many small rivers join the River Indus; these are Kabul, Kunar, Punj, and Kora River.

The River Indus and its tributaries are basic reservoirs used for surface water. At the time of partition in 1947, Pakistan had 82643.48 million m^3 water available for deflection; this volume of water was raised to approximately 104,845.95 million m^3 by the year 1960 (Ahmad, 1993). In the year 1960 Pakistan and India signed Indus Water Treaty that allocated rights of three eastern rivers Sutlej, Beas and Ravi to India and Pakistan got right to three western rivers Jhelum, Chenab and Indus River. To divert these three western rivers for irrigation purpose and to use those for electricity production Pakistan seek assistance from World Bank to design and implement Indus Basin Project. Under this project an extensive network of canals were made to join eastern rivers with western rivers and to provide water for irrigation to maximum area. This project increased the available volume of water to 133,216.04 million m^3. During flood season, River Indus and its tributaries offer approximately 181,321.83 millionm^3 water out of which 130,749.07 million m^3 is accessible for agricultural purposes. From remaining volume of water almost 39,471.41 million m^3 escapes to Arabian Sea and 10,607.94 million m^3 is lost to evaporation and seepage losses in the river system (Ahmad, 1993).

There are two large dams built on the Indus River Basin that are Tarbela and Mangla. These are multipurpose dams, which are used for irrigation as well as hydropower generation. The water from these dams is diverted toward fields through an extensive network of canals, which makes canals most important channel of irrigation water flow.There are three main types of canals in Pakistan:

1) Perennial Canals 2) Non-Perennial Canals 3) Inundation Canals

1) **Perennial canals**: These canals are filled with water year round and provide water whole year. These canals are excavated from dams or barrages and are spread to agricultural fields through network of minor canals, distributaries and water channels.

2) **Non-Perennial canals**: These canals are functional only in summer and monsoon season.

3) **Inundation canals**: These canals work only in rainy or monsoon season when water levels are high in rivers after heavy rains. The volume of water carried by these canals is not fixed. Like others, these canals are also excavated from rivers but the difference is they do not have water throughout the year rather they only have water when there is flooding in rivers.

These canals are further divided into minor canals, distributaries and water channels according to local irrigation needs (Sarwar, 2012).

2.1.2 Water distribution system of Punjab, Pakistan.

There are different criteria that are used to distribute irrigation water to its users. Some examples of water allocation criteria are ordinal setup of water rights of farmers, the urgency of water demand of crop, turn in rotation and land holding or family size (Gorantiwar and Smout, 2005). In Pakistan, the water allocation criterion is size of field or land held by the respective farmer. The water has been given to each farmer on its turn, the turns are fixed once a year and then followed whole year. Each farmer is allotted a specific day of week to get his turn of irrigation. This system is called fixed rotation system and in native language, it is famously named as "*Warabandi*" system.

The *Warabandi* system requires minimum interference by the system managers or governmental officers. This is a socio-technological system, which comprises of a physical infrastructure, informal and formal rules and laws generated through an institutional process for sharing of water (Bandaragoda, 1995).

Time allocations are done based on the size of landholdings of individual water users within the command area of a watercourse. A command area is defined as the total area that is irrigated by the specific canal or water channel. Each farmer has authority to made one opening in the boundary of farm along the water channel and let the water enter the field from the water channel. The place from where the farm boundary is cut and water is allowed to enter the farm; it is called *Nakka*. It is illegal to cut the water channel from any place other than authorized end or *Nakka* (Latif and Sarwar, 1994).

The main goal of the *Warabandi* method is to allocate the limited volume of water in an equitable way when dealing with a large operational area. The farmers in India and Pakistan before the partition have used this system in 1947 and using it until today. *Warabandi* or fixed rotation system is considered as most appropriate, suitable and successful method of irrigation water distribution below outlet to maintain equity and rightfulness among the users and make best and economical use of available water potential. The design discharge, frequency of water and duration of water allotment to each farm are fixed by the operating authority and may remain fixed for the entire season or even longer (Latif and Sarwar, 1994).

Shah et al. (2000), outlined the structure of *Warabandi* system and role of *Lambardar*. The *Warabandi* system is managed by villagers themselves but inside only their own village. From each village a committee is formed comprising 5-6 members, village head chair the committee. Village head is called *Lambardar*. A *Lambardar* is an informal connection between the farmers in his/her village and the government administration. He/she is selected by the Revenue Department (Revenue Collector), and does not have any formal position in government department. The criteria to choose a village head (also the irrigation committee head) are based on caste, good background and possession of land in the same village. According to Land Revenue Rules, the primary responsibilities of a Village Head/*Lambardar* are:

a) To collect land fee from each farmer
b) To submit the collected fees to concerned office
c) To note down the details of each payment in the record for the concerned persons e.g. for farmer, himself and government office
d) To guide and support government officials in carrying out of their responsibilities in the village
e) Assisting in functions such as crop inspections or surveys carried out in his village, and supplying the required information
f) Protecting the rights of farmers and other inhabitants of village
g) Helping the village accountant, appointed by government for a group of villages to list irrigation record.
h) Informing and assisting staff of irrigation and revenue department in enquiry of such cases as water theft and breaks and cuts in canals.

For executing these services, the *Lambardar* has been given 5.05 ha land and 5% of the calculated land fee as salary or compensation. *Lambardars* are issued a punishment if they are unable to collect the minimum amount of fee set by government. On a 5% commission, this system of payment collection is considered as one of a low-cost method for fee collection (Shah et al., 2000).

2.1.3 Current problems in irrigation system

The irrigation system of Pakistan has been weakening from the lack of repairs, dishonesty and negligence. The funds that are reserved for managing the irrigation system, most of it are spent on the large organizational make-up and only a minor proportion is spent on maintenance and repairs. Consequently, the system is not capable to embrace the current irrigation requirements for a rapidly mounting population (Latif, 2007).

The current system of water distribution lacks equity in water distribution among different farmers along the canal length i.e. head farmers are better off in terms of quality and quantity of water while farmers at tail suffer both in terms of quality and quantity of canal water. The current system caused an increase in cropping intensity in head-end farms on the expense of tail-end farmers in past. Now it is unable to support the current cropping intensity of head farmers and tail farmers are even threatened for their food security (Tariq and Kakar, 2010).

This situation raises questions on the sustainability of current *Warabandi* system, due to increased cropping intensity and decreasing canal water availability, the use of tube well water is increasing. The status of conjunctive use of ground water has been changed from being supplementary to complementary. The reliability on ground water is increasing but it is also causing problem of soil-salinity, lowering water tables and reduced yields (Murray-Rust and Velde, 1994).

Sharma and Oad (1990), projected a variable-time model for fair water distribution in conventional *Warabandi* system. The intention of these models is to provide an equivalent quantity of water per unit of land keeping in view the site of farms down a waterway unlike the allotment of the same time per unit area, which is imposed currently. This is attained by lessening the current irrigation time of the upstream land possessions and gradually rising the time per unit area in the direction of the down- stream end. In the variable time models, irrigation time for every farmer is designed by subtracting the conveyance losses.

Due to lack of extension services, fixed supply of water and fixed nature of *Warabandi* system the farmers are using conventional methods of surface irrigation, these methods are in use for more than a hundred year and these methods include flood irrigation system and furrow irrigation system. Farmers usually apply irrigation water to bordered fields that are not levelled, it results as uneven distribution of water in field and in given time less area is irrigated, some area is remained dry while the other may get over irrigated (Kahlown and Kemper, 2004). In a single irrigation for rice farmers apply around 13-18 cm deep water that is higher than recommended irrigation depth i.e. 8 cm approximately. The extra application of water causes water logging in fields and the on-farm irrigation efficiencies range between 23% and 70%. But the over irrigation is mostly done in head farms where designed discharge is less than actual water supply, in these areas the over irrigation cause deprivation of downstream farmers from water and these downstream farmers are already short of water supply (Kahlown et al.,1998).

The use of flood irrigation techniques not only cause water wastage but also decrease nitrogen efficiency in fields, the nitrogen runoff is increased causing lower yields and high water pollution. It also creates a hard crust pan in the soils that deteriorate soil properties like number of pores and it hinders root growth (Fahong et al., 2004). In Pakistan the water productivity is very low and it can only be increased by using water saving irrigation techniques like raised bed sowing, sprinkler irrigation and drip irrigation (Ahmad et al., 2004). Many efforts have been done to implement pressurized irrigation methods such as drip irrigation to grow crops in various countries. Sprinkler systems such as moveable rain-guns can be employed to supply required volume of water before sowing and in following irrigations. The use of sprinklers for irrigation has enhanced on-farm irrigation efficiencies up to 80% under the existing climatic conditions in the Indian sub-continent (Sharma, 1984). However, the potential for the adoption of sprinklers to irrigate rice and wheat has not been evaluated in the Indus Basin of Pakistan. These studies showed that current irrigation methods used in Pakistan are not sustainable as it has shortcoming related to yields, fertilizer efficiency and water conservation. But there have been many alternatives suggested by the agricultural scientists to gain higher yield with less volume of water through means of skilful irrigation techniques. These methods include pressurized irrigation systems, furrow irrigation and raised bed planting of crops.

Kahlown et al. (2007), conducted a study to assess the irrigation efficiency and economic feasibility of sprinkler irrigation system for cultivating rice and wheat and compared it with basin flooding method of irrigation. The rice produced by sprinkler irrigation used 35% less water while gave 18% higher yield than basin flood irrigation. For wheat crop, the fields irrigated with sprinkler irrigation produced 5.21 kg/m^3 of wheat while basin irrigation gave only 1.38 kg/m^3 yield per unit of water. Their benefit–cost results depicted that taking up of rain-gun sprinkler irrigation for rice and wheat is an economically feasible option for farmers. These results explained the huge possibility for getting better water use efficiency in crop production and also pointed out that in basin irrigation a hefty fraction of the water is leaching down and becomes a part of underground water bodies this can be of importance nearby large metropolitan areas which get their water from the underground water sources.

Another study done by Xiaoxia et al. (2013), found out that water-saving irrigation is economically sustainable and cost minimizing tool to deal with climate change, and it can remunerate for climate change mitigation and adaptation. Nevertheless, this irrigation technique had the extra cost for averting climate change that was estimated at 476.03 USD/t –691.64 USD/t. because it consumes more fuel to maintain the pressure of water for continuous supply of water at desired level. The increased use of fuel causes higher greenhouse gas emissions as contrast to conventional irrigation.

To overcome the above-mentioned problem of fuel use, a raised bed-planting system is recommended with a number of defined rows (usually two to four rows) and plantation is done on top of the bed. It includes the creation of troughs (furrows) between the pre-defined numbers of beds/rows in a field, these furrows are for irrigation water deliverance and the beds are used for crop sowing. This system is dissimilar from the flood irrigation system where seed is broadcast or drilled on the uneven field. In furrow irrigation system the crop is only sown in distinct strips on top of the bed. It increases the flow of irrigation water and facilitates irrigation before sowing. It makes easier to control weeds, help in improved plant growth, facilitates the movement of machinery in the furrows to control weed mechanically during early growth stage when plants are small and can easily be damaged if run over by tillage implements. Furrow irrigation method also helps farmers in reducing seed cost because when numbers of beds/rows are defined then less number of seeds are needed and the appropriate distance between beds helps in preventing plant lodging (Singh, 2002). In another study done by Fahong et al. (2004), the authors conducted field experiments and found out that raised bed planting saves up to 30% of water, increases on-farm irrigation efficiency, helps eradicate the problem of hard pan in the soil surface, enhances soil physical status, decreases crop lodging, prevents from crop diseases and increases fertilizer efficiency.

The problem related to irrigation is multi-dimensional as it not only concerned with water distribution system but also with the water management practices at farm level as farms used inefficient methods of irrigation, which cause loss of water at upstream and restrict water supply at downstream. Lack of improved irrigation methods; deprive tail farmers of yield and output. However, these problems cannot be looked alone, as there are several cultural, social and technical constraints for farmers to adopt better management techniques. For example, the fixed nature of *Warabandi* system restricts the use of irrigational methods, which need continuous or on-demand supply of water. In addition, the electricity shortage and higher fuel prices confine the use of pressurized irrigation methods.

The multi-dimensional nature of agricultural problems and the complex interconnection between different components of an agriculture system necessitates the use of a holistic approach such as the "Farming Systems Approach" to look at all opportunities, constraints and behaviour of farmers in order to solve a problem.

2.2 Farming Systems Approach

In the agricultural research, a farming system is perceived as encompassing farm choices entirely. It includes not only production but also consumption decisions taken by a farm-household. It includes choices of cropping patterns, livestock and off-farm enterprise and food consumption by the household. Nevertheless, no farm-household has the same resources or problems (Kobrich, 2003).

An agricultural system is a mean of systematizing assets based on inputs or resources like land, labour, policies, environment, information and skills of the farmers etc.; processes such as tillage processes for land preparation, sowing and harvesting; and outputs such as milk, grains, meat, eggs and hay (FAO, 1997).

Agricultural farming systems consist of "Artificial Systems" that are not entirely natural rather these are created by humans. All non-natural systems, together with agricultural systems are erected by combining either or both of social and natural rudiments and from those elements that are created or projected for explicit use by each individual system according to its needs (MacConnell and Dillon, 1997). Therefore, farming system approach takes in all the societal and natural features, their connections and organization of farm.

It entails that the farming systems can be diverse, if not exclusive, having typical decision-making problems with typical solutions. The diversity in farming decisions arise the need to categorize or group farms in some way. The farming systems are not sorted on the basis of any pre-defined nomenclature; there are different principles that help in classification of farming systems. The specific "Farming System" in a country or region is formed as a result of distinctive blend of resources and processes, these resources and processes are interlinked in nature (Kobrich, 2003).

2.3 Classification of Farming Systems

For the analysis of different elements and their inter-relationships that govern farming systems, it is necessary to have some common basis for comparison. The most commonly used basis of comparison are financial or money value. However, other criteria for systems evaluation that are also feasible and can prove to be more related in some studies. The four most important bases of classification (FAO, 1997) are as follows:

(a) Money value

The use of money value as basis of analysis is most prevalent because of its ease of calculation and conversion. All inputs can be converted into monetary cost units (e.g., seed, fertilizer, power, labour, etc.) and the outputs can be easily convert into money income, the costs and income can then be used to measure profit, profit or net returns is used widely as criteria to evaluate different options. In commercial farming, all of the inputs and outputs are measured quantitatively and are recorded in form of money. On the contrary, in subsistence/semi-subsistence farming systems, it is difficult to get prices for all inputs and outputs because mostly inputs are used from farm resources and do not have market prices, therefore, the proxy values are used. However, sometimes it is not possible to calculate imputed value of an input or output due to that the financial analysis becomes intangible and the criteria for analysis need to be changed according to requirements of analysis (Dillon and Hardaker, 1993).

(b) Family labour effort

When it comes to small farms that operate as subsistence or semi-subsistence farms, the proposed alternative of financial analysis is labour input; it is used as input and also to judge the value of outputs in terms of human productivity. This basis for analysis is popular in Asia and Africa because mostly the inputs are farm products and the outputs are not sold commercially at large scale. Therefore, the transactions are not recorded in form of money. Such farms are labour intensive i.e. most of the farm operations are done by labour not by machines and the labour comes from the farm household, therefore, these farm families have to trade-off labour content while planning different activities and the choices are made on the basis of labour demand and supply. Labour is a rather appropriate criteria for evaluating small farms, but labour is a complex entity including quantity of labour (often measure in form of labour days or hours); quality of labour in terms of skills, productivity of labour or unpleasantness associated with separate tasks. Most importantly human capital or labour is embedded in social settings and the work done by a person reflects its position in society. Thus, men, women, adult or children are valued differently as a labour due to their social position. These aspects of labour and the inferred problems of measurement often bound the utilization of this criterion as a substitute to money value (FAO, 1997).

(c) Bio-mechanical energy

One element that is present in all farming systems and their subsystems is their direct or indirect use of energy either in form of labour, draught power or fuel. Occasionally, the farming systems analysis is constructed based on different components of energy used in a farm and how the energy flow is circulated among these components (Axinn and Axinn, 1983). Deteriorating energy resources and their associated production in the world have fuelled this form of analysis. The energy production and its demand in farm-household systems can be more elaborative than financial analysis, because mostly energy flows are not represented accurately in financial analysis. This type of analysis is more relevant for macro level policy and planning rather than farm level planning.

Singh et al. (1988), delineated four kinds of farming systems depending upon use of energy, accessible irrigation methods and the extent of farm mechanisation in wheat farming system in Indian Punjab. The four systems were: (1) traditional (rain-fed); (2) improved traditional (partially irrigated); (3) semi-intensive (irrigated) and (4) intensive (irrigated using improved farm implements). The grain yield of wheat was at the lowest (612 kg/ha) for traditional farming system and was the highest (4677 kg/ha) in mechanically irrigated farming systems. The energy needs were lesser in traditional farming system and the highest in mechanised farming system. Their results implied that different farming systems with different irrigation facilities have dissimilar energy uses and it affect yields i.e. higher energy input leads to higher yields.

(d) Water consumption

Another probable starting point for analysis of farm systems is presented by water use. The water use is calculated in terms of water used by farm crops and livestock and the output produced by used volume of water. Water is considered as a critical resource in farm production i.e. a resource without which the production is zero. It shares equal importance in farming across the world and act as the only impeding factor in many countries to achieve agricultural sufficiency. Because, tropical areas of world are thought to be water sufficient and not much effort is put in studying the role of water, but the water use can exhaust the resources in these areas.

The widely affected component of farming system is cropping intensity that depends on water availability and cause differences in farming systems. Karunakaran and Palanisami (1998), explained that the cropping intensity is significantly subjective to availability of irrigation water. They found out through linear regression analysis that cropping intensity is closely related with irrigation development in a country. Their results also showed that canal water access has the highest effect followed by tubewell irrigation.

Relationship of cropping intensity with water has also been found out by looking at the differences in cropping systems in upstream and downstream areas along waterways. The farms situated at the head of a flowing water source get better quality and quantity of water and farmers' are able to grow high water demanding crops like vegetables, basmati rice that also has relatively higher market value. While the farmers that are located in tail areas they receive less volume of water as well as the quality of water is also deteriorated in these areas which push them to grow low water demanding crops (Murray-Rust and Velde 1994).

The above literature point outs that water sources, water availability and management have direct effect on farm structure specially cropping pattern and cropping intensity. This implies that water consumption can be used as a basis of evaluation of different farming systems. The other major factors that help classify the farming systems are cropping intensity, number of high water demanding crops and irrigation methods.

2.4 Summary and Conceptual Framework

The summary of above literature is represented in conceptual framework form. In farming system research all three segments of farm management i.e. inputs, processes and outputs are analysed together in order to find out problems and constraints which are rooted in any of these three parts of farm.

Input sector includes inputs that are available to farm either endogenously such as fertilizers, chemicals, water, fuel, machinery and farm size or exogenously (which farmer cannot change) such as temperature, rainfall or humidity. Beside these inputs, there are resources, which help to convert these inputs into outputs, those resources include labour, money to buy inputs, managerial skills, knowledge, machinery, government policies and socio-cultural rules and informal laws. The water is considered as a critical input in farming the availability of water is connected to the choice of high or low water demanding crops (Baland and Paltteau, 1996). Labour availability also plays a decisive role whether to use a high yielding but labour consuming crop or not. Besides that, farmer's ability to manage the resources is highly significant. The decisions to diversify the crops or to adopt new practices or not it all depend on farmers' ability to take risk and manage the resources in different ways.

These inputs and resources influence the decisions made by the farmers and farm household hence affecting the type of farming system that is pursued by the farmer. The available resources are related to farmers' decision such as cropping patterns, farm diversification, consumption and production on farm. These inputs are converted into outputs through different processes like cultivation and livestock breeding which then give output of all this farming system cycle.

The processes to combine given inputs and resources can determine the adaptability of whole farming system but if the processes are not sustainable socially and environmentally then they can cause threat not only to the farmers but also to whole society. The processes in irrigated agriculture can be analysed by calculating the productivity of resources used in these processes and the intermediate effects on resource base. If irrigation practices are not sustainable, its mean water is either over used or under used. Both of these contexts are threatening to farmers' welfare and society as well.

The outputs are in the form of yields of crops, number of crops, profit, etc. These outputs are further divided according to objective of farming. The proportion of crop produce used for household food and fuel needs, the portion of crop sold out and re-used on farm are dependent on the type of farming. In subsistence or semi-subsistence, farming major portion is used for household needs. Moreover, inputs for next crop are reserved in the form of seed or animal products as form of manure. In commercial farming, everything is sold out and profit is used to buy off-farm inputs and other household items.

If farmers are not able to change from one strategy to another, obviously they cannot cope up in long run. Due to over use of water the water productivity decreases which affect the crop yield. In subsistence farming the income is low so labour may opt out for other employment and labour for agriculture will get scarce. These complex interrelations of farming system components need to be studied jointly in order to figure out actual problem in irrigated agriculture.

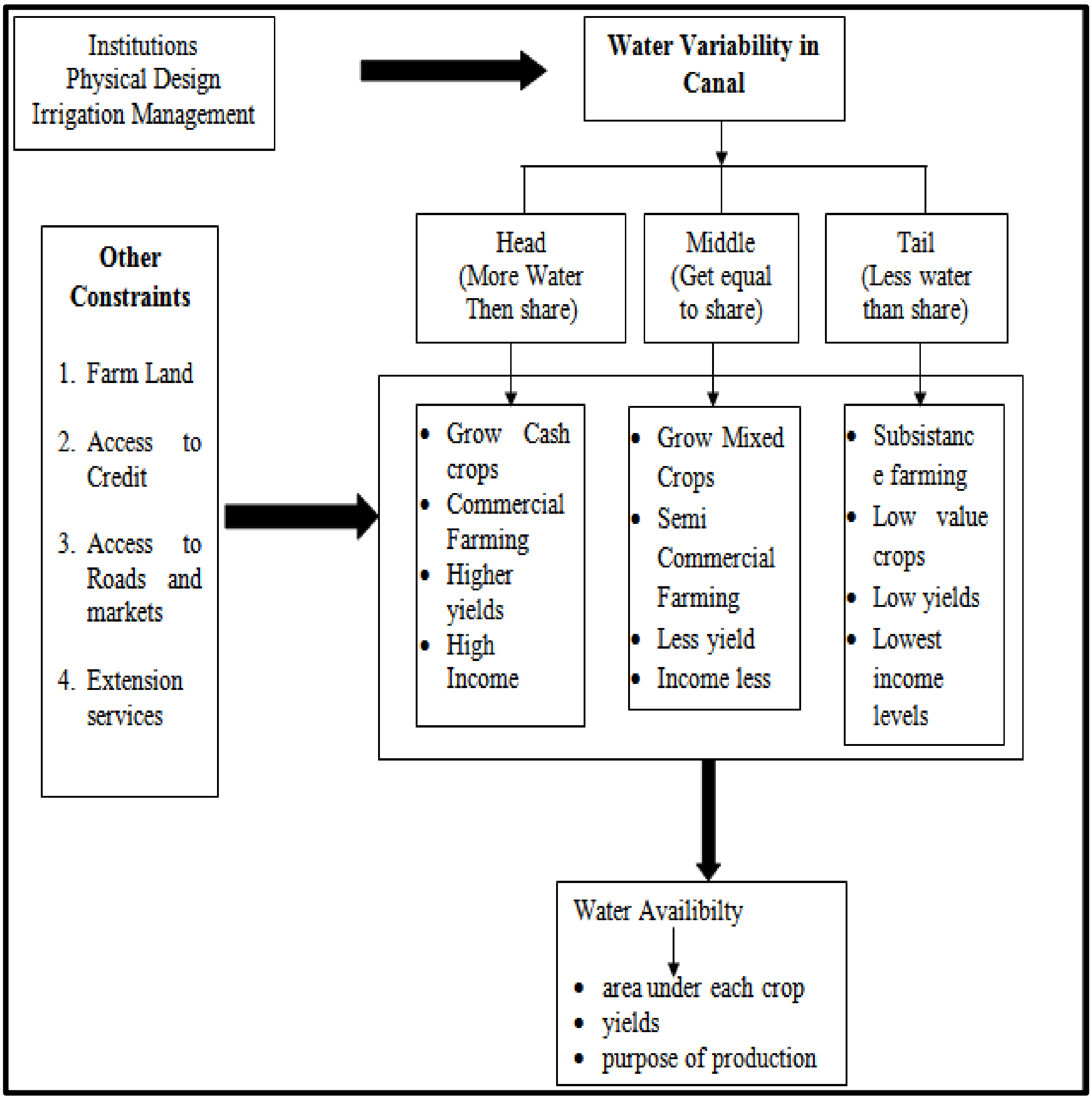

Figure 2.1: Conceptual Framework

Chapter 3

Methodology

In this chapter, the materials and methods used during the research are described. It includes sampling techniques and data collection techniques, etc.

3.1 Research Type

This research study is exploratory in nature, as it attempts to assess the variability in cropping patterns based on access to irrigation water.

On the basis of data sources it is a primary research. Quantitative data were collected from personal interviews and official website of Punjab Irrigation Department, while qualitative data were collected from focus group discussions.

3.2 Selection of Study Area

This research was carried out in Faisalabad District of Punjab, Pakistan. Faisalabad is a plain area situated in the northeast region of Punjab, Pakistan. In Faisalabad, the rainfall pattern is highly erratic, most of it pours down in months of July, August and September. The mean rainfall is recorded at 300 mm (Cheema, 2006). Due to high evapotranspiration, Faisalabad features an arid climate and irrigation is used as main source to fulfil crop water needs. It is worthwhile to study the effects of irrigation water availability on farming practices in this area.

Canal Rakh Branch is one of the main canals that irrigate the agricultural farms of Faisalabad. This canal passes from the centre of the city and its command area includes rural farms as well as farms in peri-urban areas where the farmlands are small and presence of agricultural markets favour particular farming systems.

This particular canal has been chosen due to the presence of differences in the designed discharge of water at canal head and tail. It is a branch canal of Lower Chenab Canal. Lower Chenab Canal is taken out from Chenab River from head Khanki. The designed discharge of water at head is 38340 l/s and the designed discharge at tail is 11270 l/s in Canal Rakh Branch.

Faisalabad lies in mixed cropping zone. There is no fixed pattern of cropping among farming community. More than one crop rotation is followed in different parts of Faisalabad. Due to increased industrial growth, the water supply to agricultural sector is decreasing, so farmers are using ground water and wastewater. The soil type is silt loam, whose water retention capacity is high. This kind of soil type is good for drip and sprinkler irrigation but due to small farm size and high cost of these technology farmers do not use it and the most prevalent irrigation method is flood irrigation.

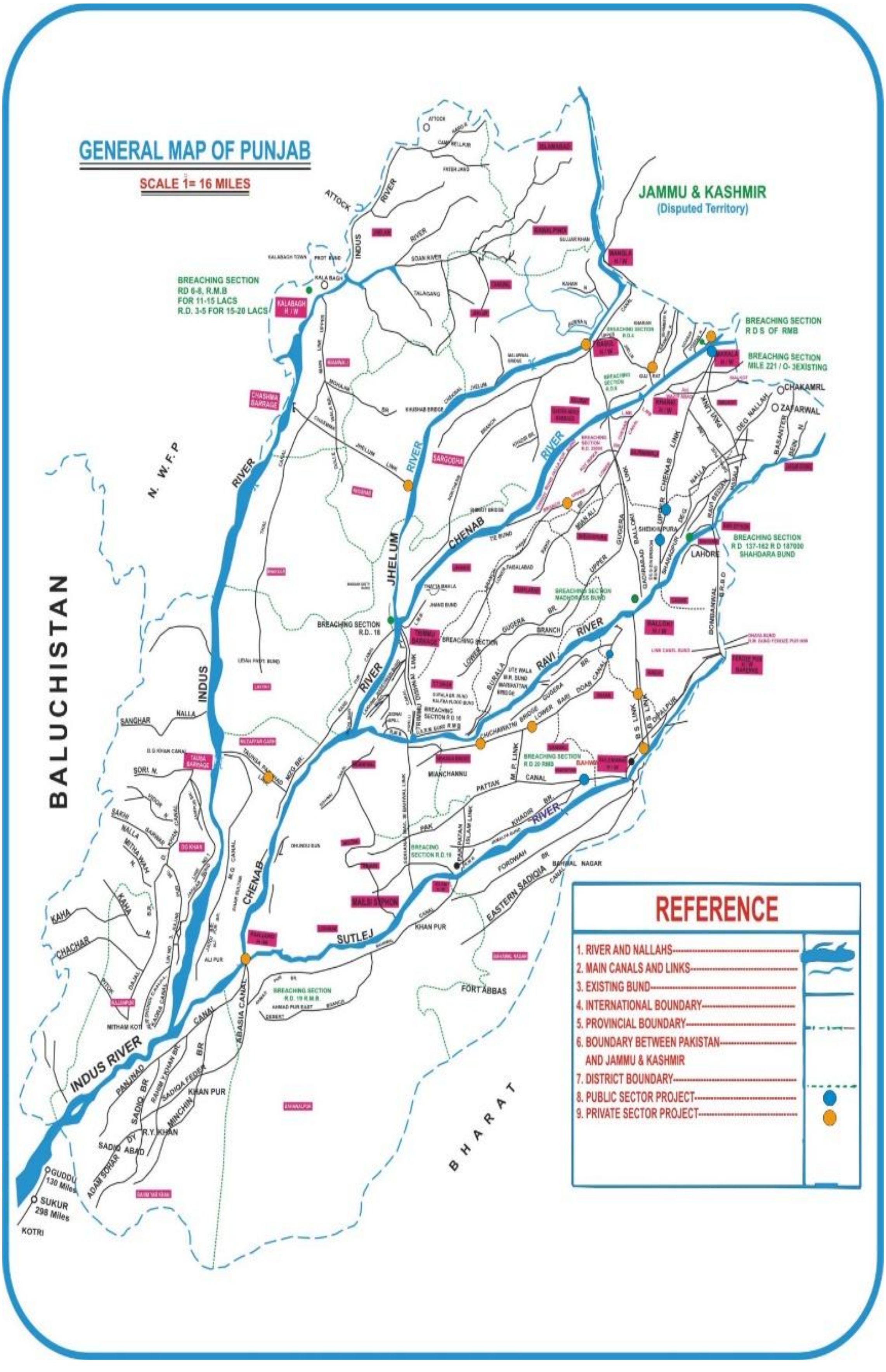

Figure 3.1: Map of Rivers and Canals in Punjab, Pakistan (*Punjab Irrigation Department, 2013)*

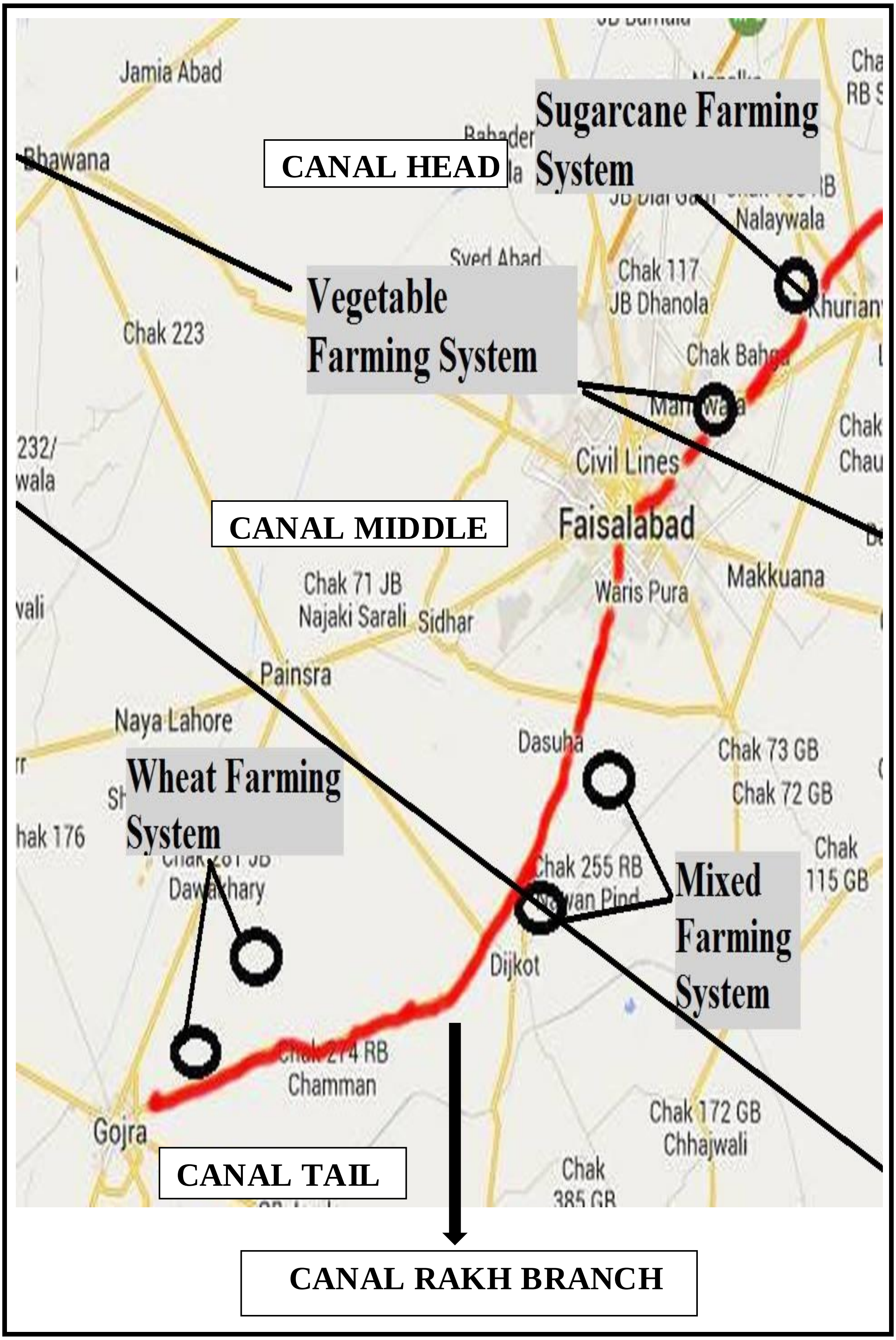

Figure 3.2: Map of Selected Villages at Canal Rakh Branch in Faisalabad

3.3 Data Collection Methods

This study is related to the assessment of heterogeneity in decisions of farmers related to water availability, so it is largely based on primary data and personal observations. The sources and methods of data collection are given below:

3.3.1 Household-survey

Primary data included information about cropping systems, personal information, farm information and input-use. A semi-structured questionnaire was used for household survey to collect all the above-mentioned data. The survey was done through face-to-face interviews.

3.3.2 Key informant interviews

The characteristics of distributaries were taken through in-depth interviews with village heads that are responsible for irrigation management system of their village. They were asked about the length of water channel, command area, number of tubewells operating in the command area and land fees. The derived information was used to compare the quantity of canal water available to each farm on each respective distributary.

3.3.2 Focus group discussions

The focus group discussions were done with the group of farmers including all those who were interviewed. The information collected through focus group discussion was pertaining to constraints and problems faced by the farmers in that particular village.

3.3.3 Secondary data

Secondary data included the information about water discharge of different distributaries of Canal Rakh Branch. The data were collected from official website of Punjab Irrigation Department and Chief Data Analyst of the department.

3.4 Sampling

The sampling criteria were the location of water distribution channel on canal, originated from Canal Rakh Branch. It was a two-step procedure. In first step one distributary was selected from head, middle and tail area of Canal Rakh Branch, it sums up to total three distributaries. In second step, two water channels were selected from each distributary that means from head, middle and tail distributaries each.

The selection of distributaries was done after consultation with an agricultural expert. Each water channel irrigates one village, so selection of water channel refers to selection of village. Keeping in view the cultural constraints for data collection, only those villages were selected which were approachable and second criterion was the knowledge of village head (*Lambardar*) about adjoining villages so that the data were not biased. From each water channel, 10 farmers were selected. The total length of water channel was divided into three equal parts and from each part, 3-4 farmers were selected. The name of villages and their respective characteristics have been given in Chapter 4. Sixty samples were collected from six different villages.

3.5 Methods and Techniques

The data analysis was performed to assess the differences in the agricultural production and the objectives of farmers in different irrigated agriculture areas. The data had been taken for cropping season of 2012-2013. The data analysis and calculation techniques had been defined below.

The data about human resources and their characteristics had been collected to look into the socio-economic context of the particular area. The human resources determine quality and quantity of labour supply in the farm and non-farm employment. Following characteristics have been assessed for human capital:

a. **Age:** Age of each respondent was noted down in the personal information. The age of all respondents was then summed up and divided by number of respondents to get mean value of age for each village separately.

b. **Experience:** The farming experience of each respondent had been calculated by counting the years when he himself started doing cultivation or started helping in farming. The farming experience was also averaged for each village.

c. **Education:** Education had been taken by asking about the grade or class until they got formal education. It did not count total number of years spend in school. The mean of education was taken to show average trend.

d. **No. of adult members:** The adult members in each household had been calculated in order to have an idea of potential labour supply. The criterion of being *Adult* was kept above 12 years of age. Normally a person is considered adult after 18 years of age. However, in farming sector informally a child is considered eligible to help in farming systems after 12-13 years of age.

e. **No. of children:** Anyone in the house who was below 12 years was considered as a child that was not considered as a potential part of labour force.

f. **No. of senior member:** Senior member are termed as those who cannot work on farm or off-farm. For classification of senior members, there was no age criterion because in villages usually there is no retiring age.

g. **Full time worker:** Full time worker on farm was classified as those who had no other occupation than farming and they spent their whole working day at field.

h. **Part-time worker:** Part time workers were those who had other occupation as well, that occupation may be off-farm employment, business or education. They could not spend whole day on farm.

i. **No. of labour:** Labour included full time paid labour that was kept on monthly or yearly wages and worked in every season. The monthly wage rate was uniform in all areas i.e. 75 USD. The seasonal workers were not included in this.

Physical resources included both natural as well manufactured resources. Some of these resources vary with respondents; some were constant for one village but vary in the villages.

a. **Length of water channel:** The length of each respective water channel was measured in kilometres. The distance was calculated from the point where the channel was diverted from the canal until the last farm served by that channel.

b. **Culturable Command Area (CCA):** The culturable command area was defined as the area that has been irrigated by a water channel. It is measured in hectares (ha).

c. **Design discharge:** It was the volume of water that is allowed to flow per second in a water canal or watercourse. It was measured in litres per second (l/s).

d. **Actual discharge:** The volume of water that actually flows in the water channel or canal. It can be higher, equal to or less than the design discharge. It was also measured in l/s.

e. **Water allowance:** It was the quantity of irrigation water allocated for one ha in a specific watercourse. It was measured in l/s/ha.

f. **Farm size:** The farm size was measured in ha.

3.6 Classification of Farming System

The farming systems had been classified according to the proportion of area under each crop i.e. which crop covered the most area and was considered as the main crop. In sugarcane and vegetable farming system, wheat occupies proportionally less area than sugarcane and vegetable, because of sufficient water supply most of the farmers focused on commercial crops and wheat was grown only for household consumption. In mixed farming system and wheat farming system, main objective of farming was household consumption because of lack of water availability they grew more wheat as it needed less water. Large land holdings in tail areas support extensive agriculture while small land holdings in head areas are suitable for intensive agriculture.

There were four major types of farming systems that had been delineated after the survey of study area. The types of farming system were named after the major crop(s) sown in the area. The farming system classification has been done from FAO basis of analysis.

The characteristics studied in each of farming system are given in Table 3.1:

Table 3.1: Classification of Farming System

Farming System	Major Crops	Source of Irrigation	Objective of Production	Livelihood Strategy
Sugarcane Farming System	Sugarcane, Wheat	Canal & tubewell	Sugarcane for sell and Wheat for consumption	Intensive
Vegetable Farming System	Vegetable, Wheat	Canal & tubewell	Vegetables for sell and Wheat for consumption	Intensive
Mixed Farming System	Wheat, Maize, Sugarcane	Canal & tubewell	Sell sugarcane, maize and wheat is sold as well as consumed at home	Semi-intensive
Wheat Farming System	Wheat, Fodder	Canal & tubewell	Only for consumption	Extensive

3.6.1 Major Crops

The proportion of farm area under each crop had determined the major crops. The crop that occupied the higher proportion of area was considered as a major crop and the farming systems were classified according to these crops. These crops not only showed the water needs of the area but also the market conditions and economic context.

3.6.2 Source of irrigation

The sources of irrigation were same in all areas. It included both canal and tubewell water. The tubewell water was becoming supplementary and its usage was increasing.

3.6.3 Objectives of production

The objectives of production were realized as commercial or subsistence agriculture but the farming systems were difficult to classify as commercial or subsistence on overall basis. Because farmers were sowing some crops for commercial purpose and some for consumption so each crop's consumption, production and selling was looked into.

3.6.4 Livelihood strategies

Livelihood strategies had been defined as the way in which the available resources were used and what outcomes were gained. The livelihood strategies included extensive or intensive agriculture it means one crop was grown on a given area or more number of crops were tried to grow on one piece of land. This aspect indicated the availability of land and water and their combination.

3.7 Qualitative Data

Beside the above-mentioned data, also qualitative data were gathered from focus group discussion about constraints, opportunities and problems faced by the respondents in each farming system. In addition, they were asked about the farming trends in past five years and state of irrigation water availability.

Chapter 4

Results

This section is divided into 4 parts that are:

i. Institutional setup and water allocation rules
ii. Inequalities in water supply
iii. Types of farming systems
iv. Constraints and problems of farming systems

It includes the results obtained from the study of irrigated farming systems served by Canal Rakh Branch in Faisalabad District.

4.1 Inequalities in Water Supply

4.1.1 Inequalities at canal level

The inequality of water supply in Canal Rakh Branch can be seen through the difference in designed discharge at head and tail. The design discharge at head was 38345.28 l/s, while the design discharge at tail was only 11271.36 l/s. The actual discharge also differed from the design discharge: the actual discharge was 32568 l/s at head and 9317.28 l/s at tail (Punjab Irrigation Department, 2013).

The authorised tail gauge is 0.69 m but the actual tail gauge was 0.31 m. The tail gauge is the minimum authorized depth of water in the canal at tail.

The irrigation water supply was designed to irrigate one third of command area, the total available water was then divided by total culturable command area and the time allocation for each farm was done on basis of area held by each farm. This was termed as protective irrigation, in which the given volume of water was tried to distribute equally among all. However, the physical design of irrigation canal system and the unscientific methods of calculating the water allowance by irrigation department created variability in water supply at head and tail of a canal. Because the irrigation department officials did not take into account the conveyance losses while calculating the water allowance for different farms along the water channel.

4.1.2 Inequalities at distributary level

The study sample covered six channels from three distributaries, namely Gutwala distributary, Butti Minor and Kalangri Distributary. Gatwala Distributary included the head reaches of Canal Rakh Branch while Butti Minor and Kalangri Minor covered the middle and tail reaches respectively.

The designed discharge in Gatwala distributary was 148.96 l/s but actual discharge was 298.46 l/s, the difference in designed and actual discharge was 50%, which implies that at head the farmers are getting double volume of water than their allocated share. The total culturable command area (CCA) of Gatwala distributary was 2178 ha and water allowance was 0.14 l/s/ha.

Designed discharge in Butti Minor was 558.56 l/s and its actual discharge was 537.89 l/s, the water supply was approximately equals to designed supply. Its culturable command area was 7464 ha and water allowance was 0.07 l/s/ha, which was less than Gatwala distributary.

The design discharge in tail distributary, Kalangri Minor, was 498.54 l/s while its culturable command area was 3738 ha. The actual discharge was less than the design discharge, the actual discharge was 120.31 l/s. the water allowance was 0.03 l/s/ha.

Table 4.1: Variation in Designed Discharge of Three Sampled Distributaries/minors

Distributary Name	Location	CCA (ha)	Design Discharge (l/s)	Actual Discharge (l/s)	Water Allowance (l/s/ha)
Gatwala Distributary	Head	2178	148.91	298.46	0.14
Butti Minor	Middle	7464	558.56	537.89	0.07
Kalangri Minor	Tail	3783	498.54	120.31	0.03

(Source: Punjab Irrigation Department, 2013. http://irrigation.punjab.gov.pk/index.aspx)

The present results comply with the studies of Bhutta and Vander, (1992) and Bandragoda, (1998) that actual discharge at head was higher than designed discharge at head of canals in Pakistan. The inequalities in distributary and main canal level are due to physical design, construction and management of irrigation system, which makes some water channel get more water per unit area than other (Bandragoda, 1998).

4.1.3 Inequalities at tertiary level

The tertiary level in irrigation system of Pakistan is water channel level. In this study, six water channels were selected. Two water channels were chosen from each selected distributary at head, middle and tail. Each selected water channel is shown by the name of village that it irrigates. The water allowances for these channels are given in Table 4.2:

Table 4.2: Location, CCA and Water Allowance in Six Sampled Watercourses

Water Channel	Location	CCA (ha)	Designed Discharge (l/s)	Water Allowance (l/s/ha)
199 R.B.	Head	101.20	14.17	0.14
192 R.B.	Head	121.44	15.79	0.13
248 R.B.	Middle	404.00	40.40	0.07
254 R.B.	Middle	172.04	12.04	0.05
277 R.B.	Tail	394.68	11.84	0.03
279 R.B.	Tail	333.96	06.68	0.03

(Source: Punjab Irrigation Department, 2013. http://irrigation.punjab.gov.pk/index.aspx)

There was a considerable difference in water allowance of three distributaries, but relatively less difference in water allowance among channels of same distributary/minor. The water allowance decreased gradually from head to middle and from middle to tail. The water allowance was compared from head to tail and the difference was almost 79%. The farmers at village number 277 R.B. mentioned that due to political influence, some villages had widened their outlets and since sometimes, villages at start of tail bath their animals in canal that blocks water supply for the following villages. One more reason was the unlined water channels due to which the conveyance losses increase and tail farmers are deprived off their fair share.

4.2 Institutional Setup and Water Allocation Rules

The institution of *Warabandi*, the rotational water management system, had been set in India by British government under the Northern Indian Canal Drainage Act in 1873, later on it was amended and new rules were added (Bandragoda and Rehman, 1995). In *Warabandi,* system water was continuously supplied to irrigators in form of a rotational cycle of one week. Each farmer got fixed share of water during one turn. The cycle operated from head toward tail of the watercourse. On each turn farmer had legal right to use or leave whole water in watercourse. The time given to each farmer was proportional to its land holding. Turns were rotated by 12 hours once in a year so that the farmers who had their turns at night now they could shift to daytime and vice versa.

The *Warabandi* system worked on watercourse level, the volume of water that had to be discharged from main canal to minor canal or distributaries and to water channels was managed by governmental irrigation agency at district level; the name of district irrigation department was Irrigation Department of Faisalabad. Above district level, Punjab Irrigation and Drainage Authority (PIDA) managed the canal systems at provincial levels.

PIDA had created Area Water Boards (AWBs) and Farmers Organizations (FOs) so that large landowners could not exploit the small farmers. The AWB received water from the PIDA and delivered it to FOs, and the FOs operated and maintained the distribution channel with the autonomy of financial self-sufficiency. A FO consisted of Water Users' Associations (WUA), where each WUA operated at watercourse (tertiary level). One FO represented one distributary, and one WUA represented the farmers below an outlet or gate, that was called *Mogha* in native language (Nakashima, 2000). But when discussed with farmers they told that FOs were not working at all, because the AWBs were made up of *Lambardars*, the elections for AWBs were politicised and powerful party came in charge. The *Lambardar* of village number 277 R.B. was the treasurer of AWB and he mentioned that he had been protesting for the insufficient water supply but PIDA did not take notice.

The method of time allocation was to record farm size of each farmer in a village and calculate the total CCA of a watercourse, total time of turn was calculated and divided on number of hectares by the officials. The time of irrigation was allotted to fill one third of CCA (Qureshi and Hussain, 1994). Each farmer can irrigate one third of his/her area at maximum. Nevertheless, due to seepage losses, even one third is not filled and there is no allowance given to tail farmers for seepage losses (Bandragoda and Rehman, 1995). The sanctioned schedule of turns and time allocated per ha was given to farmers by District Irrigation Department and farmers agreed upon the turns mutually. Once these arrangements were settled between officials and farmers, then government officers did not interfere with internal management system at tertiary level. The duty of irrigation department was to ensure uniform water supply in watercourse that was proportional to CCA of water channel. Farmers themselves did the tertiary level water management. Village Head/*Lambardar* acted as the link between farmers and officials. He collected the land fee, solved the issues related to land and water if they could be solved outside the legal system and helped the officials update data about the village.

Village heads had powers to tamper the water outlets by influencing the officials. The Canal Rakh Branch had a water discharge of 38341 l/s from head to 11270 l/s at tail (Punjab Irrigation Department, 2013). It depicted that tail had less water; moreover some *Lambardars* or village heads even blocked the canal water to tail by throwing tree logs and farmers that had less powers they cannot do anything about this.

The *Warabandi* system was developed to distribute scarce water in equitable manner. However, sometimes the influential participants could constrain others from getting their fair share. The villagers were dependent on *Lambardars* for the solution of water related issues and *Lambardars* favoured other large landholders. The power structure of *Warabandi* system had its benefits as it distributes water equally, it puts fewer burdens on officials, farmers could better communicate with village heads and everyone got fixed water time allocation. However, it also had disadvantages like exploitation of small farmers by large landowners, lack of sensitivity to growth stages or water requirements of crops.

4.3 Water Variability and Farming Systems

Due to design of Canal Rakh Branch, conveyance losses and power structure of *Warabandi* system, the water availability was not uniform along the supply line. The farmers mentioned that they have changed their livelihood strategies according to variability in water access and its availability. They adapted to water availability by changing crops, production patterns and consumption patterns, which resulted as different farming systems in the study area.

4.3.1 Sugarcane farming system

This farming system was present in village number 192 R.B that is situated at head of Canal Rakh Branch. The major crop of this farming system was sugarcane that is why it had been indicated by the name Sugarcane Farming System in this study (Table 4.3). The main features of the farming system were as follow:

Socio-economic characteristics:

Socio-economic characteristics or household characteristics influence the cropping strategies and farmers' ability to cope with water availability conditions. The household characteristics included farmers' age, education, family size, income etc., and these variables affect farmers' skills and ability to avail new opportunities and learn new techniques (Somda et al., 2002). The socio-economic characteristics of farmers in sugarcane farming system are presented in Table 4.3. It includes the household characteristics of selected farmers and their households from sugarcane farming system. The average age of farmers was 48 years and they have formal education until grade 7th (secondary school). The farming experience was 28.9 years. The farming experience was related to formal years of schooling as they started doing full time work on farm after finishing education. Mostly male family members did help their elders in agriculture from adult age i.e. 12 years in this study, so informal experience could be more than the formal experience.

Table 4.3: Household Characteristics of Respondents in Sugarcane Farming System

Average Age (Years)	48
Formal Education (Grade)	7
Average Experience (Years)	28.9
Average Members/ Household (Numbers)	8
Senior Members/Household (Numbers)	1
Average No. of Adults/ Household (Numbers)	4
Average No. of Children/ Household (Numbers)	3
Full-time Family worker on Farm (Numbers)	2
Part-time Family Worker on Farm (Numbers)	1
Family Members Employed Off-farm (Numbers)	1
Permanently Hired Labour (Numbers)	1
No. of Farms having Permanent Labour (%)	10

(Source: Own data, household survey, 2013)

Average family size was eight members per household. Family size included only the number of people who were dependent on the farm. Out of eight family members, three were below age of 12 and were not included in labour force, one person was senior member of household who did not work on farm or engaged in other income generation activities. Four members were adults who could work on farm or off-farm and were considered in labour force. Out of total labour force, 50% worked on farm for full time, as they did not have any other occupation. About 25% labour force worked part time on farm and 25% were employed off-farm. The trend to hire permanent labour was low, only 10% farms had permanent labour, remaining farms operated on family labour (Figure 4.1).

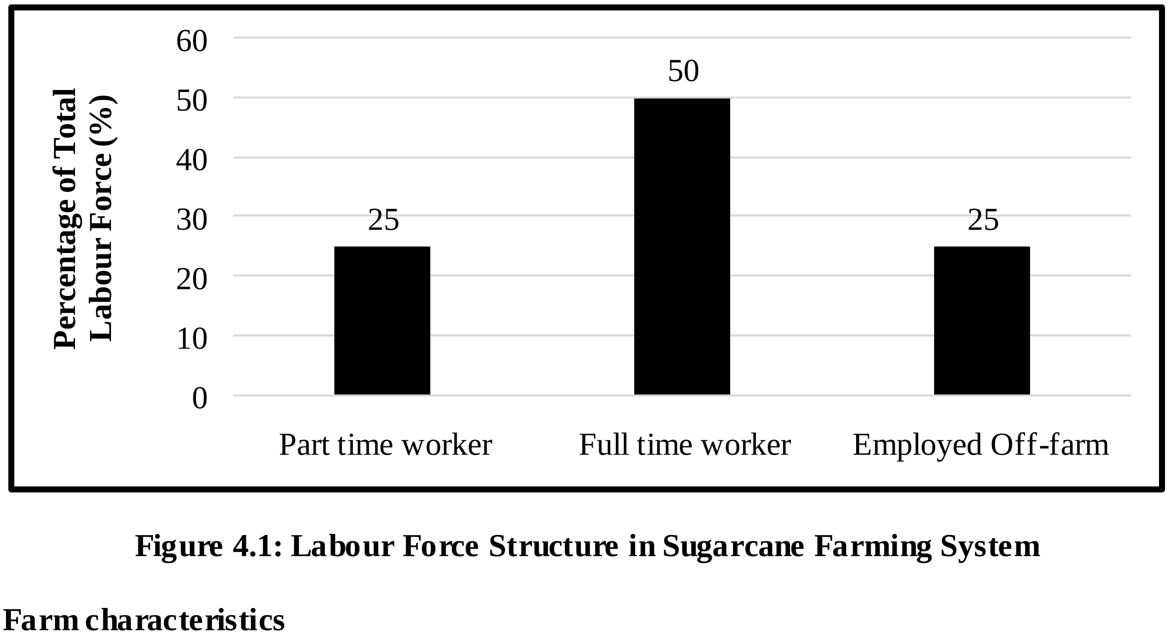

Figure 4.1: Labour Force Structure in Sugarcane Farming System

Farm characteristics

This section presents the salient features of farms in sugarcane farming system. The average farm size was 4.53 ha (Table 4.4). The farm size was actually determined by the land owned by the family and number of shareholders in it. Each son in family got 1/2 of land while a daughter gets 1/4th of land. The land holding size per household decreased gradually as the land was passed from father to children. The daughters were usually not given their share, so only shareholders were sons.

Table 4.4: Farm Characteristics in Sugarcane Farming System

Characteristic	Value	Percentage
Average Farm Size (ha)*	4.53	100
Largest Farm (ha)	11.33	--
Smallest Farm (ha)	0.60	--
Cultivated Land (ha)	4.50	99.34
Non-cultivated Land (ha)	0.03	0.66
Farms having Livestock (Numbers)	6	60
Average Herd Size (animals)	8	--
Milking Animals (Numbers)	5	62.5
Non-milking Animals (Numbers)	3	37.5

***** 1 ha=10,000 m^2* **(Source: Own data; household survey, 2013)**

The cultivated area is the area under the crops out of total farm holding size. More than 99% land was under cultivation in this area. Less than 1% land was left fallow for constructing a small building for keeping farm inputs, for animal shed and for building a place where villagers can gather and sit (Table 4.4).

In the selected farms 60% farm households had both livestock and crop farming systems. The numbers of milking animals were higher than that of non-milking animals. Milking animals included cows and buffaloes, although goats were also included in milking animals but in this area, goats were usually kept for offering sacrifice on the religious occasion of Eid. Oxen were kept as draught animals, but now they were not used for ploughing rather they were used for transporting crops, largely fodder, from farm to house (Table 4.4).

Water availability

Canal water availability, its frequency and supplementary water sources are presented in Table 4.5.

Table 4.5: Irrigation Setup in Sugarcane Farming System

Characteristic	Value
Type of Water Channel	Perennial
Frequency of Water	Once a week
CCA (ha)	121
Allocated Time (h/ha)	1.02
Water Allowance (l/s/ha)	0.14
Frequency of Repairing	Fortnightly
Persons/ farm (Numbers)	1
Tubewells in CCA (Numbers)	25
Command Area of One Tubewell (ha)	4.84

(Source: Own data, field survey, 2013)

As shown in Table 4.5, the water channel was perennial i.e. it provides water whole year. The water frequency in summer and winter season was similar, each farmer got water once a week.

The area irrigated by the selected water channel of village number 192 R.B. was 121 ha. Officials of district irrigation department did the time allocation and it was proportional to command area. The time allocated for one hectare was 1.02 hours while it was only sufficient to fill 0.47 ha instead of one hectare. The water flow was 113.26 l/s in water channel, which irrigates village number 192 R.B. The farm was irrigated up to a depth of 10 cm approximately. To fill the remaining area, farmers mixed tubewell water with canal water. There was one tubewell installed to irrigate 4.84 ha. The tubewell water was used mostly to irrigate sugarcane crop as it was an annual crop and it needed water after every two weeks (Table 4.5).

The farmers themselves maintained the water channel, as this water channel was located at head of canal so water flow was higher. The channel needed to be cleaned twice a month, otherwise it was blocked and water over flowed. From every farm, one person took part in cleaning of water channel.

Cropping system

The major crops included sugarcane and wheat. The minor crops were berseem and maize. Sugarcane was an annual crop but wheat, maize and fodder were seasonal crops i.e. they were harvested within one season. Wheat was followed by maize, the sowing and harvesting of different crops have been shown in cropping calendar (Table 4.6).

Table 4.6: Cropping Calendar of Sugarcane Farming System

	Year 1				Year 2										
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Sugarcane															
Wheat															
Maize															
Berseem															

(Source: Own data, field survey, 2012-13)

Mean area under each crop in sugarcane farming system is presented in Table 4.7. Sugarcane crop covered 53.8% of farmland. Wheat occupied 34.2 % area in a farm while berseem had 8.8% share. About 0.7% area was left for non-cultivated uses. 2.5% area out of total was under double cropping or sequential cropping i.e. after harvesting the wheat farmers grow maize on same plot or piece of land (Table 4.7).

Table 4.7: Average Area and Yield of Major Crops in Sugarcane Farming System

Crop	Area (ha)	Percentage	Yield (t/ha)
Sugarcane	2.38	53.8	104
Wheat	1.51	34.2	4
Maize	0.11*	2.5	5
Berseem	0.39	8.8	8.96**
Non-cultivated	0.03	0.7	--
Total Area	4.42	100	--

(Area under wheat previosuly) ***(Source: Own data, field survey, 2012-13)***
*****(Yield as ton/ha/cutting. Total cuttings are 4-5)***

Objectives of production

The general operating objective in this farming system was earning cash income and family sustenance, pursued first by production of wheat and fodder (berseem) for household consumption and animal feed and second by generation of cash income from the production of sugarcane and maize. The priority was given to grow the cash crop i.e. sugarcane. The income from cash crop was used to: 1) access better education and health facilities, 2) purchase of non-farm produced food, other essentials such as clothing, motorbikes, home appliances and farm inputs such as fertilizers and 3) for savings.

Sugarcane and maize was produced only for selling. Wheat was produced for household consumption but surplus wheat was also sold. Similar was the purpose of raising milk animals, they were raised for household consumption of milk but the extra milk was sold. The cash obtained primarily by sale of commodities like sugarcane was used for major expenditures and savings. The income generated from milk was used in day to day expenses or sometimes female save it separately.

Income diversity

Diversity, or the degree to which farm income is derived from a range of activities and products rather than from a single source, is called income diversity (FAO, 1997). Diversity includes the number of crop/livestock activities present and the income obtained from those activities and the number of ways in which each product can be used or disposed of.

Sugarcane farming system consisted of three crop activities and three livestock activities. The crop activities included consumption of main product, selling of main product and by products including dry fodder. The livestock activities included selling and consumption of milk, use of manure and draught power. These farms largely operated on a business-like approach to profit maximization by growing cash crops and specifying more time and effort for income generation. Table 4.8 shows that the major source of income was crops. The second major source of income was livestock, while off-farm employment was on third (Table 4.8).

Table 4.8: Annual Income per Household and its Sources in Sugarcane Farming System

Source of Income	**Annual Income/household (USD)**	**Percentage Share in Income (%)**
Crops	9366	58
Livestock	5214	33
Off-farm	1458	9
Total Income	16038	100

(Source: Own data, calculated from field data 2012-13)

Sugarcane crop had the highest share in the income (Figure 4.2). Wheat was cultivated on less area and its major purpose was household consumption, so it was sold only when it was surplus. Berseem was not giving any income to farmers, but they grew it for animal feed. The income from berseem fodder was less than the cost incurred on it. Maize provided good income as compared to fodder.

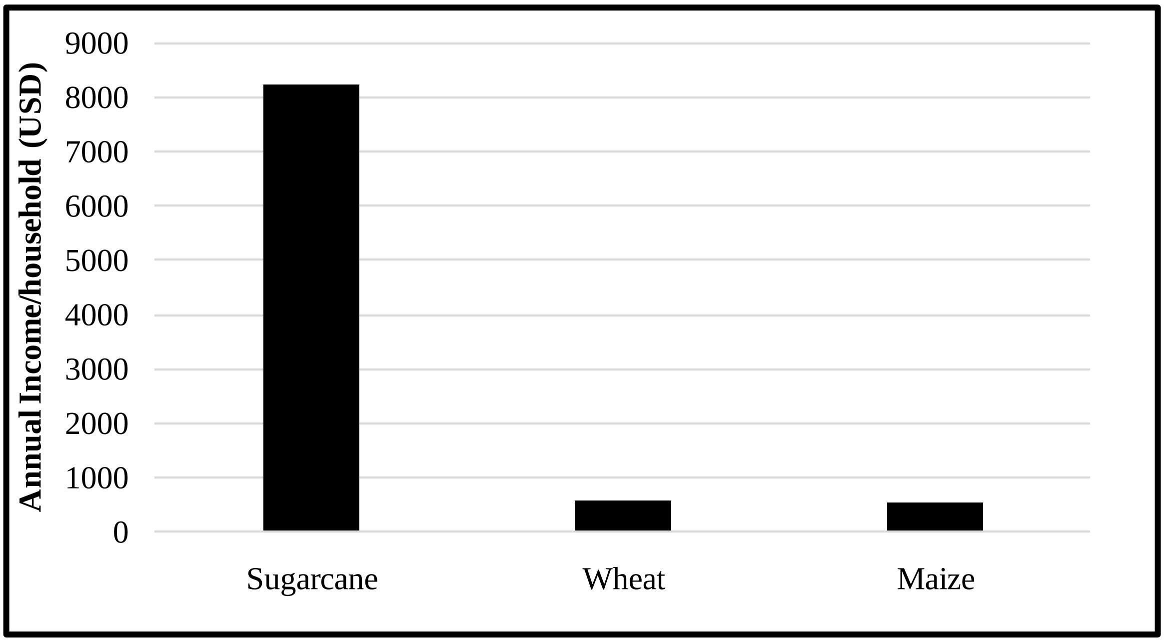

Figure 4.2: Income from Major Crops in Sugarcane Farming System

4.3.2 Vegetable farming system

Vegetable farming was practiced in upstream areas of Rakh Branch Canal. It had been given the name of vegetable farming system because major crop was vegetable. The main features of this farming system are given below.

Socio-economic characteristics

The household characteristics of respondents who were studied in vegetable farming system are presented in Table 4.9. The average age of farmers was 54 years, their formal education was grade 8th (secondary school) and farming experience was 32.2 years. The farmers were mostly aged and their formal education level was low but they had more experience. One reason of higher age was that the land size was small so younger members of families were working off-farm and mostly elders were working on farm.

Family size was seven persons per household; out of these family members, two persons were not considered in labour force as they were children, one member in each household was a senior member who was not able to help on farm or in income generation activities because of their age. Out of total labour force, 25% worked on farm for full time, as they did not have any other occupation. While 25% labour force worked part time on farm because they were student or have off-farm employment; and 25% were employed off-farm. Remaining 25% were females and those family members who study full time (Figure 4.3). There was no trend to hire permanent labour; farms operate only on family labour. The reason was smaller farm size, due to which they did not need extra labour

Table 4.9: Household Characteristics of Respondents in Vegetable Farming System

Average Age (Years)	54
Formal Education (Grade)	8
Average Experience (Years)	32.2
Average Members/ Household (Numbers)	7
Senior Members/Household (Numbers)	1
Average No. of Adults/ Household (Numbers)	4
Average No. of Children/ Household (Numbers)	2
Full-time Family Worker on Farm (Numbers)	1
Part-time Family Worker on Farm (Numbers)	1
Family Members Employed Off-farm (Numbers)	1
Permanently Hired Labour (Numbers)	0
No. of Farms having Permanent Labour (%)	0

(Source: Own data, household survey, 2013)

Figure 4.3: Labour Force Structure in Vegetable Farming System

Farm characteristics

The average farm size was 1.36 ha, the largest farm was 4.85 ha while smallest farm in village was 0.40 ha. The farm area was being completely cultivated and no land was left fallow.

Table 4.10: Farm Characteristics in Vegetable Farming System

Characteristic	Numbers	Percentage
Average Farm Size (ha)	1.36	100
Largest Farm (ha)	4.85	--
Smallest Farm (ha)	0.40	--
Cultivated Land (ha)	1.36	100
Non-cultivated Land (ha)	0	0
Farms having Livestock (Numbers)	6	60
Average Herd Size (animals)	8	--
Milking Animals (Numbers)	5	75
Non-milking Animals (Numbers)	2	25

(Source: Own data, field survey, 2013)

About 60% farm households had both livestock and crop farming systems. The number of milking animals was higher than that of non-milking animals. Milking animals included cows and buffaloes, although goats were also included in milking animals but in this area, goats were usually kept for offering sacrifice on the religious occasion of Eid. Oxen were used for transporting crops, largely fodder, from farm to house.

Water availability

Canal water availability, its frequency and supplementary water sources have been presented in Table 4.11.

Table 4.11: Irrigation Setup in Vegetable Farming System

Characteristic	Value
Type of Water Channel	Perennial
Frequency of Water	Once a week
CCA (ha)	101
Allocated Time (h/ha)	1.20
Water Allowance (l/s/ha)	0.13
Frequency of Repairing	Fortnightly
Persons/ farm (Numbers)	1
Tubewells in CCA (Numbers)	6
Command Area of One Tubewell (ha)	16.83

(Source: Own data, field survey, 2013)

The water channel was perennial water source that supplies water throughout the year. The water frequency in summer and winter season was similar, each farmer got water once a week. The quantity of water flow was higher in monsoon or rainy season as compared to winter season.

The area irrigated by the selected water channel of village number 199 R.B. was 101 ha. The time provided for one hectare in this area was 1.2 hours and farmers could irrigate 48% land in given time. The designed discharge was 103.07 l/s in the water channel of village number 199 R.B. The land was irrigated up to a depth of 10 cm approximately. Tubewell water usage was lower in vegetable farming system, because due to small land size fewer farmers could afford to install a private tubewell. There was one tubewell installed to irrigate approximately 16.83 ha. The farmers irrigated portions of land on alternative irrigation turns. One week they irrigated one-half and the other week remaining land was irrigated. The tubewell water was used only when needed highly.

The farmers themselves maintained the water channel, as this water channel was located at head of canal so water flow was higher. The channel needed to be cleaned twice a month, otherwise it was blocked and water overflowed. From every farm, one person took part in cleaning of water channel.

Cropping system

In vegetable farming system, the shortage of land pushed farmers to grow cash crops, which could give higher profit to small farmers such as vegetables. Table 4.13 presents share of crops cultivated in vegetable farming system.

Table 4.12: Cropping Calendar of Vegetable Farming System

	Year 1				**Year 2**										
	Sep	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Sugarcane															
Wheat															
Cauliflower															
Berseem															

(Source: Own data, field survey, 2012-13)

Table 4.13: Average Area and Yield of Major Crops in Vegetable Farming System

Crop	**Area (ha)**	**Percentage**	**Yield (t/ha)**
Sugarcane	0.20	14	76.8
Wheat	0.40	30	4.19
Berseem	0.19	14	9.97*
Vegetable (Cauliflower)	0.57	42	10
Non-cultivated	0	0	--
Total Area	1.36	100	--

(Yield as ton/ha/cutting. Total cuttings are 4-5) ***(Source: Own data, field survey, 2012-13)***

Vegetable (cauliflower) occupied approximately 42% area. Wheat occupies 30% area while sugarcane and berseem had 14% share each (Table 4.13). They were not practicing double cropping because no two crops can be grown in sequence on same plot.

Objectives of production

The general operating objective of this farming system was same as sugarcane farming system that was semi-commercial, wheat and fodder were cultivated for household consumption and animal feed; and vegetable was grown for cash income. Wheat was produced for household consumption and surplus wheat is sold out. The purpose of rising milk animals was selling of milk but they were also raised for household consumption. The cash obtained by sale of commodities like sugarcane and vegetables was used for major expenditures and savings.

Income diversity

Vegetable farming system consisted of three crop activities and four livestock activities. The crop activities included consumption of main product, selling of main product and use of by products including dry fodder at farm. The livestock activities included selling and consumption of milk, use of manure in fields and transportation. Diversification of these farms resulted largely from the shortage of land; access to nearby markets and better transportation. They could sell their product easily in nearby markets and get cash at the spot unlike sugarcane farming system where the crop was sold to mills and payments were delayed. People wanted to secure income by growing high income generating crops, which could earn profit so they focused more time and effort for income generation.

Table 4.14: Annual Income per Household and its Sources in Vegetable Farming System

Source of Income	Annual Income/household (USD)	Percentage Share of Each Source of income
Crops	2956	34
Livestock	3438	40
Off-farm	2242	26
Total Income	8636	100

(Source: Own data, calculated from field data, 2012-13)

The major share of income was gain from livestock (Table 4.14). Because of smaller land size, the crop income was less. The share of off-farm income was relatively higher in vegetable farming system then sugarcane farming system.

Vegetable crop has highest share in the income (Figure 4.4). Wheat was grown on less area and its major purpose was household consumption, so it was sold only when it was surplus. Berseem was not giving any income to farmers, but they grew it as fodder for animal feed. The income of berseem was less than the cost incurred on it. Although sugarcane occupied less area than wheat but its income share was higher because it had no consumptive use at home like wheat.

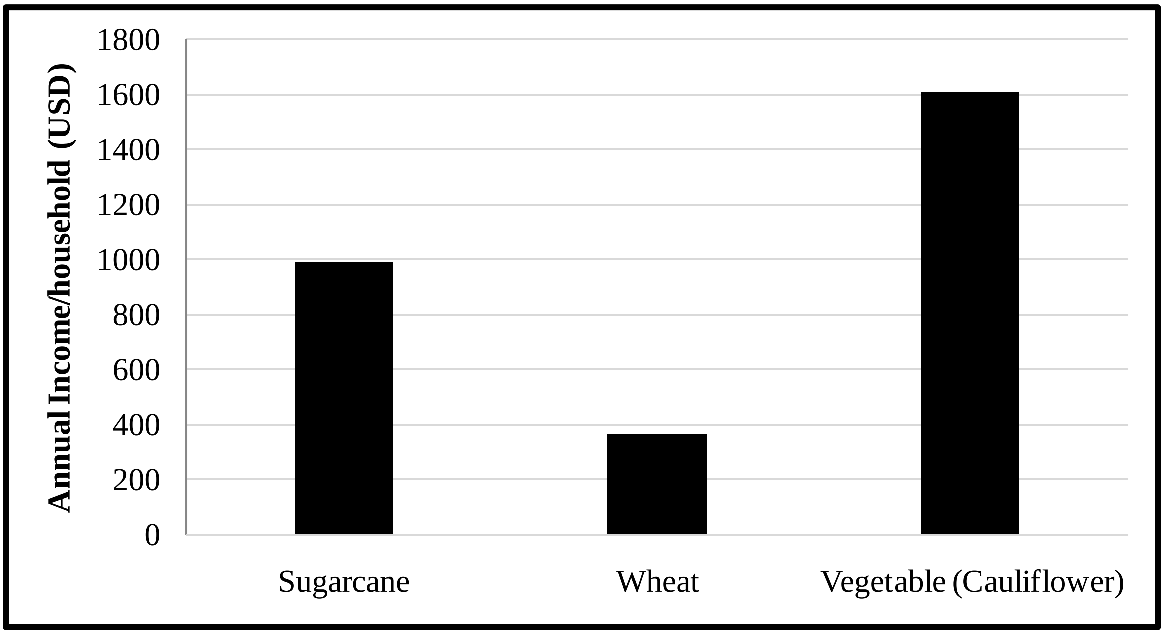

Figure 4.4: Income from Major Crops in Vegetable Farming System

4.3.3 Mixed farming system

Mixed farming system was found in the middle areas. Major crop was wheat but maize, sugarcane and fodder were all grown without any special focus on one crop. The main features of this farming system are as follow:

Socio-economic characteristics:

Table 4.15 includes the household characteristics of respondents from two villages situated at the middle of Rakh Branch Canal. The average age of farmers in village number 248 R.B. was 41.33 years and in village number 254 R.B. average age was 51.4 years. The farmers in village number 248 R.B. were young and more educated because they had a secondary school in the village so most of them had passed secondary education. The farmers in village number 254 R.B. were more aged and they were less educated but they had more experience as compared to farmers of village number 248 R.B. In village number 254 R.B., more family members were involved in farming than village number 248 R.B. because their family size was larger (Figure 4.5).

The number of households that kept livestock was also higher in village number 254 R.B. as compared to village number 248 R.B. (Table 4.15). Milking animals included cows, buffaloes and goats and non-milking animals were Oxen.

Table 4.15: Household Characteristics of Respondents in Mixed Farming System

Characteristics	Value	
	Village # 248 R.B.	Village # 254 R.B.
Average Age (Years)	41.33	51.7
Formal Education (Grade)	10	8
Average Experience (Years)	17	28
Average Members/ Household (Numbers)	7	10
Senior Members/Household (Numbers)	0	1
Average No. of Adults/ Household (Numbers)	5	6
Average No. of Children/ Household (Numbers)	2	3
Full-time Family worker on Farm (Numbers)	1	2
Part-time Family Worker on Farm (Numbers)	2	2
Family Members Employed Off-farm (Numbers)	1	1
Permanently Hired Labour (Numbers)	1	1
No. of Farms having Permanent Labour (%)	60%	90%

(Source: Own data, household survey, 2013)

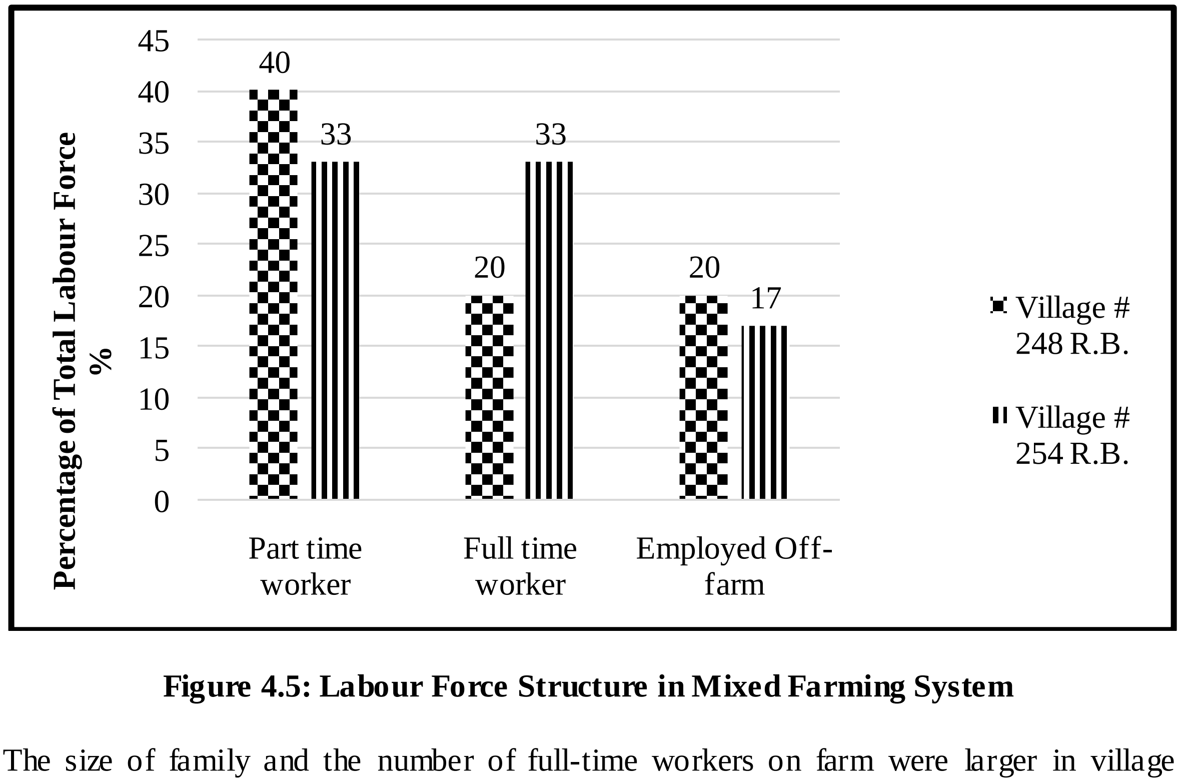

Figure 4.5: Labour Force Structure in Mixed Farming System

The size of family and the number of full-time workers on farm were larger in village number 254 R.B. On the other hand, farmers in village number 248 R.B. had small family size and less number of people to work on farm, but part-time workers were higher in village number 248 R.B. because many farmers were also doing jobs or some family members were pursuing higher degrees at city. The number of permanently hired labour was highest in village number 248 R.B. of all the sampled villages. It was due to presence of a nomadic community, who had been living nearby this village and those community members requested farmers to give them a job on farm for a minimum wage and food (Figure 4.5).

Farm characteristics

The average farm size was 4.37 ha and 2.85 ha in village number 248 R.B. and village number 254 R.B. respectively (Table 4.16). The family size was smaller in village number 248 R.B. and the land was divided into fewer share-holders that were why the land size was larger.

Table 4.16: Farm Characteristics in Mixed Farming System

Characteristic	Village # 248 R.B.		Village # 254 R.B.	
	Value	Percentage	Value	Percentage
Average Farm Size (ha)	4.37	100	2.85	100
Largest Farm (ha)	9.71	--	8.90	--
Smallest Farm (ha)	1.41	--	0.40	--
Cultivated Land (ha)	4.26	97.41	2.65	97.61
Non-cultivated Land (ha)	0.11	2.6	0.06	2.4
Farms having Livestock (Numbers)	5.55	55	7	70
Average Herd Size (Animals)	5	--	6	--
Milking Animals (Numbers)	4	80	4	66
Non-milking Animals (Numbers)	1	20	2	34

(Source: Own data, household survey, 2013)

Water availability

Table 4.17: Irrigation Setup in Mixed Farming system

Characteristic	Village # 248 R.B.	Village # 254 R.B.
Type of Water Channel	Perennial	Perennial
Frequency of Water	Once a week	Once a week
CCA (ha)	404	172
Allocated Time (h/ha)	0.57	0.95
Water Allowance (l/s/ha)	0.07	0.05
Frequency of Repairing	Once a month	Once a month
Persons/ farm (Numbers)	2	1
Tubewells in CCA (Numbers)	16	10
Command Area of One Tubewell (ha)	39	17

(Source: Own data, field survey, 2013)

The water channel was perennial and its frequency was uniform all-round the year. The area irrigated by the selected water channel of village number 248 R.B. was 623 ha and that of village number 254 R.B. was 172 ha. The time provided for one hectare in village number 248 R.B. was 0.57 hours while the farmers of village number 254 R.B. were getting 0.95 hours for one hectare. Due to larger command area, the time given to each farm was decreased in village number 248 R.B. The water discharge was 85 l/s in village number 248 R.B. and 81.55 l/s in village number 254 R.B. The farmers could fill 0.16 ha of land in village number 248 R.B. and 0.25 ha in village number 254 R.B. The average depth of irrigation was 7.5 cm in both villages. As this water channel was located at middle of canal so water flow was less than head. The channel needed to be cleaned only once a month and the cleaning took less effort than head farms so from every ten hectare one person was needed for cleaning (Table 4.17).

Cropping system

Table 4.18: Cropping Calendar of Mixed Farming System

	Year 1				Year 2										
	Sep	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Sugarcane															
Wheat															
Maize															
Berseem															

(Source: Own data, field survey, 2012-13)

Table 4.19: Average Area and Yield of Major Crops in Mixed Farming System

Crop	**Village # 248 R.B.**			**Village # 254 R.B.**		
	Area (ha)	**Percentage**	**Yield (t/ha)**	**Area (ha)**	**Percentage**	**Yield (t/ha)**
Sugarcane	0.81	18.52	79.04	0.66	24.18	49.40
Wheat	2.81	64.26	4.94	1.68	61.94	4.45
Maize	0.64*	14.63	3.5	0.26*	9.7	3
Beseem	0	0	0	0.05	1.79	8.90**
Non-cultivated	0.11	2.59	--	0.06	2.39	--
Total Area	4.37	100	--	2.71	100	--

(Area under wheat previously) ***(Source: Own data, field survey, 2012-13)***
****(Yield as ton/ha/cutting. Total cuttings are 4-5)***

Table 4.19 shows that wheat crop occupied approximately 64.24% and 61.94 % area in farm in village number 248 R.B. and village number 254 R.B. respectively followed by sugarcane. In village number 254 R.B. farmers grew more sugarcane and less maize, whereas in village number 248 R.B. farmers grow more maize.

Objectives of production

The general operating objective of this farming system was family sustenance, pursued first by production of wheat and fodder for household consumption and animal feed and second by generation of cash income from the production of sugarcane and maize. The income from cash crop was used to access better education and health facilities, purchase of non-farm produced food and other essentials such as clothing, motorbikes, home appliances and some farm inputs (such as fertilizer).

Wheat was produced for household consumption and for cash generation. Milking animals were raised for household consumption of milk and selling. The cash obtained primarily by sale of commodities like sugarcane was used for major expenditures and savings. The income generated from milk was used for daily expenses.

Income diversity

Mixed Farming system consisted of more crop activities and livestock activities than the previous two farming systems. The crop activities included consumption of wheat, selling of wheat, consumption and selling of sugarcane and maize, consumption of berseem as animal feed. They also used their by-products on farm or at house. The by-products included manure, dry fodder for animal and fuel use. The livestock activities included selling of milk and consumption of milk. Manure was used only on own farm.

Diversification of these farms results largely from a subsistence approach to farming. People preferred to secure food supply at home for whole year of wheat, milk and fodder. Moreover, due to absence of cooking gas facility, these villagers used dry leaves of sugarcane as fuel. One more activity was to make brown sugar from sugarcane and make corn bread from maize. These two activities were absent in upstream farming systems, due to more commercial approach toward sugarcane farming.

Table 4.20: Annual Income per Household and its Sources in Mixed Farming System

Source of Income	**Village # 248 R.B.**		**Village # 254 R.B.**	
	Annual Income/household(USD)	**Share in Income (%)**	**Annual Income/household(USD)**	**Share in Income (%)**
Crops	4584	40	2742	40
Livestock	3438	30	1349	20
Off-farm	3364	30	2804	40
Total Income	11386	100	6895	100

(Source: Own data, calculated from field data, 2012-13)

Table 4.20 shows that in village number 248 R.B. the crop income was higher than village number 254 R.B. The off-farm employment and sale of milk played more important role in income of farmers in village number 254 R.B., because their land holdings and livestock size was smaller.

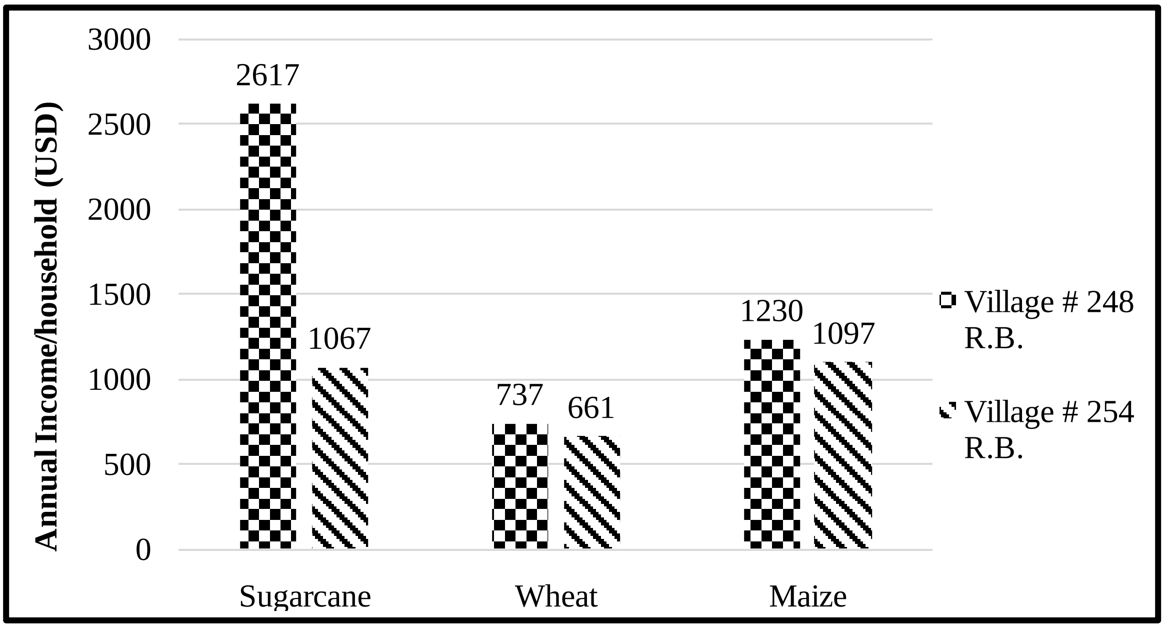

Figure 4.6: Income from Major Crops in Mixed Farming System

Sugarcane crop had highest share in the income. Wheat was main crop and its major purpose was household consumption, it was kept for consumption for whole year, paid as wages for harvesting of wheat crop and gave to landless casts in village as their fee for availing services whole year. Whatever wheat is left after storing and payments to labour that is then sold for generating cash. Maize gave good income but it was not cultivated on large area, because due to wheat harvesting maize sowing becomes late (Figure 4.6).

4.3.4 Wheat farming system

Wheat farming system was the last farming system found in tail areas of Canal Rakh Branch. It included the villages that situated at tail end. Major crop was only wheat. The main features of this farming system are as follow:

Socio-economic characteristics:

Table 4.21, includes the household characteristics of respondents from villages where wheat farming was practised. The average age of farmers in village number 277 R.B. was 50.18 years and in village number 279 R.B. average age of farmers was 51.7 Years. There were not much difference in age of farmers in both villages and their experience of farming was almost 28 years. There was also less difference in their education level and socio-economic status.

Table 4.21: Household Characteristics of Respondents in Wheat Farming System

Characteristic	Value	
	Village # 277 R.B.	Village # 279 R.B.
Average Age (Years)	50.18	51.7
Formal Education (Grade)	7	8
Average Experience (Years)	28.45	28
Average Members/ Household (Numbers)	8	9
Senior Members/Household (Numbers)	0	0
Average No. of Adults/ Household (Numbers)	6	6
Average No. of Children/ Household (Numbers)	2	3
Full-time Family worker on Farm (Numbers)	1	2
Part-time Family Worker on Farm (Numbers)	0	0
Family Members Employed Off-farm (Numbers)	1	1
Permanently Hired Labour (Numbers)	1	0
Farms having Permanent Labour (%)	60%	90%

(Source: Own data, household survey, 2013)

Family size was smaller in village number 277 R.B. so they had less members working part time on farm and had to hire labour. Farmers in village number 279 R.B. had larger family size but they also had more number of people working on farm. The number of off-farm employers was equal in both villages. Those who worked in city, they could not come back to their villages every day due to lack of access to transportation in evening and could not help in farm work as part time member. People did not hire farm labour on permanent basis in village number 279 R.B.; due to lack of water there was not much work on farm and crops were not giving higher yields so fewer people could handle the work (Figure 4.7).

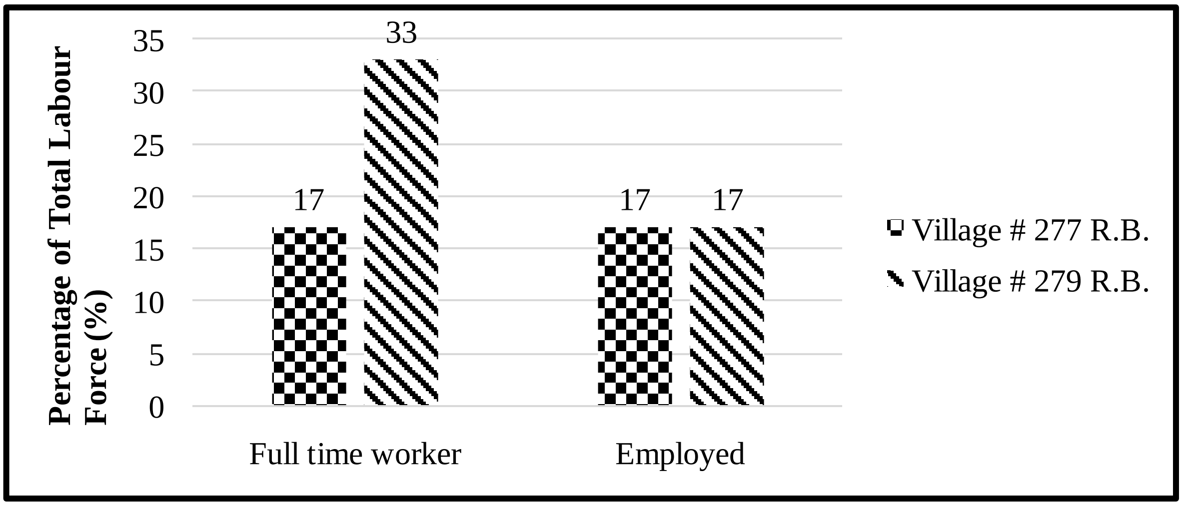

Figure 4.7: Labour Force Structure in Wheat Farming System

Farm characteristics

Table 4.22: Farm Characteristics in Wheat Farming System

Characteristic	Village # 277 R.B.		Village # 279 R.B.	
	Value	**Percentage**	**Value**	**Percentage**
Average Farm Size (ha)	6.16	100	4.54	100
Largest Farm (ha)	20.24	--	8.91	--
Smallest Farm (ha)	0.81	--	2.83	--
Cultivated Land (ha)	5.40	88	3.79	83
Non-cultivated Land (ha)	0.76	12	0.75	17
Farms having Livestock (Numbers)	9	90	7	70%
Average Herd Size (Animals)	5	--	3	--
Milking Animals (Numbers)	3	60	2	66
Non-milking Animals (Numbers)	2	40	1	34

(Source: Own data, household survey, 2013)

Table 4.22, shows that the average farm size was 6.16 ha and 4.54 ha in village number 277 R.B. and village number 279 R.B. respectively. Farmers in village number 277 R.B. had largest farm sizes of all farming systems. In tail end farms, more land was left fallow due to less availability of water. Village number 277 R.B. being located farthest at the downstream had highest percentage of fallow land that was 17 %.

Larger number of households kept livestock because of less income from crops, they could generate some income from livestock (Table 4.22). The number of households that kept livestock was highest in village number 277 R.B. as compared to all 6 villages that had been studied. Milking animals included cows and buffaloes. Oxen were kept for transporting crops (largely fodder) from field to house.

Water availability

Table 4.23: Irrigation Setup in Wheat Farming System

Characteristic	Village # 277 R.B.	Village # 279 R.B.
Type of Water Channel	Perennial	Perennial
Frequency of Water	Once a week	Once a week
CCA (ha)	394.68	333.96
Allocated Time (h/ha)	0.37	0.57
Water Allowance (l/s/ha)	0.03	0.03
Frequency of Repairing	After 2 month	After 2 months
Persons/ farm (Numbers)	1	1
Tubewells in CCA (Numbers)	35	25
Command Area of One Tubewell (ha)	11.27	13.35

(Source: Own data, 2013)

The area irrigated by the water channel of village number 277 R.B. was 394.68 ha and that of village number 279 R.B. was 333.96 ha. The time provided for one hectare in village number 277 R.B. was 0.37 hours while the farmers of village number 279 R.B. were getting 0.57 hours for one hectare. The water discharge was only 38.22 l/s in village number 277 R.B. and 22.08 l/s in village number 279 R.B (Table 4.23). Due to less water, farmers were only able to fill 0.11 ha of land in village number 277 R.B. and 0.06 ha in village number 279 R.B. Also the farmers were filling the land up to a depth of 6.25 cm that was less than recommended.

As this water channel was located at the tail of canal so water flow was lowest in this area as compared to head and middle. The channel needed to be cleaned after two month and the cleaning took less effort then head farms so from every ten hectare one person participated for cleaning.

Cropping system

Wheat was cultivated on 70% and 66% area in village number 277 R.B. and village number 279 R.B. respectively. Sugarcane was the second most grown crop, but its yield was very low (Table 4.21). These farmers also grew cotton, because it needs hot weather and less irrigation. However, the yield of each crop in tail areas was less than middle and head areas.

The farmers in tail areas grew cotton immediately after harvesting the wheat and vice versa. The area under this sequence cropping was 4% in village number 277 R.B and 5% in village number 279 R.B.

Table 4.24: Cropping Calendar of Wheat Farming System

	Year 1				**Year 2**										
	Sep	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Sugarcane															
Wheat															
Cotton															
Berseem															

(Source: Own data, field survey, 2012-13)

Table 4.25: Average Area and Yield of Major Crops in Wheat Farming System

Crop	Village # 277 R.B.			Village # 279 R.B.		
	Area (ha)	Percentage	Yield (t/ha)	Area (ha)	Percentage	Yield (t/ha)
Sugarcane	0.65	11	36.38	0.58	13	32.11
Wheat	4.11	67	3.78	2.79	61	3.55
Cotton	0.22*	4	2.69	0.22*	5	1.81
Berseem	0.40	7	6.91**	0.18	4	6.42**
Non-cultivated	0.76	12	--	0.75	17	--
Total Area	6.14	100	--	4.54	100	--

(Area under wheat previosuly) ***(Source: Own data, field survey, 2012-13)***
*****(Yield as ton/ha/cutting. Total cuttings are 4-5)***

The farmers mentioned that the yield of crops were lower in the tail end areas because they got less amount of water as compared to middle and head areas. Although they were given more time but the water allowance was low that was 0.03 l/s/ha (Table 4.2), so the longer time allowed for one hectare were not giving them much benefit in terms of yields.

Objectives of production

In wheat farming system, the general operating objective was subsistence agriculture that was pursued firstly by producing wheat and fodder for household consumption and animal feed and secondly by generation of cash income from the production of wheat and cotton.

Cotton was produced only for selling purpose. Sugarcane was produced for using it as fodder. Wheat was produced for both household consumption and selling. Selling of milk was difficult in these areas because each household had its own animals for milk.

Income diversity

Wheat farming system consisted of around nine crop activities and four livestock activities than the previous farming systems. The crop activities included consumption of wheat, selling of wheat, consumption of sugarcane for sugar making and fodder, selling of sugarcane and cotton products, use of by products as fuel and hay and consumption of fodder as animal feed. The by-products included dry fodder for animal and fuel use. The livestock activities included selling of milk, consumption of milk, use of manure in fields and draught power. Manure was used only on farm, not sold.

Table 4.26: Annual Income per Household and its Sources in Wheat Farming System

Source of Income	Village # 277 R.B.		Village # 279 R.B.	
	Annual Income/household (USD)	Share in Income (%)	Annual Income/household (USD)	Share in Income (%)
Crops	1468	45	865	32
Livestock	137	4	188	7
Off-farm	1682	51	1682	62
Total Income	3287	100	2735	100

(Source: Own data, calculated from field data, 2012-13)

Table 4.26, shows off-farm employment was the largest source of income. Due to water unavailability, the yields were low and farmers could not get as much profit as the farmers in other farming systems. Furthermore, as more number of households had livestock so price of milk was lower in this area and the income from milk was not substantial. The largest source of income was off farm employment. Nevertheless, due to lower education level the off-farm employment was also paying lower income to these villagers.

Wheat was grown on larger area but lower yields, higher cost of production and inability to sell it to market decreased income from wheat. Berseem was not giving any income to farmers, but they grew it for animal feed. The income of fodder crop was less than the cost incurred on it. Cotton gave good income but it was not sown largely, because its cost was higher and farmers had to use larger quantities of tubewell water.

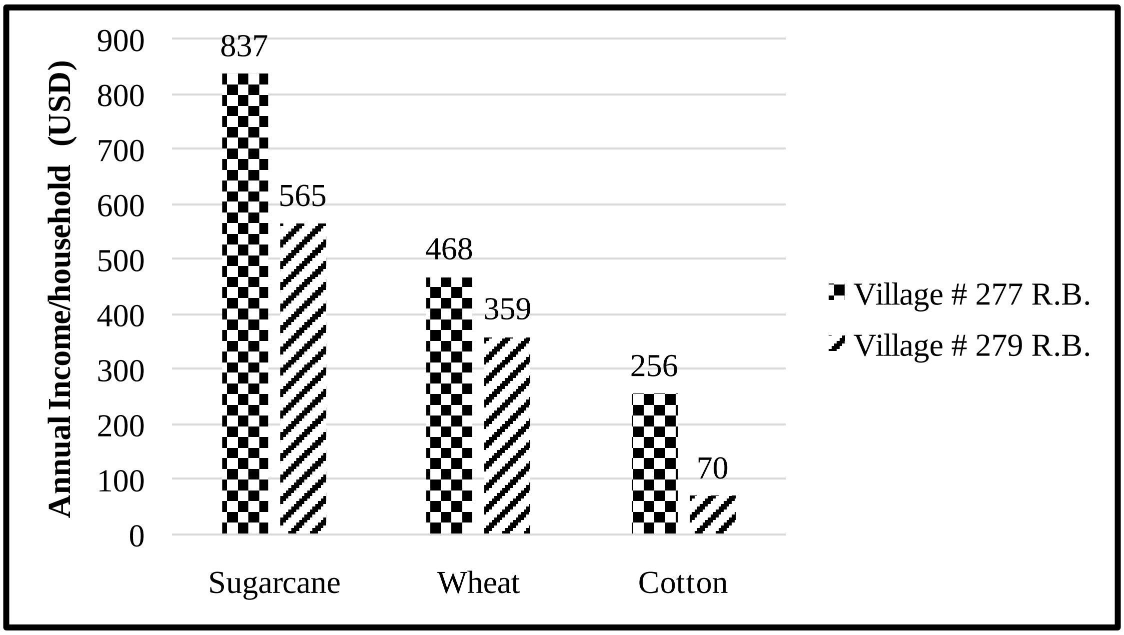

Figure 4.8: Income from Major Crops in Wheat Farming System

4.4 Constraints and Problems

Table 4.27 shows the constraints and problems perceived by farmers in different farming systems.

4.4.1 Availability of water

In vegetable farming system and sugarcane farming system, villagers did not have any issues of water shortage; the water supply was enough to irrigate half portion of farm. Due to the seepage of water from canal to the adjoining areas, the quality and quantity of underground water was also good. People had ground water pumps at their homes and they could conveniently access water. No farmer mentioned about water supply as constraining factor in upstream farming systems.

In two villages of mixed farming system, the tubewell water was of average quality and excessive use destroys the crop. Due to quality of ground water, people could not use it for domestic purpose. But they did have water supply in village which provides water from tubewell installed on canal. This water supply project had been started two years ago before that people had to bring water from wells or bores at distant places and had problems in household water access.78% farmers mentioned that they could grow more cash crops like maize and sugarcane if water allowance would be increased.

The two tail end villages had been facing the water supply shortage, since the water quality of tubewell water was also not good and with less income it was difficult for farmers to install tubewells. As a result, in every season people in these two villages suffered from water shortage problem. Due to poor quality of ground water the villagers had to travel more than 1 km to bring water for drinking and cooking. For washing the clothes the villager women carry all the clothes, went to water channel and washed them there. During the interview, 100% of respondents from wheat farming system explained that they had been facing with water shortage problem since many years. Water shortage problem had caused many inconveniences to villagers; sometimes they did not have enough water for drinking, cooking and sanitization, resulting as unhygienic food and sanitary conditions.

Table 4.27: Constraints in Different Farming System

Farming System	Sugarcane	Vegetable	Mixed		Wheat	
			Village # 248 R.B.	Village # 254 R.B.	Village # 277 R.B.	Village # 279 R.B.
Shortage of Agricultural Land	42	77	44	63	0	0
Insufficient Availability of Water	0	0	78	78	100	100
Lack of Access to Roads	0	0	66	73	100	100
Lack of Access to Credit Facilities	100	100	100	100	100	100

(Source: Own data, 2013)

4.4.2 Shortage of agricultural land

In sugarcane and vegetable farming systems, water access was easier so people preferred to buy land. The increase in demand of land caused upward surge in prices of agricultural land and the villagers sold their agricultural land to buy houses in urban areas. 42% respondents from sugarcane farming system and 77% respondents from vegetable farming system mentioned that they could grow more crops and earn more profit if they had larger land size. In vegetable farming system the land holding size was smallest of all farming systems and 100% farmers replied about land shortage as constraining factor and the reason for lower crop diversification.

In middle areas, 44% respondents of village number 248 R.B. said that land shortage had been acting as constraint for growing more number of crops like vegetables. While 63% respondents from village number 254 R.B. considered smaller land size as constraining factor. The farmers wanted to grow more sugarcane, maize and vegetables.

In the downstream areas, the only problem was lack of water and unfit quality of ground water. No respondent from both villages of tail areas consider land size as insufficient. They told that water availability was not even sufficient for the existing land size, so increasing the land size will be of no use for farmers. The land size actually acted as favouring factor for the farmers of tail areas, because they could practice extensive agricultural practices by growing those crops on larger area that need less water.

4.4.3 Lack of access to roads and markets

The upstream farmers had easy access to roads and public transport so they could bring their crops to markets easily. Moreover, they could go to the city and comeback any time, the transport was available until late night. Zero percent respondents mention about restricted access to roads and markets.

In middle stream areas, village number 248 R.B. had better access to road because they had public transport available. For transporting the crops they could easily hire the vehicles. For students and workers who travel to city every day, they had two special vans who took them to city right from the village. Remaining time in day they had transport like *Rickshaw* people went to the bus stop on *Rickshaw* and got bus. In village number 254 R.B. people had access to roads but not to the transport, being a smaller village the public transport did not stop at this village and villagers had problems to travel after evening. They first went to a nearby town and then travelled to city. For transporting the crop, they also had problem because the road was not good for heavy vehicle that was used for transporting sugarcane. For students and jobholders it was difficult to travel to city especially in morning. About 66% respondents from village number 248 R.B. and 73% village number 254 R.B. answered that lack of access to roads and markets was a problem.

In tail areas, the access to road was very limited. The villagers had only two buses in whole day from village to city and two buses from city to village. They had to make their visits to city or other towns according to this schedule. If they had to travel urgently or for some emergency, they could hire *Rickshaw* to go to a town that was 6 km and from there they could get the bus. But *Rickshaw* availability was also restricted. After 5 p.m., no transport went to these areas and it was dangerous to travel on private transport due to theft and robbery. All farmers mentioned about access to roads and transport as a major problem.

Due to lack of access to roads and transport, they could not bring their crop to market and had to rely on intermediary who came to village to buy the crop.

4.4.4 Lack of access to extension services

The extension services were poor in all four farming systems. The extension workers and officers only visit the village heads or large landowners. Remaining farmers never attended any training and they were never introduced to new techniques or methods of farming.

The only source of information for farmers was other farmers and some monthly magazines for cultivation guidelines. Due to lack of access to information and extension services, farmers were not aware of any new irrigation techniques for water efficiency. The only focus was new varieties to increase yield. All respondents point out about lack of extension services.

4.4.5 Lack of access to credit

The farmers mention that due to lengthy and complicated process of credit access, they never applied for loan or any other credit facilities. They also mentioned that if they had been provided with the easy ways of credit access they could use it for purchasing costly inputs like fertilizer on time and could buy machinery to increase their production.

Chapter 5

Discussion and Conclusion

This study was done to assess the differences in volume of water available to head, middle and tail areas of Canal Rakh Branch in Faisalabad, Pakistan. The study found out not only the differences in water supply but also the role of given water supply on cropping patterns of farmers.

5.1 Reasons of Water Inequalities

The findings showed that water supply was not equal in the areas, which were irrigated by same source of water i.e. the Canal Rakh Branch. The differences were of two types; 1) the difference in design discharge (the volume of water that is officially allowed to flow in a water source) and 2) the difference in the actual water discharge and design discharge.

The reasons behind the differences of design discharge among different water channels, originated from same canal, were largely related to physical design and management of irrigation system. At start of canal larger volume of water had to be passed so the width of canal was kept larger but as the canal length increased the pressure and volume of water decreased due to extraction of water, conveyance losses and presence of other particles like sand and silt. Therefore, the width of canal was gradually decreased to handle smaller quantity of water to tails. Secondly, design discharge was calculated by the irrigation department after considering the available volume of water, the capacity of infrastructure (canal, water channel), the area that had to be irrigated and the cropping patterns. But it was difficult to upgrade the system according to the needs which cause disparity in water supply. The system was made for 75% cropping intensity while the intensity of cropping had been increased from 125% to 200% in some areas making it difficult to fulfil the water demand of current cropping pattern (Nakashima, 2000).

The difference in designed and actual discharge supported the results of (Nakashima, 2000) that there were three types of farmers 1) those who got more than their designed discharge 2) those who got equal to their designed discharge and 3) those who got less than their fair share. The cause of difference in actual and design discharge was the inefficient management of canal system by the officials. At the main canal level, head distributaries got more water than designed discharge because there was no mechanism to control the water supply according to design discharge. The tail distributaries got less water than their designed discharge because when designing the water flow, the conveyance losses were not considered. So the volume of water that was lost during conveyance it was deducted from the share of tail distributaries.

At watercourse level more actors were involved in water management that were farmers, village heads and irrigation staff. At this level, political and social power could work in favour or against one party or other. The powerful farmers could tamper the outlet because these outlets were not gated, those who had their influence could alter the water supply that affected adversely to the other water users. But when an outlet was tampered it actually benefited all water users on that water course not only the one who modified it. My results contradicted with the results of (Bandragoda and Rehman 1994; Bandragoda, 1998; Shah et al., 2000) that the farmers could individually affect the water availability of other farmers in the water channel. According to my interaction with farmers, when one powerful farmer modify the outlet the whole village got benefit from it and the other whole village(s) got affected by reduced water supply.

While fixing the water turns and water allowance the officials did not take into account the conveyance losses and each farmer was given time proportional to his land, there was no compensation added for the water that was lost in seepage or infiltration because of unlined water courses. Each farmer was assigned fixed day of week, if on that day the water was blocked by some reason there was no compensation for that also. The reasons of water inequality could be summed up as institutional related to *Warabandi*, structural related to design and managerial related to old infrastructure and system.

5.2 Farmers Adaptability to Water Supply

The volume of water that reached to the farmers at their farm gate, it was decided by the irrigation department and was largely affected by the spatial positioning of farm along the water source. But the demand of water depended on the irrigation needs of crops, as the farmers could not change the irrigation water volume provided to them so the gap between water demand and water supply was tried to minimize by selecting cropping patterns which could be pursued in given water supply.

The farmers had adapted to given water supply by deciding type of crops, area under each crop and the production purpose of each crop accordingly. However, water availability had not found affecting the number of crops grown in one year, as it is clear from the results that numbers of crops were same in all areas. In all areas farmers grew four crops in a year, out of these four crops three were same in head, middle and tail i.e. sugarcane, wheat and berseem. Only one crop differs in head, middle and tail.

My study supported the results of (Murray-Rust and Velde, 1994) that farmers at tail rely on low valued crops like wheat and fodder. The tail farmers were also growing cotton and sugarcane but due to lack of water the crops were unable to provide same value as it provided to head farmers in terms of profit per hectare.

The farmers decided area under each crop by looking at the water demand of the crop. The farmers at head grew sugarcane on larger area because they could fulfil its water needs and it gave them highest profit. In village number 277 R.B. farmers grew vegetables on larger area because they had large family size but small farm size and they wanted to grow most out of it to generate sufficient income for family. In the middle farms farmers grew wheat on more area because they had enough water to grow wheat but not sugarcane, if they grew sugarcane on more area they could not provide enough water. The tail farmers also grew wheat on larger area because they could grow more wheat in given volume of water but less sugarcane and sugarcane is unable to provide them as much income as they spend on its cost.

The farmers in middle areas was able to plant supporting crops like maize to earn some extra money and similarly head farmers planted wheat for supporting home consumption, but still they were always left with some surplus to sell. However, tail farmers did not have a supporting crop they grew wheat for consumption and for selling, the other crops did not help to increase income because they were all used as farm inputs or for household consumption. The sugarcane could only be used as fodder, cotton only for household fuel and cotton consumption. The tail farmers have more diversity in terms of crop activities but less diverse source of income.

Not only engineering faults and infrastructural inadequacies of irrigation system but also social and economic context played equally significant role in determining the soundness or deterioration of agricultural production. The areas, which were rich in irrigation water access they happened to be close to city centres, more educated and equipped with greater facilities, making it more convenient for farmers to diversify their livelihoods. This was because water availability tended to put these areas in stronger geographical and economical position and often markets were established around these agricultural hubs. While on the other hand, the downstream areas who suffered from lack of water were also ignored in terms of governmental welfare works. More emphasize was put on development of those areas which were rich in natural resources to get more out of these resources. Those areas were neglected significantly, which could not offer higher benefits in terms of natural resources.

5.3 Questions for Further Research

- Why the "Warabandi" system is not flexible enough to satisfy the increasing water demands? How it can be modified to incorporate the water demands of crops?

- How is the water allowance been calculated? What rules and scientific approaches are used? Can water allocation improved by adopting different criteria of water allocation?

- What is the role of extension services and information possessed by farmers? What are the important factors affecting information access and processing in farming community? How the information gap can be filled and in what ways it can help in efficient water management?

- Is the development of the area influences by agricultural production and irrigation water supply? What is the relationship between development of an area, irrigation water supply and agricultural production? What is the relationship between irrigation water supply and industrial sprawl?

- How the access to roads and transportation can improve the off-farm employment opportunities in low yielding areas? Can it improve the market conditions for tail and middle areas? What is the relationship between development of irrigation structure and markets?

5.4 Conclusion

The irrigation system of Pakistan was designed to provide supply of scarce water to all farmers. Nevertheless, the results showed that the system was unable to allocate equal volume of water to all water users. The water inequality was present both at canal as well as water course level, the inequality was of three types; 1) the inequality generated due to physical design, 2) inequality due to management of system and 3) inequality due to weak institutions. The inequalities arisen by the physical design were the most prominent one and they lead to the exploitation of institutions at formal and informal level by those who had power to do so.

The water availability was considered fix to farmers, they adjusted their demand according to supply. The water demand was embedded in crop water requirements so farmers grew those crops for which they could have enough water, those crops which could give higher yield in given water are grown on larger area, while the other crops are grown on less area. The farmers tried to adopt crop diversity as much as possible by growing all crops but changing their purpose of production.

Although water availably was a major factor in determining the cropping pattern. But there were many non-irrigation related factors as well which determine the outcomes of a cropping pattern. Those were extension services, use of farm and non-farm inputs and access to markets and roads.

Given that it was difficult to update or modify the physical design of irrigation system, the focus should be given on management of system and the technical education of farmers to use irrigation water more efficiently.

The water supply should be monitored more cautiously to avoid excessive supply at head hence maintain at least designed supply at tails. The *Warabandi* system should be made flexible by allowing the exchange of turns among farmers when needed. The government should monitor the irrigation staffs to control corruption and bribery that helps the influential people to use government officers for their own interest.

There should be more participatory research in the study area to know the results of more flexible and scientifically calculated water allowances according to crop needs.

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Appendix I: Questionnaire

Length of watercourse (km) ________________Command area (ha) _____________ No. of farms______________ Village name: ___________Rotational Length__________ fixed/flexible rotation__________ pricing structure_________

Farmers Head of Household Particulars

Name	Age (years)	Education	Experience(years)

Household members & Labour supply

	Total	Male	Female
Family Members (Dependent on that farm)			
Adult members			
Children below 10 years			
Senior members (who cannot work)			
Labour Supply	**Total**	**Part time**	**Full time**
No. of family members working on farm			
No. Of members employed			
No. of labours			
Wage rate (yearly/per activity)			

Farm Specifications

Characteristics	Value
Size of farm (ha)	
distance from head(km)	
ownership status	
Source of water (Surface/ground/both)	

Irrigation Source:

Characteristics	Canal	Tubewell
Water frequency		
Distance from the head of source		
Time taken to fill one acre		
Fuel used/hour of irrigation		
price of water / (season or hour)		

Irrigation System:

Characteristics	Canal	Tubewell
Management of system		
Pricing structure		
Turn in rotation		
Frequency of Repairing		
Repair work done by		
Cost/repair		
Who collect payments		
Who resolve issues		

Cropping production system

Name of Crop					
Area sown					
No. of ploughings					
No. of planking					
FYM /Acre					
Price/trolley					
Seed rate					
Seed price					
Seed bought or used previous					
Sowing methods					
Sowing cost					
Labour required for sowing					
No. of canal irrigation					
No. of tubewell irrigations					
No. & rate of DAP bag					
No. & rate of Urea bag					
Weeding cost/acre					
Hoeing cost/acre					
Harvesting cots					
Yield/acre					
Maximum yield in village					
Price/unit					

Animal Production system

Animal	Cow	Goat	Buffalo	Bullocks
No. of animal				
Quantity of hay/animal				
Price of hay/mound				
Quantity of green fodder				
Price of fodder				
Quantity of milk				

Price of milk/kg				
Quantity of meat				
Price of meat/kg				
Amount of manure				
Price of manure/trolley				

Product Balance

Item	**Average production**	**Quantity sold per year**	**Quantity consumed per year**
Hay			
Dry sticks for fuel			
Milk			
Meat			
Manure			

Farmers' Perceptions:

1. Do you think farming is good business nowadays? Why yes or not?

2. What would you do if you had more land to grow crops?

3. What would you do if you had access to more water each time it is served?

4. What would you do if you had water served more often or differently?

5. What would you do if you had the possibility of contracting more credits?

6. What would you do if you had more persons from the family working the land?

7. Do you think your farm is at a good location to get enough water and access in terms of transportation?

8. Do farms at the head get more water then you?

9. When do you need the water most can you get it then? Are you satisfied with current rotational schedule?

10. Do you know you can get more yield with the same water with other irrigation techniques?

11. How many times extension workers visit you? How do you come to know about new technologies? Do you adopt them without consulting with other farmers and family?

12. Did you see any change in the water served to you in the recent years (last 5 years)?

13. Did you see any change in the labor available from the market in the recent years (last 5 years)?

14. Did you see any change in the recent years (last 5 years) in terms of your farm access to markets:

    (a) Better roads?

    (b) Increase of the markets for current crops?

(c) Increase markets for new crops

15. Are you satisfied with the current organization of the irrigation system (I suppose surface irrigation)

16. If no, what are the things that would need to be changed to fit your needs?

Change proposed	**What would be the advantages/ benefits for you?**	**Why is it not done yet?**	**Who else would gain from that change**	**Who else would lose from that change**
1.				
2.				
3.				