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PART OF WAGENINGEN UR

IMPROVEMENT OF WATER MANAGEMENT PRACTICES IN BALKH CANAL SERVICE AREA

BALKH DISTRICT, BALKH PROVINCE, AFGHANISTAN

Hameedullah Ahmadzai

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Wageningen
The Netherlands

PERMISSION TO USE

Director of Research
Larenstein University of Applied sciences
Part of Wageningen UR
Forum-Gebouw 102
Droevendaalsesteeg 2
6708 PB, Wageningen
Post box 411
Tel: +31 31 7486230
Fax: +31 31 7484884

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DEDICATION

This thesis is dedicated to my dear father, Sher Mohammad who has been always inspired and supported me in getting knowledge. This is also dedicated to my beloved mother who has given me real love and never forgotten from her pray. I wish to dedicate this thesis to millions of innocent Afghans martyred and their Widows and Orphans during the war in Afghanistan.

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ABREVIATIONS

RBC	Right Balkh Canal
Mirab	Water Master responsible for Canal overall management
Ha	Hectare
NAIS	National Agricultural Information System
ADB	Asian Development Bank
MAIL	Ministry of Agriculture, Irrigation and Livestock
MEW	Ministry of Energy and Water
MRRD	Ministry of Rural Rehabilitation and Development
ASAP	Accelerating Sustainable Agriculture Program
DAI	Development Alternative Incorporation
FAO	Food and Agriculture Organization
ICARDA	International Centre for Agricultural Research in the Dry Areas
USAID	United State Aid for International Development
ICID	International Commission on Irrigation and Drainage
NGO	Non-Governmental Organization
UNDP	United Nations Development program
CHDP	Center for Policy and Human Development
AWAT	Afghanistan Water, Agriculture and Technology Transfer Program Team

GLOSSARY AND TECHINCAL TERMS

Jerib	Unit of land measurement (1 Jerib = 0.5 hectares)
Paikal	Unite of water allocation in the Balkh Province which is for 72 hectare land and it is equal to 0.013m^3 sec^{-1} discharge of water.
Mirab	Water master
Chakbashi	community level water bailiff for each secondary and territory level of each village and assist the mirab
Intake	in this case study, an intake is a structure designed to acquire water from river to main canal.
Off take	an in-canal structure designed to acquire water from a first level canal to a secondary level canal (i.e. from a main canal to a sub canal)
Tail reaches	the area which is at end or far from the main canal
Middle reaches	the area which is at middle along the canal level
Head reaches	the area which is located in the up of main canal
GPS	Global Positioning System
GIS	Geographical Information System
Ha^{-1}	Per hectare

ABSTRACT

The field study was conducted at Balkh District of Balkh Province, Afghanistan to find factors that influence irrigation water productivity in the Right Balkh Canal service area. Key stakeholders, water right and its practices, allocation and distribution, irrigation management system as well as equity, adequacy, flexibility and reliability were evaluated through interviewing of farmers at the head, middle and tail reaches during the study period.

Water stakeholders in the scheme are; Directorate of River Basin which is responsible to control and allocate water for canal and Off-takes based on water availability. Irrigation Department is directly involved in the irrigation system and contact with local water masters. Mirab is in charge of overall management (operation, maintenance, water distribution and solving conflicts related to water) of the canal. While Chakbashi is water master for specific village that supervises daily operation and manage his village farmers during general maintenance and cleaning period. Nonetheless, these local masters are elected and paid by farmers. Furthermore, farmers are also involved in the system such as participation in the cleaning and maintenance of the canal.

Water use right is clearly defined that water use for irrigation is free but water delivery cost has to be paid. Land and water owners are the farmers, and have the right to sell the land or water temporary and permanently. Water use right says that every water user should be fed equally by irrigation water within the same scheme.

Water allocation were proportionally done in main intake from river, separation Off-take of Right and Left Balkh Canal as well as in every Off-take along the canal was based on landholding through traditional Paikal system.

Water distribution was based on centuries old system among the farmers that each farmer had five minutes water per Jerib (0.5 ha) and distribution system was based on turn. For instance, every water user was getting water interval (turn) of water in the secondary or tertiary canal after exact 10 days in the tail reach while in the head and middle it was after each 7 days.

Generally, water use right is really not implemented that is why water distribution along the canal were not equitable due to lack of flow control and distribution structure, improper water management of water users and low capacity of governmental officials. In the canal system, the management skills of concerned stakeholders should be enhanced for better water productivity in the area.

Although Mirab and Chakbashies' management had some limitation and they were not so effective but they are experienced water administrators in this traditional system and accepted representatives in the community therefore, it is proposed to be supported by government and water users in the existent situation to have enforcement and strong management as well as to have budget for maintenance of the canal.

CHAPTER 1 INTRODUCTION

This chapter covers the background of the study and describes the problem statement. It further includes the formulated research questions that guide the study as well as describe the limitations and general thoughts of the research conducted in the area.

1.1 Background information

Agriculture production without irrigation is impossible under the arid to sub-humid climatic and an erratic rainfall conditions. Climate is not favorable for rain fed agriculture during winter, as the temperature is low and precipitation occurs in form of snow, where as in summer, temperature is high and virtually no rainfall. Snow stored in the Hidu Kush during winter which is melting from spring and provides irrigation water in early summer. Therefore, Irrigation plays a vital role in crop production and in rural livelihoods; it is used to grow 85 of the households engaged in agriculture, 79 percent of Afghanistan's economy rely on irrigated land.

Providing reliable irrigation water to Afghans will result in multiple socio-economic benefits because it represents one of the most important interventions to reduce poverty in a country heavily dependent on agriculture. At 37 percent of gross national income, agriculture is a key component of Afghan livelihoods and economic growth. Agriculture also consumes more than 95 percent of the water used in the country. If properly managed, irrigation systems can support a wide variety of agricultural production for country. Unfortunately, irrigation is currently performing appreciably below potential. Afghanistan has the capacity to cultivate more than 7.5 million hectares of cultivated land, of which 60 percent would be irrigated. In the mid-1970s, over 3.0 million hectares of cropland were sustained by some form of irrigation. Although, population growth has been rising intensively but today, only an estimated 1.8 million hectares are being irrigated. This means that the country is currently missing out huge amount of agricultural production and income.

Afghanistan has five major river basins such as Amu Darya, Helmand, Hari-rod, Murghab, Kabul and Northern river basin (Map 1) that Helmand basin supports the largest irrigated area (44 percent) in the country (Rout, 2008).The total land of Afghanistan is 64 million hectare, out of which approximately 5% irrigated, 7.5% is rain fed, 3% covered by forest and rangeland and other consist of 84.5%. Only 30% of the irrigated area of Afghanistan is managed satisfactory; 20% has poor on farm water management practices, 10% has become waste land due to war and 40% is damaged due to the lack of maintenance (Walter, 1997).

The irrigation system of Afghanistan can be divided into two main categories: Traditional and modern systems. Modern irrigation system is sub-divided into three sub-categories which are; Formal surface irrigation systems without storage, Formal surface water systems with storage and Formal ground water systems. Traditional system is sub-divided into five sub-categories that are (i) Small-scale informal (ii) Medium scale informal (iii) Large-scale informal surface water systems (iv)arhad and (v) Karez (qanat) systems. Throughout the country these systems are irrigating an area of approximately 3.29 million hectare (Rout, 2008).

The allocation of water and land in these systems is closely related to customs and traditions of the sedentary population, and maintenance works of irrigation systems have always been a well-defined activity in the farmer's seasonal calendar (Walter, 1997) As it has been throughout Afghanistan, these systems could also have received the impact of war both in Physical (irrigation systems infrastructures) and social (mismanagement, lack of maintenance, etc) terms, resulting in deterioration of the performance of these systems such as yield reduction per unit area of main crops, inequitable water, high water losses at both main and tertiary levels.

The general conclusion among researchers are that the greatest weakness in the Afghan agricultural production system, and the cause for the decline in agricultural production during the drought years, are lack of water during the crop cycle and a general poor water management [FAO, 2002; ICARDA, 2002; Azizi, 2002; Bhattacharyya, et al., 2004; Roe, 2009; Savage et al., 2009].

Agriculture is main economic source of inhabitants which 1, 14,900 people of Balkh Province are employed in agriculture and livestock (Klemm and Shobair, 1996)**.**Main Agricultural crops of the province are; Grains (wheat, barley, maize and rice), Fruits (graphs, pomegranates, melon, water melon and almond), Vegetables (onion and tomato), Fodders and Industrial crops (cotton and alfalfa).

The province has 2, 24,500 hectare irrigated area, which is mostly irrigated by Balkh River.

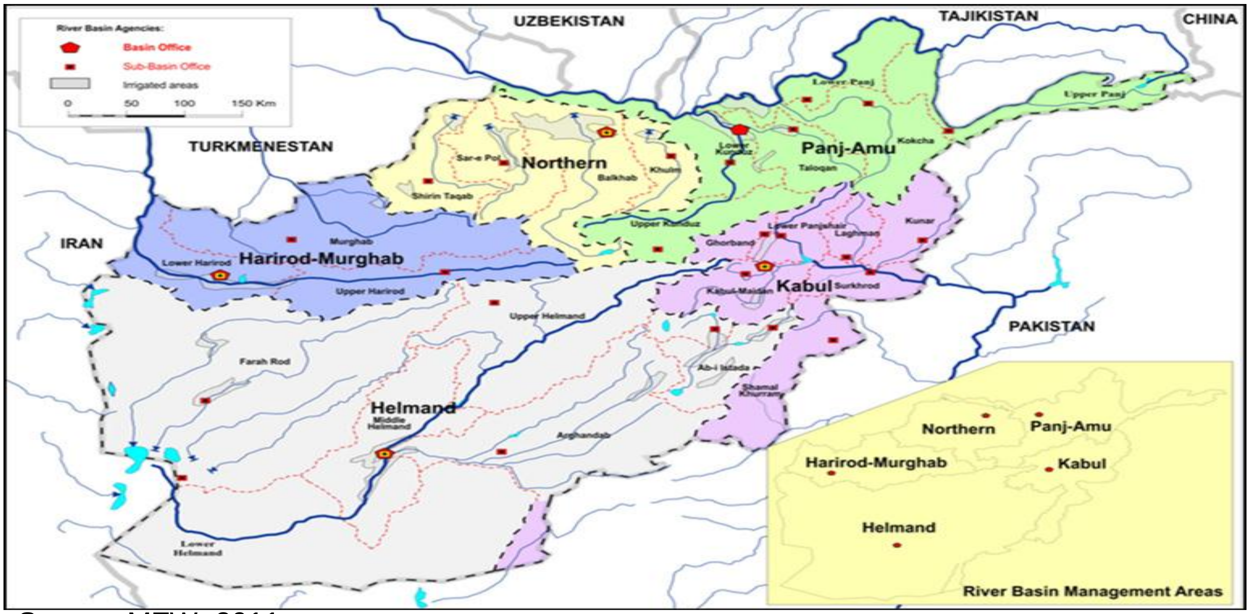
Traditional Surface Irrigation system has been using across the Balkh Province through canals by Mirab system. Mirab is the traditional water master who supervises distribution, operation and maintenance of the canal. Across the Balkh canal there are improper water management practices, insufficient infrastructure and maintenance which has been suffered the agricultural production.

Therefore, a need was felt to carry out a research study to learn about the actual water management practices under existent stakeholder and find factors that contribute to increase water productivity the Balkh Canal service area.

Balkh River

The Balkh River is part of the Northern Basin (Map 1) flowing in Balkh province. This river originates from Band-e- Amir Lake located in Bamyan province. The river first flows west, then north, and terminates in irrigation canals in the area of Balkh and Jawzjan provinces. And its end is also in the Northern Afghanistan. The Balkh River has a total length of 400 $km^2$with the watershed area of 18,700 $km^{2.}$

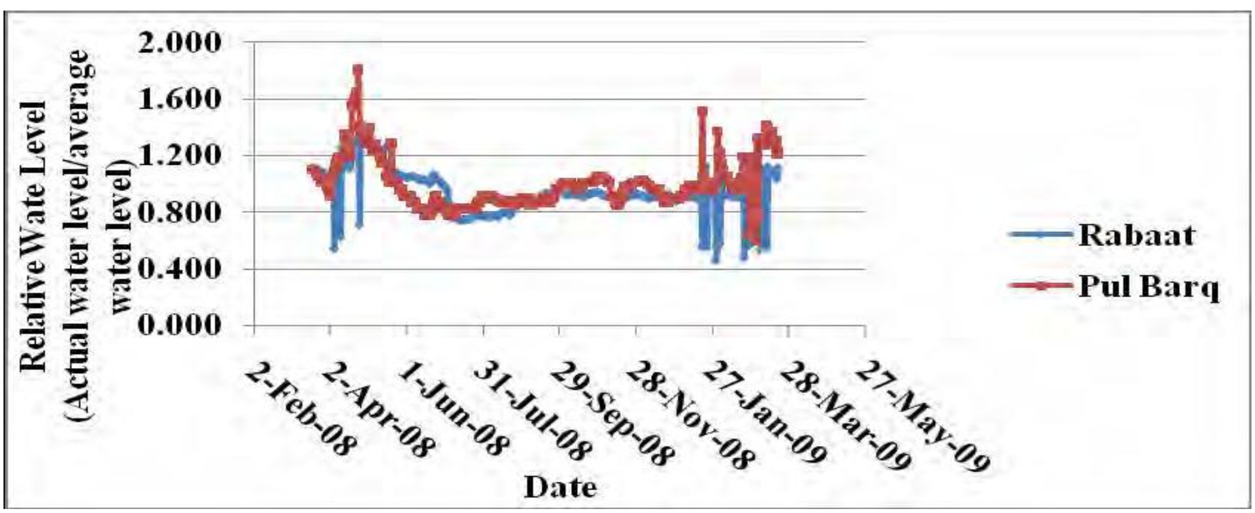
Map 1: River basins map of Afghanistan



Source: MEW, 2011

According to1964- 1978 record its discharge flow fluctuates from 19.8 to 168 m^3 sec^{-1} with overall average of 53.35 $m^3 sec^{-1}$as per 1964-1978 record (AWAT, 2010).It has 18 main intakes without any reservoir and canals have been drawn directly from the river. Therefore, the water diverted to canal system differs according to the water availability in the river system. During the winter season snow falls in upper mountains of the Balkh River basin. After the winter season, temperature rises and flow in the river increase while the highest flow occurs in summer (May, June, July and August) and lowest during the winter months (November, December, January and February) (Figure 1). By contrast to the mean discharge (53.35 m^3 sec^{-1}) of Balkh River, the highest discharge of 1430 m^3 has observed during May, 2009.The required water in the river basin is 400m^3 sec^{-1}land. But during the plantation season the water available in the canal is only 38 $m^3 sec^{-1}$. Based on (aims, 2004) record presently this river is irrigating 28835 km^2 (over 5.7 billion hectares) of land with more than 1.5 million settled population (AWAT, 2010).

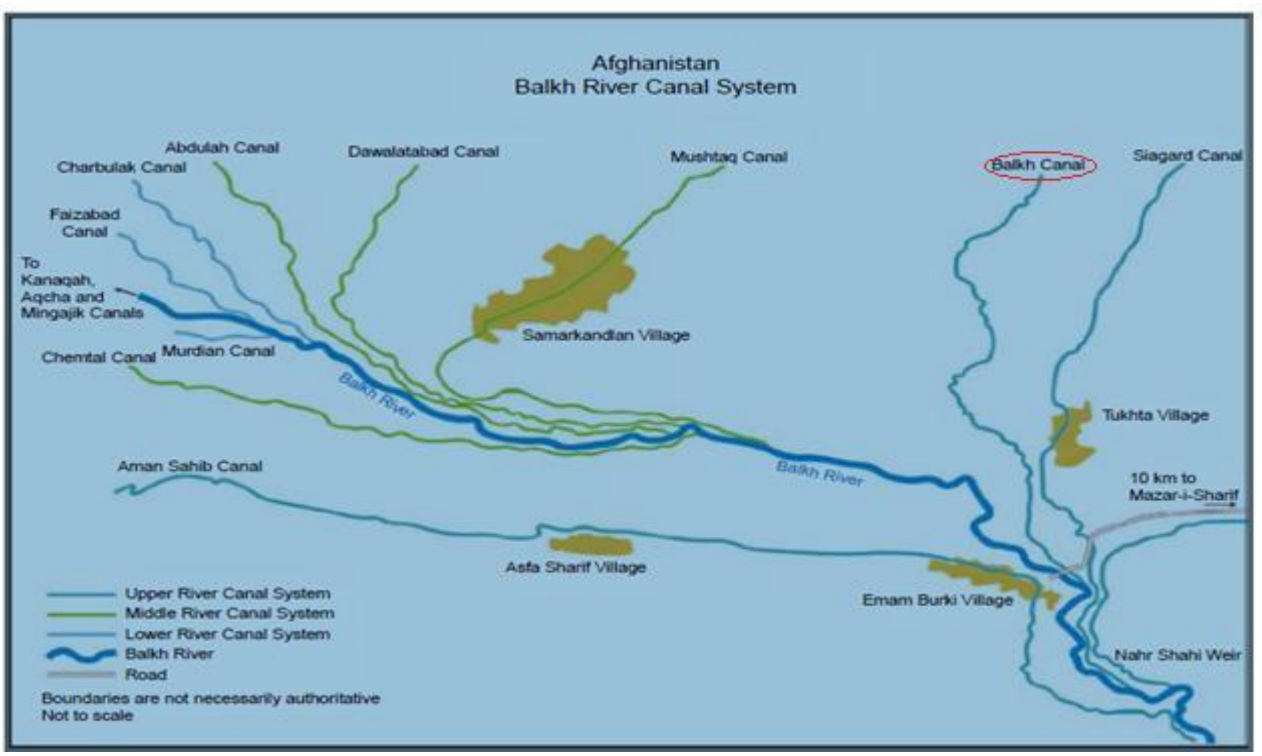
Figure 1: Variation in Relative Water Levels of Balkh River during February, 2008 to May 2009



Source: AWAT, 2010

The Balkh River grant irrigation water into two separated systems a) Sholgara valley situated upstream in the Balkh River basin being supplied by seven canals. b) The downstream irrigated area alongside the Balkh river consist of Hazda Nahir irrigation network, that serves about 424,880 ha area through a system of 11 distinct canals (Figure 3) with a total length of 457 km across the Mazar, Balkh, Aqcha and Jawzjan regions (Lee, 2003).In this system, water allocation and water rights has been fixed related to an agricultural taxation systems exist in a unit called Paikal (ADB, 2002) , where one Paikal is equal to 360 to 400 Jaribs (72 to 80 ha). Thus, water-allocation to each canal arrangement is based on historical water rights of each canal. Among these canals, Balkh canal is the one that flows into the Balkh district and its brief information shown in (Table 2), (AWAT, 2010).

Map 2: Balkh River Canals



Source: ADB, 2004

1.2. Problem Statement

The Right Balkh Canal is 9 Km long and has a total command area of 2209 agricultural land. Currently, huge agriculture land is fallow due to the shortage of irrigation water in the canal. Recently, local institution, including governmental and community based institution, have been facing with various challenges in the water management system along the Balkh canal while the high population pressure has necessitated increasing the cultivated land in the district. It is therefore necessary to find out the options and possibilities to irrigate more land with the available water in the Canal.

1.3. Objective

The main objective of this research is to analyze various factors in the selected schemes to identify factors that contribute to increase water productivity.

1.4. Research Questions

1.4.1. Main Question

1. To what extent Agricultural production will increase by improving level of irrigation services in the Balkh district?

1.4.2 Specific Questions

1. What is the existing condition of surface irrigation service in the Balkh selected schemes?
2. What are the main problems of existing irrigation system?
3. What are the possible options to improve level of irrigation service in the selected scheme?

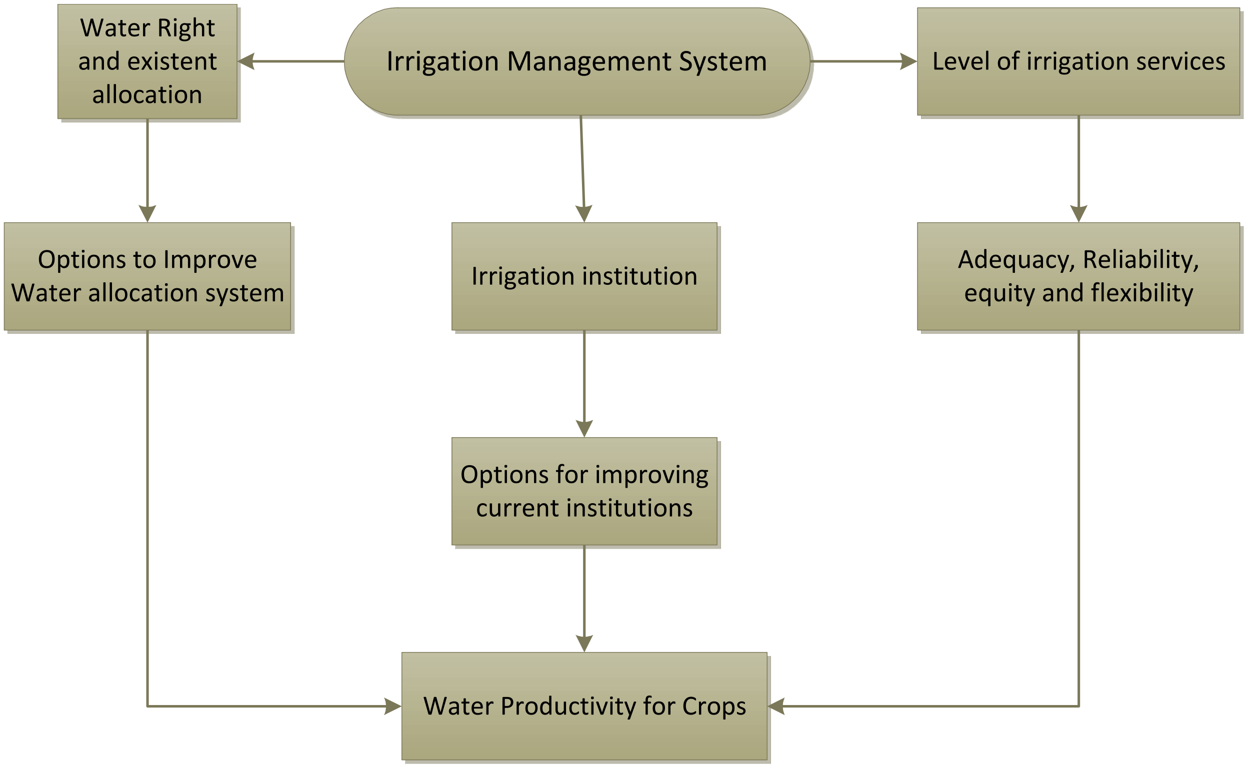
1.5. Expected output

This research focuses on the water management practices for agricultural production in the Balkh district, Right Balkh Canal service area. It is expected that the research would find out the challenges in current water management institutions and the way of solution to optimize water productivity for agricultural production.

1.6. Theoretical and Conceptual Framework

This Research aims to contribute major Agricultural production by improving of irrigation service. Which can be achieved through several approaches as outlined in (Figure 2). This Research has focused on identifying options for improving the level of irrigation service. Improving level of irrigation service is related with several factors; from each factor specific activities have been analyzed in this research. Figure2is a summary of the conceptual framework used in this research to address the study objectives.

Figure 2: Theoretical frame work of the Research



1.7. Limitation of the study

Three decades of war and destruction have destroyed the irrigation construction and infrastructure. Lack of technology, illiteracy, extension working, nonexistence of correct documents and data, security condition and limited sources are the main challenges for the researchers and required data is hard to obtain in almost all sectors particularly in Agriculture and Irrigation Department respectively. Therefore, the current situations make the study to rely on limited sources because there was no technical data for exact description and bringing the study to mirror.

The provided information of this report is through observation of the irrigation system, stakeholders and their practices. The full description of current circumstances needs broader investigation and practical measuring of water discharge, losses in the scheme, and soil analysis and so on through instruments. However this study can be used for future study and planning.

1.8. Outline of the Study

This study is organized into six (6) main chapters. Chapter 1 deals with the background of the study and describes the problem statement. It further includes the research objectives and main question followed by its sub questions which forms basis of the study.

Chapter 2 gives a review of literature for the research where finding and views of related studies to the research topic has been carried out. This chapter reviews factors that influence irrigation system.

Chapter 3 deals with the research methodology involved on the research area, research strategy, tools used for collection of data and the data analysis. The result of empirical findings of the research and its following discussion are enclosed in Chapters 4 and 5 respectively.

Chapter 6 presents conclusion and recommendations which is drawn from the study.

CHAPTER 2 RIVIEW OF LITERATURE

This Chapter focuses on review of different literatures related to the research problems and recommendations. In this stage available published and unpublished reports and books, journal articles and research documents and literature will be reviewed to describe general challenges which hinder water productivity and options for its improvement.

3.1 Population growth

The current growth rate of population in Afghanistan has been estimated as 2.6 percent which is the highest in the region. This will have a significant impact on the amount of water available for Afghan households (Thomas and Naim 2011). Even if the population growth rate was too slow to less than 1 percent within four decades, US Census Bureau point to a dry future, as follows:

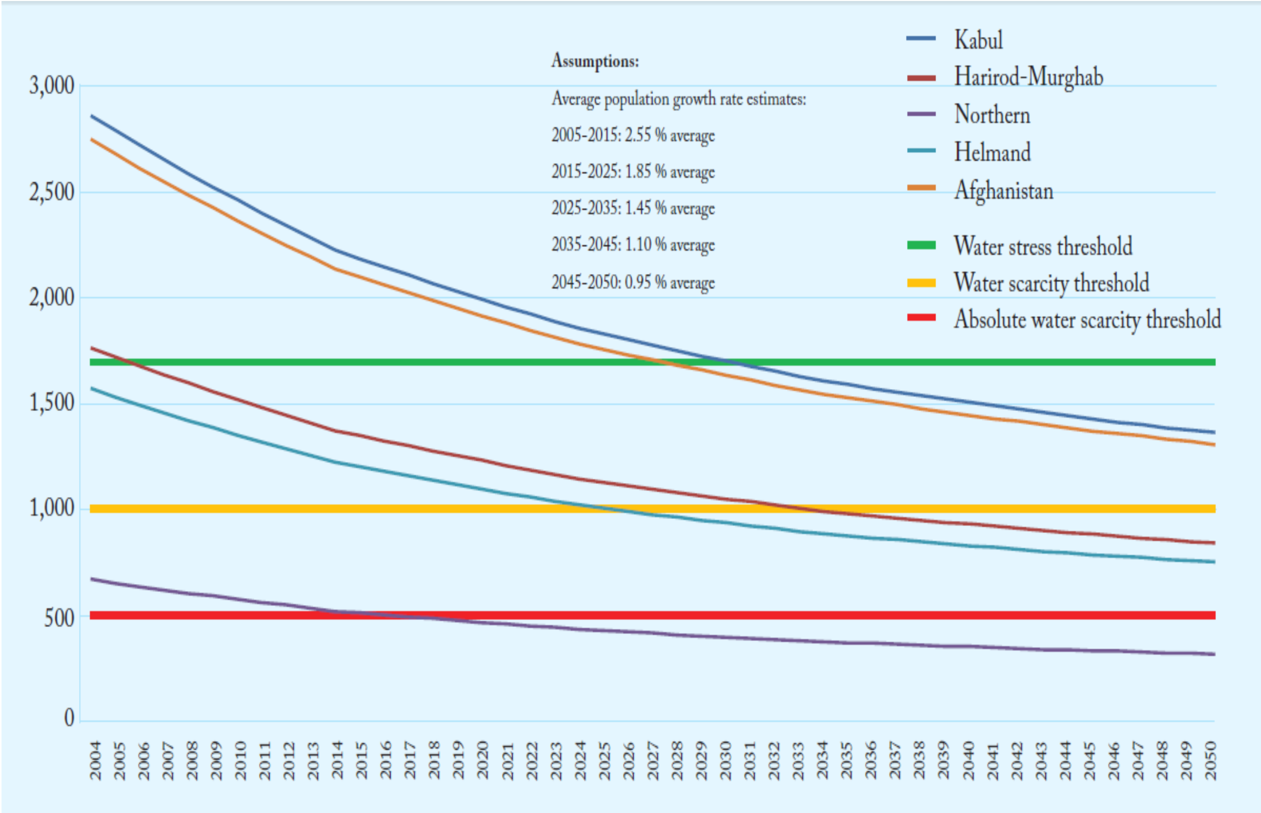
In 2025:

- The Helmand river basin could fall below the absolute scarcity threshold of 1,000 cubic meters per capita per year.
- The Northern river basin could fall below the absolute scarcity threshold of 500 cubic meters per capita per year.
- Countrywide, the availability of water per capita per year could decline to only slightly above the water stress threshold of 1,700 cubic meters per capita per year, a reduction of approximately 36 percent relative to 2004.

In 2040:

- Water availability could fall below 1,500 cubic meters per capita per year. The country may not have enough water to remain self-sufficient in cereal crops. More pessimistic predictions find the country dipping below this threshold by 2030.
- The amount of available water per capita will drop by almost 50 percent relative to 2004.
- The amount of available water in the Harirod river basin will decrease to slightly below the scarcity threshold of 1,000 cubic meters per capita per year, while the water supply in the Helmand river basin will decline to more than 15 percent below this threshold.
- At an estimated 355 cubic meters per capita per yea, water availability in the Northern basin will fall to approximately 30 percent below the absolute scarcity threshold.
- The Kabul river basin in problematic because of the geographical distribution of the water resource (Figure 3). Despite an overall positive outlook for availability per capita per year in decades to come, 87 percent of the basin area, accounting for 88 percent of the land and 92 percent of the population, will decline below absolute water scarcity by 2042.

Figure 3: Projection of water availability per capita in 4 river basins (m^3 $capita^{-1}$ $year^{-1}$)



Source CHDP, 2011

By 2040, the availability of water per capita could decline by 50 percent relative to 2004. Though the projections presented here are indicative and based on datable assumption, population growth will certainly be a major factor behind water insecurity and, thereby, food security and overall well-being. In fact, population pressure would be representing an even more critical issue if current growth rates- an estimated 2.6 percent per year- are maintained over the next four decades. If this is the case, the country will fall below the water stress threshold by 2024 and below the water scarcity threshold by 2045. In 2050, the Helmand, Harirod-Murghab and Northern River basins would decline to 10, 24 and 58 percent, respectively, below the absolute scarcity threshold (Thomas and Eqrar, 2011).

3.2. The way to satisfy food demand

The volume of water consumption would rise in 2050 from 70%-90% depending on actual growth in population and income. Also if assumption for water requirement of livestock and fisheries be estimated then crop water consumption will reach 12,050-13,500 km^3 which is 7,130 Km^3 today (Johan and Eric, 2007)

The possible ways to satisfy future food demands with world's available land and water resources are:

- Increasing water productivity and upgrading irrigated areas by sufficient management of runoff and local runoff through water harvesting (building feasible small reservoir for storing of irrigation water).
- Increasing annual irrigation water supplies by developing new surface water storage facilities and enhancing groundwater withdrawals and use of wastewater;
- Increasing water productivity in irrigated areas and value per unit of water by integrating livestock and fisheries in irrigated systems;
- Promoting agro-trade from available and efficient water producing areas to water scarce areas.

ICID has pointed that; enhancing the productivity of agricultural water is possible. It can be accomplished through various methods; increasing hydraulic efficiency of irrigation schemes by reducing losses, changing the irrigation technologies, improving the operation and maintenance activities of the scheme etc. Such improvement would save the order of 500 to 700 billion m^3. Water productivity can be improved also by increasing low yields (i.e. less than 2 ton/ha) that results in excessive evaporation. If all yields would be above 2-3 ton/ha, water use would be reduced about 1,500 billion m^3 (ICID, 2008)

Johan Rockstrom and Eric Kemp-Benedict proposed three strategies which world policy makers have to decide for investment, to feed 9.2 billion people in 2050; increase rain fed production, increase irrigated area production and improve international food trade.

3.2.1. Increased Irrigated Area Production

Irrigated agriculture now provides 40% of the global cereal supply (60% of the cereals produced in developing countries). About 46% of the gross value of agricultural production (total production multiplied by world market prices in 2000) comes from irrigated areas, which make 28% of the harvested area (Watersim estimates for the Comprehensive Assessment). Many expect that the contribution of irrigated agriculture to food production and rural development will increase in the coming decades (Seckler et al, 2000; Bruinsma 2003).

Irrigated area increases by 0.6% per year from 340 million hectares (ha) in 2000 to 450 million ha in 2050, simulating the expansion of the Middle East and North Africa and in East Asia, and a doubling of irrigated area in Sub-Saharan African from 6.4 million ha to 12.8 million ha.

Harvested area increases by 110 million ha, partly by increasing irrigation intensity (growing more crops per season) and partly by expanding the area by 76 million ha. Without improvements in application efficiency agricultural water diversions for irrigation increase from 2, 630 Km^3 per year today to 4,100 km3 per year in 2050 also at least US $ 400 billion will be required to expand the harvested area by 110 million ha.

In the Middle East and North Africa water scarcity constrains further irrigation expansion, and the scope for improving rain fed agriculture is limited. In South Asia the lack of suitable land is becoming a constraint and water resource are stressed in many basins. China has sufficient water in the south but not in the north. Land and water are limited, institutions are weak, and much of the infrastructure needed to support economic development is not yet in place.

Many irrigation schemes, particularly in South Asia, perform below potential, and the scope for improving water productivity is high.

Potential contribution to global food production of improving irrigation performance by formulating an irrigated yield growth scenario that assume bringing 75-80% of the exploitable yield gaps in coming decades.

The potential gains from enhancing productivity in irrigated areas are larger than the gains from area expansion. Improving irrigated cereal yields by 77% meets 50% of global additional demand by 2050, while expanding irrigated areas meets just 23%.

Improving irrigated cereal yields by 77% contributes 550 million metric tons of grains, or 50% of global additional demand by 2050.

Therefore, it is clear that the best option to improve agriculture or food production in Balkh Province is to enhance productivity of irrigated area, in order to contribute agricultural self sufficiency in the area. Surface irrigation system is dominant in this area with very low level practices and services.

3.3. Crop water productivity

Hengsdijk et al. (2006) studied that the higher water productivity reduces the need for additional water and land resources in irrigated and rain fed systems. According to them developing water productivity was a critical response to growing water scarcity, including the need to leave enough water in rivers to sustain ecosystems to meet the growing demands of cities and industries.

Cook et al. (2006) concluded that estimates of water productivity (WP) have two basic uses: firstly, as diagnostic tool t identify the level of water-use efficiency of a system under study and secondly, to provide insight into the opportunities for better water management.

Mdemu et al. (2008) studied the physical crop water productivity at farm and scheme scales for two different systems: a medium and small reservoir in semi-arid environment of the Upper East Region in Ghana. The study concluded that water productivity for the study reservoirs was low, and that potential for improvement existed through improved irrigation water management and agronomic practices.

Molden et al.(2009) studied that the priority areas where substantive increase in water productivity are possible as (i) areas where poverty is high and water productivity is low, (ii) areas of physical water scarcity where competition for water is high, (iii) areas with little water resources development where high returns from little extra water resources development where high returns from little extra water use can make a big difference, and (iv) areas of water-driven ecosystem degradation, such as falling groundwater tables, and river desiccation.

3.4 Principles of Water Allocation

Roe (2006) and Qureshi (2002) studied water allocation and distribution of irrigation systems and found that the main characteristics of community based irrigation management were;

Community- embedded Mirabs (water-masters), water rights, allocation and maintenance of water infrastructure (intakes and canal). Mirabs were appointed, paid and supported by landowners. Water rights and allocation regimes in the systems were decided by communities based on landownership and contributions for canal maintenance. The maintenance of the systems was based on contributions (in kind or financial) from water users. The role of the state in these systems was minimal or absent and most of the conflicts regarding water allocation and distribution were settled by elders of the community.

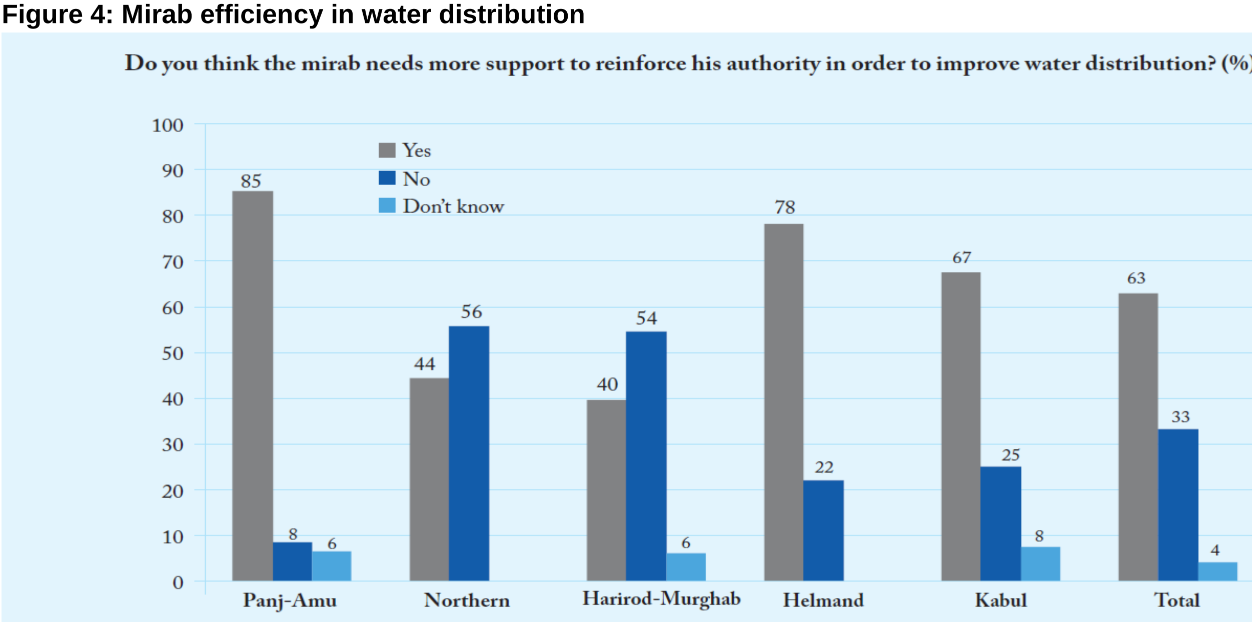
Pain (2006) studied the impact of poppy cultivation on loss of crop production and reported that the cultivation of poppy in the irrigated areas of Kunduz and Balkh province of Afghanistan caused loss in crop production at tail reaches of the canal due to unequal water distribution. The existence of effective and resilient community water management, namely water allocation and distribution mechanisms, are the key means by which to discourage local water users from cultivating the less water-intensive poppy.

3.5 Irrigation Water Management

CPDH (2010) conducted survey in five river basin irrigatedareas and reported most crucial problem of water management constraints and inequity in the region;

- Density of population has led to more competition for decreased irrigable land. This has meant greater problem of mirab and other actors involved in controlling of water distribution (Figure 4). Because of more competition among more numerous water users, the chances that local agreements may be bypassed are heightened if negotiations become more difficult.

Figure 4: Mirab efficiency in water distribution



Source: CHDP, 2011

- Combined with a collapse of local government capacity to support mirabs and local institutions, the erosion of social capital has led to an increase in illegal practices. These include an expansion in the cultivation of water-intensive crops, such as rice and cotton in the head reaches of the canal but farmers in the tail reaches are suffering the consequences of reduced access to water.
- Collective maintenance has decreased partly because the erosion in social capital has contributed to a reduction in the conveyance capacity of canals and poor infrastructure performance. The low irrigation efficiency contributes to limiting the access to water in downstream service areas.
- Increasing insecurity in some regions is contributing to a decline in canal and water management capacity. Overall, the performance of local institutions in the provision of water resources to all farmers is weakening in numerous canal systems.

Afghanistan is spread over an area of 46 million ha, out of which approximately 5 percent is irrigated, 7.5 percent is rain fed, 3 percent of the irrigated area of Afghanistan is managed satisfactorily, 20 percent has poor on-farm water management practices, 10 percent has become waste land due to war and 40 percent has been damaged due to the lack of maintenance (Walter, 1997).

According to the survey made by ICARDA (2002), the leveling of Afghan farmer fields and the knowledge of proper irrigation requirements for different crops are generally poor. The Afghan farmers do not plan their irrigation or have any knowledge on the crop requirements, but irrigate from previous experience and sight of dryness (ICARDA, 2002).

Shahand Khan (2011) conducted a research to assess the Performance of two irrigation systems (Shergar canal and Canal No. 15) in Nangrahar Province, Afghanistan. They founded based on physical survey that, there were no proper distribution structures at Shergar branch canal and it was operated traditionally by using tree bushes, rocks, sand filled bags, tent and plastic sheets for water diversion and close up of outlets. At head of Canal No.15, there were head regulator gates present and operated by Mirab (water master) but their maintenance was poor. Moreover, they have mentioned that, In general the water distributions in the canals were not equitable due to lack of flow control and distribution structures, poor implementation of water rights and limited management capacity of the governmental officials and water users. They have proposed in their report that, the management skills of concerned institution be enhanced for better utilization of scarce water resources in the area, and proper flow control and distribution structures shall be installed for equitable water distribution and capacity of the government officials, Mirabs (Water masters) and water users association shall be enhanced.

Riviere (2005) studied the irrigation management in Northern Afghanistan and concluded that the maintenance of user managed irrigation system was based on the contribution of each water user. He reported that the canal cleaning start before the irrigation season. The cleaning of watercourses was conducted manually under the leadership of Mirab (water master). He found that technical problems in the irrigation systems wee irregular shape of canals due to dense plantation along the banks of the canal.

Viala (2004) studied irrigation management in Afghanistan and reported that farmers have developed structures and mechanisms to cope with limited supply of water. He reported that the country has rich tradition of water user associations and operation and maintenance of traditional irrigation systems were carried out by local water users in the leadership of Mirab (Water master). Mirab was responsible for water conveyance infrastructures, flow control and facilitation of water allocation for water allocation disputes.

Jonson et al. (1978) reported that over half of the water delivered from the channel system to watercourses managed by the farmers is not made available to the farmers crops in Pakistan. Most of this water loss is due to the loss of water through the banks of watercourses. Lack of maintenance and lack of cleaning is a result of inadequate organization of the 10 to 15 framers who use the watercourse and a deficiency of knowledge concerning the amount of their water which is being lost.

Ali and Khan (1997) conducted research on the effect of physical condition on water management practices in selected tertiary units to find collective action for water management below outlets, different physical and social conditions related to the existing form of organization, the important water acquisition, water allocation, water distribution and water course maintenance and physical factors were size of the command area, type of soil, cropping pattern, condition of crops, slope of watercourse, numbers of tube wells, water table depth, rainfall, water logging and salinity. They suggested that an inequitable water allocation and distribution, absence of the drainage system, water logging and salinity, watercourse maintenance and high water losses are the serious problem of the research area, which cannot be solved by individual farmer.

Latif(1993)studied that rotational water supply system deliver unequal amount of water among the irrigators along tertiary channels. This leads to many technical and social problems. Under the existing rotational system, transmission losses along channel are not considered. A constant time per unit area is allocated to all the farmers regardless of their location along the watercourse. This result in decreasing amount of water delivered to the downstream farmers in a watercourse area.

Soetapa (1980) in his study of irrigation system found that great wastage of irrigation water occurred during conveyance from main intake to the farm level. He concluded that most these losses could be avoided if there is a proper distribution, planning and a sufficient supervision during its implementation. He also described the role of farmers association in this regard and emphasized on the importance of this organization.

Hurmaz (1999) studied the assessment of conveyance losses and maintenance status of Surizai Minor of Warsak Gravity canal, Peshawar, Pakistan. They obtained the data regarding watercourse maintenance through social survey. According to his findings, 50 percent respondents at watercourse cleaned their watercourse twice a year, 20 percent once per year and 30 percent respondents said that they clean it four times in a year. He also reported that the watercourse cleaning are carried out participatory manner and they would fine the absent water users during cleaning. They also reported that now the elders of the community only organized the cleaning but cannot impose fine on free riders due to their social dominancy.

3.5.1. Equity

Inequity in water access, which includes insufficient water distribution to tail reach areas, is associated with three broad categories of factors, as follows;

- **Water demand:** A progressive rise in the demand for water and the withdrawal of water in upstream areas in a context of increased pressure on agricultural land.
- **Social Capital:** A degradation of community social capital and the resulting weakening in the performance of local water management institutions.
- **Infrastructure:** A degradation in the efficiency and conveyance capacity of traditional canal systems that are already characterized by low efficiency and limited control over water. It also illustrates that interventions aimed at tackling the cause of inequity and the indirect consequences should adopt an **integrated approach** focusing on technical, social and management issues. (Thomas and Sabawon, 2011)

Rajan (1993) concluded that the main objective of any management is to deliver and control water so that individual of fields gets their required share at the right time. Water distribution within the system has to be improved in maintenance to a level acceptable to the same time it should result in increased productivity, which is the foremost aim of any irrigation system, which lies in southern part of Tamil Nadu, India. The main crop was paddy and was grown for two seasons. First crop raised during northwest monsoon i.e. November to February was known as pishanam. The water regulation is done by Irrigation Department, Government of Tamil Nadu up to distributaries level. To assess the existing water distribution. The day to day water regulation decisions were taken and O&M policies practiced by irrigation department were also noted down. The relative water supply (RWS) value obtained both at distributor level and at field level indicated that there was adequacy in water supply However, the water distribution was varying significantly between different distributaries. The lower percentage of effective rainfall utilization, the water regulation practices adopted by the irrigation department and inadequate number of maintenance staff available rainfall will improve the distribution pattern.

Uphoff (1985) found that the distribution has the universal problem of their advantage where upstream users have greater opportunity to obtain their share of even more than their share than do users downstream. Inequalities in distribution are frequently observed and organizations are not uniformly successful in promoting equitable allocation and distribution.

Freeman, et al. (1989) studied that an inequitable water distribution within the tertiary units are a big problem in Pakistan specially affecting the tail end farmers. The farmers who are settled in the tail of the system receive less water rather than the farmers who are located in the head of system and they do so without regard for land owned or cultivated, education or case affiliation. Freeman also has mentioned that the warabandi distribution system provides poor water control for all farmers. The location of the land is related to water scarcity, higher seepage losses, bigger command area and the number and location of tube well. These are all the physical factors that might reduce or increase tail-enders control over water.

2.5.2. Flexibility

Batti and Kijni (1990) studied the irrigation allocation problems at tertiary level in Pakistan and concluded that optimal water management at farm level required a flexibility of water allocation, which the present warabandi system could not provide. In farming out a new set of rules for distribution and allocation of irrigation water, consideration should be given to the dominantly increased amount of water available at the farm gate through development of ground water. New rotational rules should aim at flexibility in providing of irrigation an assured seasonal supply as a first step towards more equitable distribution of irrigation water. Furthermore, the rules should not be same everywhere but they should be given appropriate for each environment. They meant that assured supplies should be given to saline ground water area and farmers using poor quality ground water should be given priority in the allocation of an assured amount of good quality water.

2.5.3 Reliability

Pacha (2002) conducted a field research at three selected traditional karez schemes in Ghazi province, Afghanistan. He found that water allocation and distribution systems was based on centuries old tradition, which gives rights to families, who contributed in Karez construction. He mentioned that, base on respondent at each scheme; water allowance at Kala-Minar scheme for all families was 2.73 hrs/ha and at Aqasi scheme it varied from 9.72 to 11.89 hrs/ha. while at Deh-Hamza Scheme it varies from 0.32 to 0.71 hrs/ha. Furthermore, he has stated for majority of framers water distribution system at three selected schemes were satisfied and was fixed for all share holders. Therefore, reliability in timing was not found during the research period.

Jones and Anderson (1972) found that wide spread under irrigation was the main factor for less agricultural development in Pakistan. Redesigning of irrigation system would be necessary to provide the farmer with adequate and timely of water. Better utilization of water by the farmer in the watercourses and at the farm level for achieving higher yield per acre was emphasized.

CHAPTER THREE

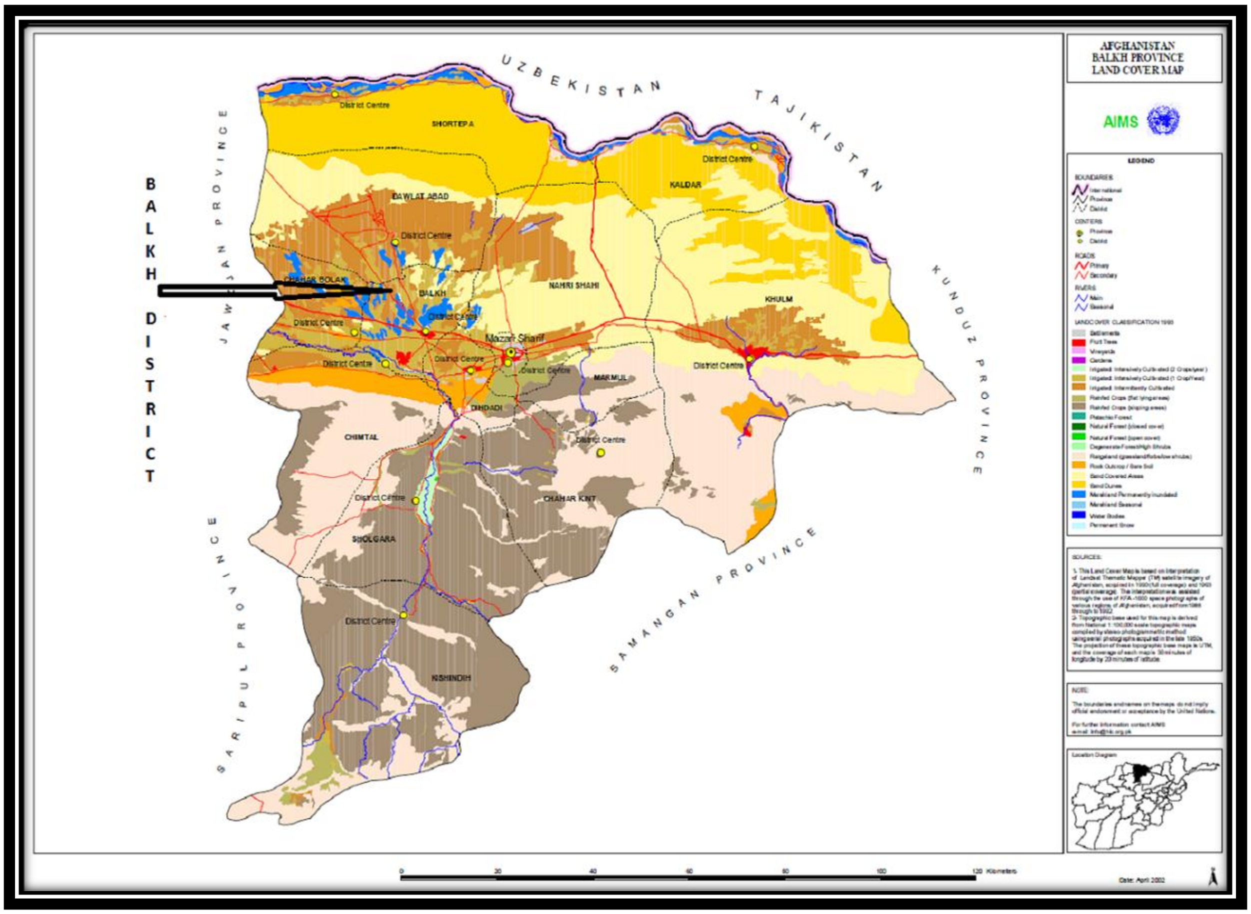
RESEARCH METHODOLOGY

This chapter includes glance on the study area and describes the approach of data collection and tools used for analysis; it further describes the sources used for secondary data.

3.1 Study area

Balkh Province is located in the north of the Afghanistan between 35.37 40-67 degrees latitude and 68.20-66.25 degrees longitude (NAIS). Balkh province has borders with Uzbekistan in the North, Tajikistan in the Northeast, Kunduz province in the East, Samangan province in the South east, Sar-e-Pul province in the Southwest and Jauzjan province in the west (Map 3). The province covers area of 16,840 km^2 which 113,212 hectares are cultivated, nearly half of the province is mountainous or semi mountainous. Balkh Province has 15 districts and Mazar-Sharif is its provincial capital which is famous commercial and financial center in the Afghanistan. The province has total population about 1.12 million (BPP, 2007).

Map 3: Balkh Province and Balkh District



Source: AIMS, 2010

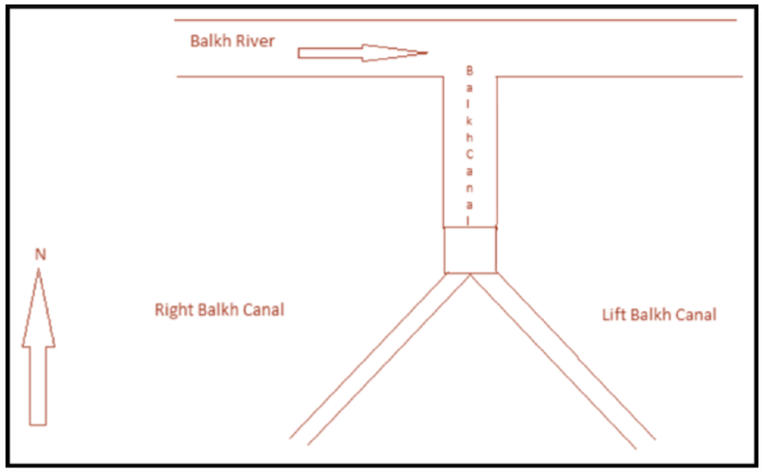
Balkh district (Map 3) has 511km^2 terrain, 97,055 populations and 129 villages (BDDP, MRRD. 2006). Whole agriculture land in the Balkh district is irrigated land that Wheat, Cotton, Vegetables (onion, tomato, etc), melon and water melon are major cultivated crops.

The study has been conducted in Balkh Canal service area, Balkh district, Balkh Province, Afghanistan. It is located in the Northern Afghanistan with the latitude of 36.45^o E and altitude of 331 m.

Balkh canal is one of the 11 canals of Balkh River Irrigation System which irrigates 5040 ha of land with the average discharge of 0.86 m^{3}sec^{-1}.Total length of the canal is 15 km with 11 tertiary canals/off-takes from the main canal (Klemm and Shobair, 1996).

Balkh canal is further divided into two Branch Canals i.e. Right Balkh Canal (RBC) and Left Balkh Canal (LBC) which is shown in Map 4. RBC consists of 7 outlets and its total length is 9 km with an average discharge of 0.40 m^3 sec^{-1}.

Map 4: Schematic map of Balkh Canal

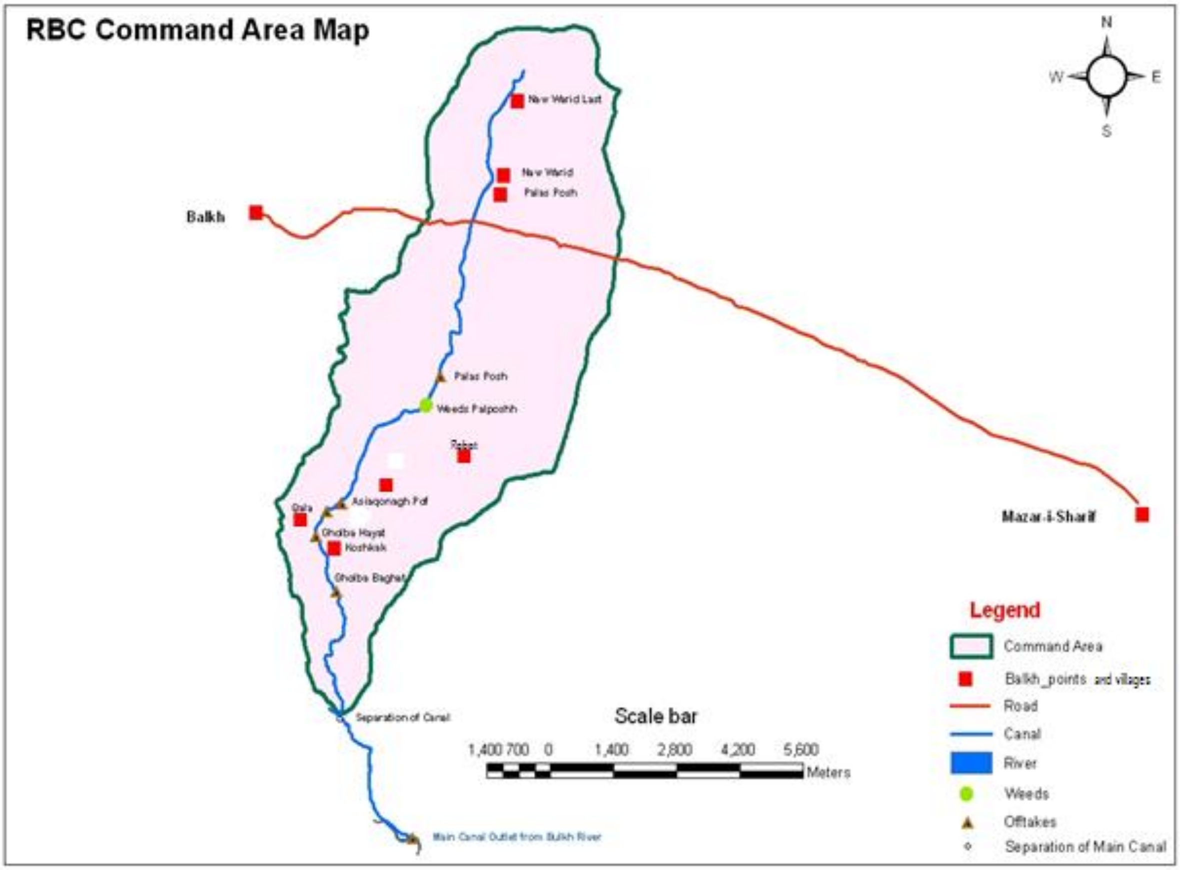


Source: Field Work

3.1.1 Command Area Map of Right Balkh Canal

There were no existing maps of RBC command area available. While, it was very important to determine the command area map and layout of the irrigation system. Therefore, Global Positioning System (GPS) was used to mark the command area and layout map of the canal. Every interviewed village was marked at regular intervals. Waypoints and off-takes were also marked along the length of RBC. The marked data was transferred to computer software “Map source” and layout map was developed in the GIS Program for the further use in the study (Map 5).

Map 5: Command area map of Right Balkh Canal



Source: Field work

3.2 Research Methods and approach

The research methodology of this paper has qualitative and quantitative approach which is based on following methods:

1. Literature review and review of the key driving forces for improving water productivity;
2. Selection of study area;
3. Field data collection (from on selected site);
4. Study, analysis and screening of data from studied areas;
5. Identify options to improve level of irrigation service;
6. Inference making from the findings and results

Concise of the research and necessities for promotion has summarized in Conclusion and Recommendations.

3.2.1. Literature Review

General literature about water productivity at the global and relevant area has reviewed. In this stage available published and unpublished reports and books, journal articles and research documents and literature was studied to describe water productivity and water institution.

3.2.2. Selection of the study area

For detailed analysis, Balkh district of Balkh Province, Afghanistan has selected. Then Right Branch of Balkh Canal service area was selected.

3.2.3. Field Work

Observation of Balkh selected area and following field work has carried out:

- Balkh Canal Right Branch was visited to observe its existent condition.
- Interviewing of the Farmers, Water Masters (Mirab and Chakbashi).
- Collecting information on major crops in the Balkh district selected area.
- Identification of irrigation organizational system in the community.
- Discussion with Mazar-i- sharif Directorate of River Basin and its department in the district as well as with Mazar-i- sharif Irrigation Department in the Province.

3.2.4 Interview

The interview has conducted through structured and semi-structured questionnaires and has approached from water users, water masters and relevant Organizations.

B. Water Master (Mirab and Chakbashi)

The Mirab who is the water master for entire scheme and Chakbashi is water master for specific village that has good experience about the system in the scheme were interviewed elated to water availability and its challenges as well as their management system

C. Farmers

Two villages were selected in up, middle and in downstream which were close to the Right Balk Canal. For finding out of precise status of current water users, irrigation services and agricultural production within the canal service area. In every village farmers who had high acreage, average acreage and minimum acreage farms were interviewed and some time without this investigation farmers were getting in the field and were interviewed, because it was difficult to approach farmer every time, everywhere and ready for interview. Farmers were asked about irrigation scheduling, water availability and practices, irrigation management system, land size, major crop pattern and so on.

D. Directorate of Water River Basin and Irrigation Department

Directorate of Water River Basin and Irrigation Department were asked about their organizational structure, main responsibility and authority, technical data of Right Balkh Canal , field map, and other relevant data which was impossible to obtain from local people and field observation in this duration of time.

3.2.5 Screening and Analyzing of Irrigation Service in Selected Scheme

As it has mentioned that this research analyzes the system of irrigation service in the Right Balkh Canal service area, which has obtained from different resources. After collecting of primary and secondary data it found out what is the current level of irrigation service and what are the options to improve level of surface irrigation services in the selected area and relevant data for each activity has separately screened and analyzed.

3.2.5.1. Cropping Pattern
Information about cropping pattern has collected from farmers by interviewing and field observation at head, middle and tail of the selected area. The percentages of the existing crops in the selected scheme were determined by using of following formula:

Percentage of Crop= $\left(\frac{\text{Cultivated Crop}}{\text{Total Land of the interviewee}}\right)$*100

3.2.5.2 Analysis of Irrigation Stakeholders
Generally, in irrigation schemes in the world, government, groups of formal and informal organized users and individual farmers are involved in the schemes performance. For this scheme four levels of stakeholders are studied,

- River basin authority;
- The irrigation authority;
- Community based water masters;
- Individual users and elders;

In this research responsibility and authority of each mentioned stakeholder has identified in the selected schemes.

3.2.5.2. Analysis of Irrigation system

Water Right
This research has glance on current water rights principles and options how to improve water use right for agriculture in the selected schemes.

Water allocation and distribution
Information on the water allocation was collected from farmers through interviews and having discussions with the officials in the River Basin Directorate and Irrigation Department.

Water allocation and distribution data was collected from the farmer in the selected area through interviews and having discussion with the officials in the Directorate of River Basin and Irrigation Department of Mazar-i-Sharif, Balkh Province. Also water allocation structure was observed during the field study.

- **Adequacy**

This is a measure of the degree to which deliveries meet soil-plant-water requirement. A system that has adequacy objective anticipates delivering water in sufficient volume at appropriate times to avoid potential yield reduction caused by period (Murray-Rust and Snellen, 1991). Adequacy in the scheme was asked from farmers in the field has found distinguish between users over the scheme.

- **Reliability**

Reliability is an idiom of confidence in the irrigation system to distribute water as in the design. It is defined as the proportion of the quantity delivered to that scheduled. It is essential to the farmers because it allow them for proper planning and decision. By ensuring an adequate and reliable supply of water, irrigation may increase yields of most crops (FAO, 2003). This tool has also asked from water users in the field.

– **Equity**

Equity is defined as the delivery of equitable share water to users throughout the canal. Inequitable distribution results in the overuse of water by upstream water users and little remained into the downstream water users. This tool has obtained from farmer through identifying of water accessibility for each water user in the selected area.

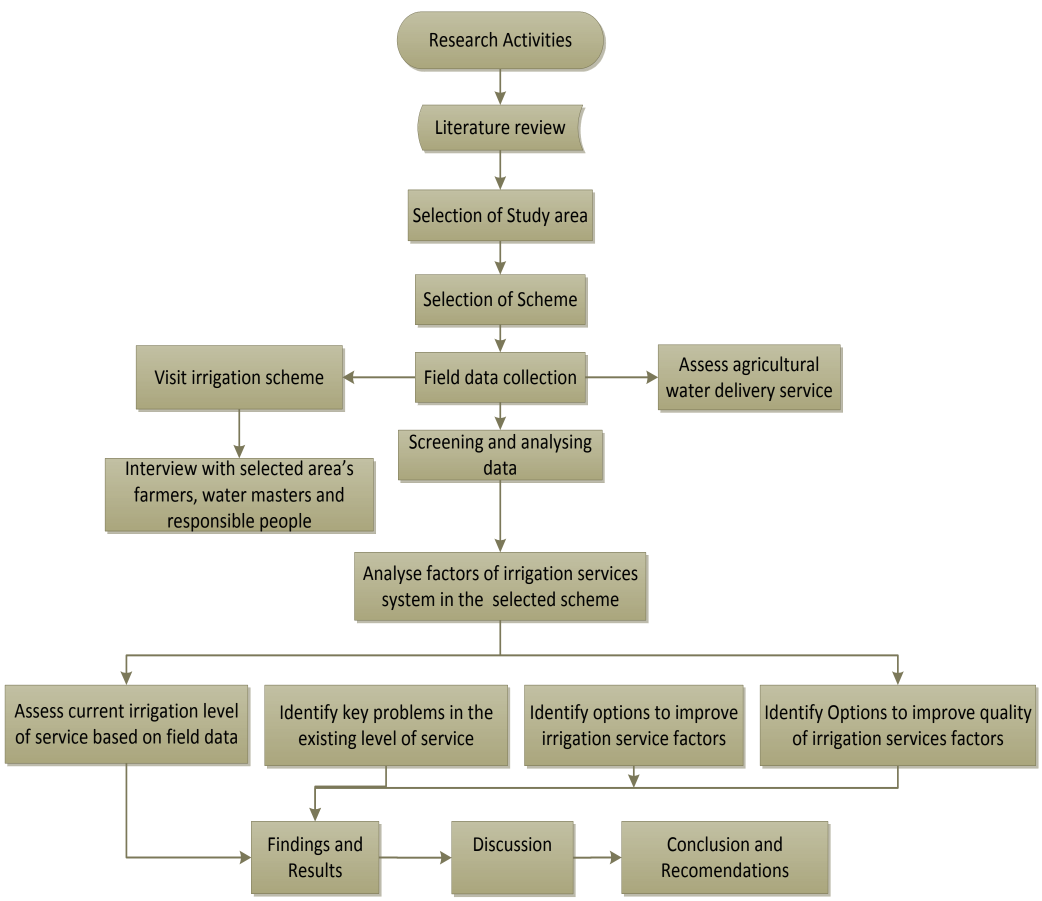
– **Flexibility**

The ability of users to choose the frequency, rate and duration with which irrigation water is supplied as well as determined the degree of flexibility of supply. This tool acquired thorough interviews from selected interviewees.

3.2.6. Result, Conclusion and Recommendation

After the achievement of the above mentioned activities, final conclusion and recommendations is formulated. A conceptual framework of the research methodology is presented in the (Figure 5);

Figure 5: Conceptual frame work of research methodology



CHAPTER 4 RESULTS

This Chapter analyses the collected data of the field and describes the cropping pattern, water right and its practices, involved stakeholders and their responsibility and authority, it also includes general factors that hinder water productivity for agricultural production in the selected scheme.

4.1 Crops

Main crops of the scheme are wheat, cotton, Melon, Water Melon, Alfalfa and vegetables. Cultivation of the crops was based on the local experience; no crop water requirement is calculated, farmers were not receiving any type of assistance and guidance for the crop cultivation from the government and NGO’s. The farmers decide their cultivation calendar, amount of supplying water to the crops based on their experiences.

4. 1.1 Cropping Pattern

4.1.1.1 Winter season

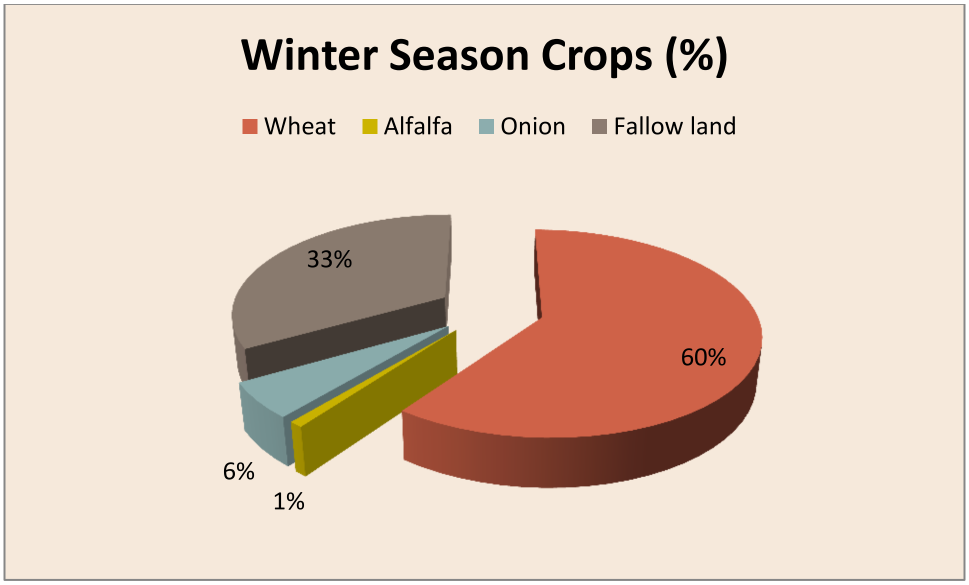
Cropping pattern at the head, middle and tail reaches of the Right Balkh Canal (RBC) during winter season is given in Table 1. Wheat is the most dominant crop grown at head, middle and tail reaches on area of 69.33, 58.75 and 46.94% respectively. At the tail reaches onion was 2nd dominant crop grown on 15.86% of the cultivated area. At the tail reaches water table was relatively shallow (9-10 m) from the ground surface (stated by farmers). Due to scarcity of irrigation water at the tail reaches 70 tube wells have been installed which are used for the irrigation of cash crops (onion and cotton).

Table 1: Cropping pattern of winter season in the RBC service area.

Crop Name	Cropping Pattern (%)		
	Head	Middle	Tail
Wheat	69.33	58.75	46.94
Alfalfa	0.92	0.71	1.01
Onion	0.46	0	15.86
Fallow Land	25.4`	38.88	32.69

It is indicated in the Figure 6 that the major crops grown in the winter season were wheat, onion and alfalfa. The most dominant crop was wheat (60%) followed by onion (6%) and Alfalfa was grown on small percentage (1%). The remaining 33% cultivatable area was follow due to scarcity of irrigation water in the service area of RBC.

Figure 6: Winter Season Cropping Pattern (%)



Source: Field work

4.1.1.2 Summer Season

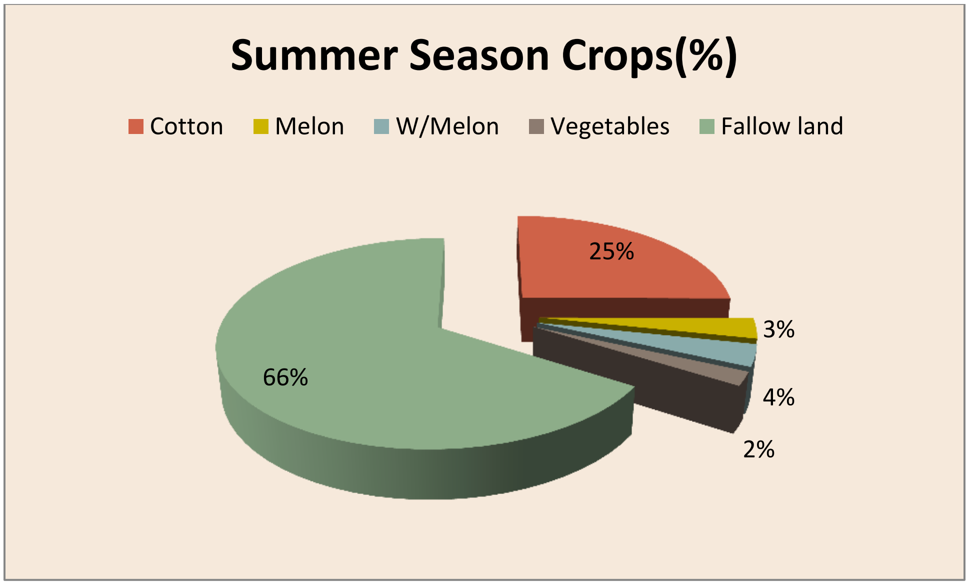
Cropping pattern at the head, middle and tail reaches of RBC during summer season is obvious in the Table 2.That cotton was the most dominant crop grown at the head, middle and tail reaches on areas of 13.43, 10.21 and 48.49% respectively, followed by water melon and melon. Vegetable was growing on small ranged from 4.09 to 0.81, while the remaining cultivatable area was fallow land. Cotton was dominantly grown at the tail reaches of RBC which was mostly irrigating by tube wells, while vegetable and melon were further grown at the head and middle reaches of RBC service area.

Table 2: Cropping pattern of summer season in the RBC service area

Crop Name	Cropping Pattern (%)		
	Head	Middle	Tail
Cotton	13.43	10.21	48.49
Melon	3.57	4.2	1.37
W/Melon	3.43	5.56	0.85
Vegetables	4.09	0.81	1.24
Fallow land	72.36	77.49	40.22

The cropping pattern of summer season is given in Figure 10. It is clearly shown that major grown crops were cotton, water melon, Melon and Vegetables. Cotton was the dominant crop grown on area of 25 % followed by water melon and vegetable. Due to scarcity of water, vegetables were grown on less percentage (2%). While the remaining (66%) of the cultivated area was fallow land.

Figure 7: Summer Season cropping pattern (%)



Source: Field work

4.2 Water management Stakeholders

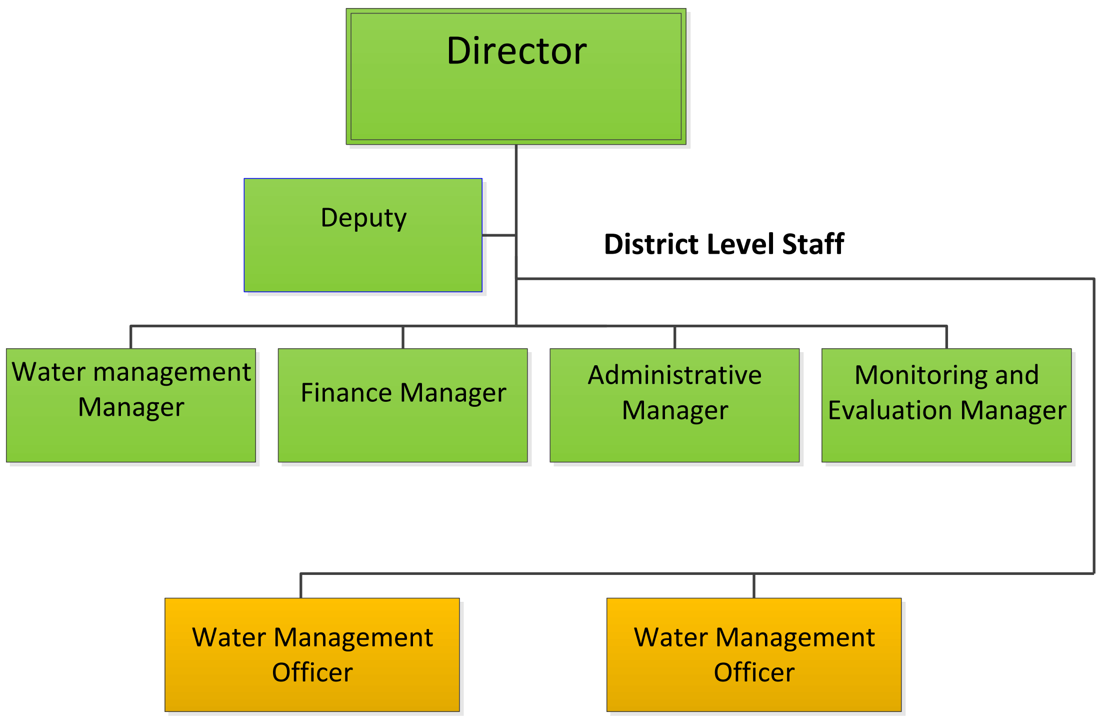
Development of modified irrigation scheme has been managed by the government agencies; the organizational structure of informal surface irrigation systems varies upon on the history of the system, water availability, land owner and irrigated area. Generally number of system management staff is related to the size of the systems, large systems have more staff and small systems have less staff. As it is mentioned that Balkh Canal irrigation system is one of the informal irrigation schemes in Afghanistan which is managed by local communities. field work has realized that there is four category of authority are involved in the water management system; Balkh district and Province River basin, which department is in the district and Directorate is in the Capital (Mazar-i-Sharif) of Balkh Province, Mazar-i- Sharif Irrigation department in the Mazar-i-Sharif, Mirab& ChakBashi and farmers & elders. These mentioned four categories manage all activities of the RBC scheme, which are described separately below;

4.2.1. Mazar-i-Sharif Directorate of River Basin and its Department in the Balkh district

This organization is part of Ministry of Energy and Water. Duties and Responsibility of this organization is limited to administration work, and they are not involved in irrigation management in the field. But they are involved in allocation of water percentage to all main canals in Balkh province from river including Balkh canal based on availability of water in the River. Moreover, record of general land ownership in the area, solving large scale conflicts e.g. conflict between villages and canals because water entitlement are the main duties of this organization. The organization was structured from one director and his deputy with four managers, Water Management manager who was involve in whole Province water management issues related to this organization, such as managing of Mazari-i-sharif and all District level water management officers. Finance Manager was involved in the Finance issues. Consumption and annual budget of this Directorate is determined from Ministry of Energy and Water.

Administrative Manager is involved in Administrative performance and Monitoring and Evaluation Manger has been Monitored and Evaluated the performance of entire staff in the province and sending of its copy to Ministry of Energy and Water. Water management deals with all water allocation and river O&M in overall province. Furthermore, Directorate of River Basin has sub offices in the district level (Figure 8). Director of River Basin said we have one while in some district two Water management officers to manage district level canal flow, for instance water flow has been changing time to time and they allocate percentage of water in the main outlet (Sarband) based on availability of water and report to the directorate about their supervision, as well as they are involved in conflict resolution of farmer in the district level.

Figure 8: Organization chart of River Basin Directorate located in the Balkh Province and its Department in the Balkh District



In the district there were two water management officers, one was for RBC service area and the second one was for Lift Balkh Canal Service area (LBC).

4.2.2. Mazar-i-Sharif irrigation department

This department is part of Agriculture "Directorate of Agriculture, Irrigation and Livestock (DAIL) of Mazar-i-sharif" which under Ministry of Agriculture, Irrigation and Livestock (MAIL). The department of irrigation is recently established by MAIL in the province including in the DAIL of Mazari-i-sharif. This department has only one officer who has contact with Mirab and ChakBashi, farmers and elders of all over province to hair their voice, solve their small scale and on farm irrigation conflicts and problems.

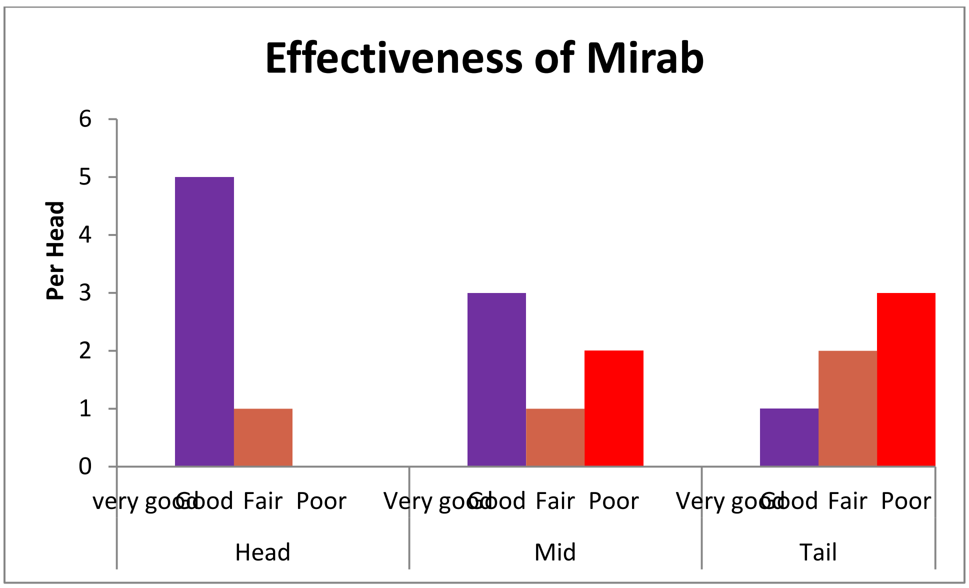
4.2.3. Mirab (water administrator)

There was one general Mirab for all RBC service area, He is in charge of overall irrigation management system in the scheme and also serves as a link between government personnel authority and the farmers. Mirab is elected by farmers and elders and has been working as a Mirab for long time. Farmers said election of Mirab take place at the end of year Hut to early Hamal. This is over the period of Afghan New Year (mid march).

Mirab is paid by entire farmers of scheme at the end of wheat harvesting period. Farmers stated that, we pay one Maani Kabul (7 kg) wheat per 60 Jerib (12 hectare) owned land for their work.

Farmers were asked about Mirab effectiveness in management of irrigation system; an answer of five was good and from the one was fair in the upstream. Answers in midstream was like, three farmers replied good, one fair and two poor. Also the same question has asked in the downstream which answer of one was good, two fair and three poor (Figure 9).

Figure 9: Effectiveness of Mirab in the irrigation management system



Source: Field Work

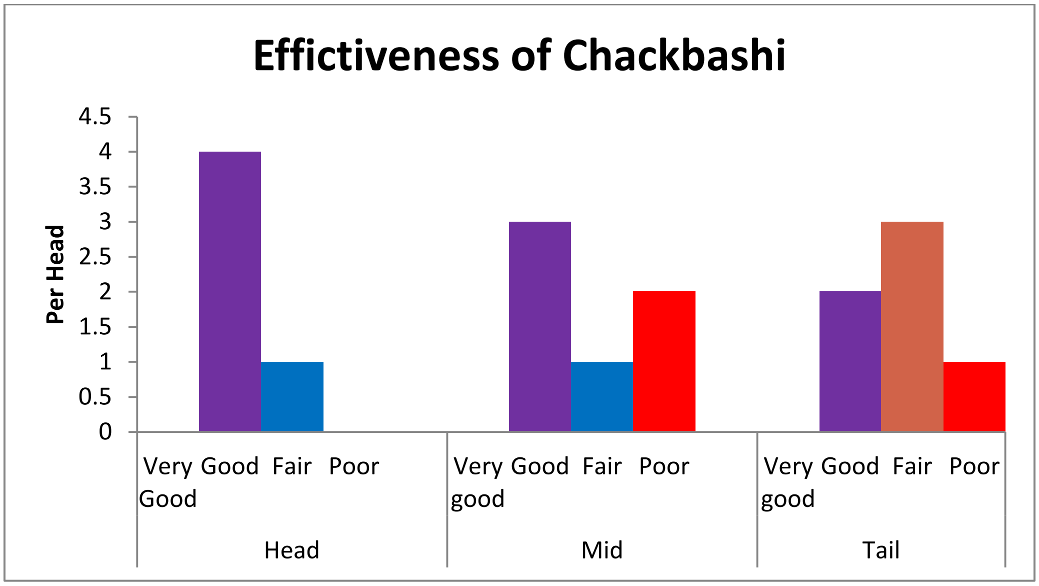
4.2.4. Chakbashi (water administrator)

Chakbashis were Water Masters for specific Village, who were responsible to manage village level water distribution system. Chakbasi also come to the ground by election of his own village elders and farmers. Which this election take place at the end of Afghan year (mid March),Mirab inform all Chakbashies for reconstruction or other emergency work in order to make ready own villagers, he collect villagers for reconstruction, maintenance and cleaning of canal and outlets in needed time.

Farmers of his village pay him 14 kg wheat per 30Jerib (6 hectare) of owned land per a year at the wheat harvest time for his performances.

Farmers were asked about their Chakbashi effectiveness in the management of irrigation system, answer of four were good and the rest three was fair in the upstream, in the midstream answer of three were good, one fair and two poor. Meanwhile, in the downstream two farmers have judged good, three fair and one poor (Figure 10).

Figure 10: Effectiveness of Chakhbashi in irrigation management system



Source: Field work

4.2.5. Farmers and Canal elders

Farmers are responsible to use their own allocated water from the canal and participate in the needed work when they are informed by their Chakbashi and Mirab, when they are not able to participate in public work about canal they pay for each day in order to Mirab or Chakbashi appoint labor instead of him.

Elders of Village and district get together to solve emergency issues such us conflict resolution, and general needs and problem solution on village or canal level. Moreover, they meet governmental and NGOs authorities in case of requirement.

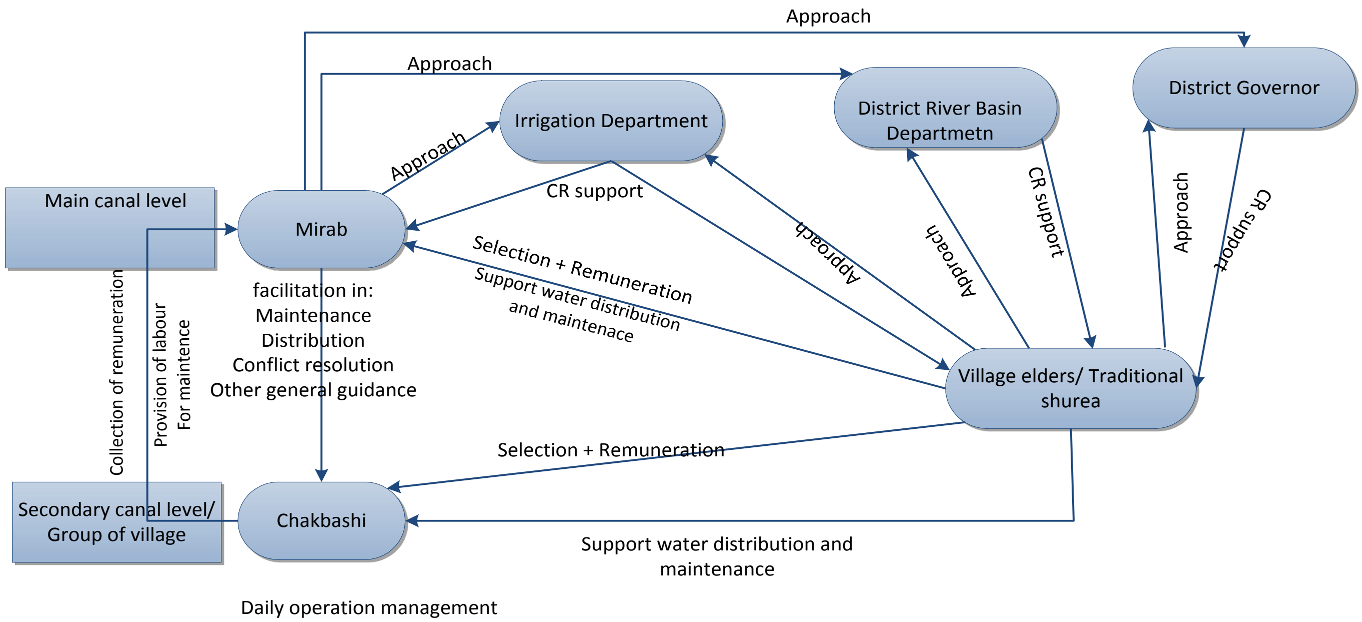
Table 3: Community based irrigation management hierarchy in the RBC system

Level	Title	Responsibility
Main System	Mirab	– Overall management – Coordinating hasher and cash contribution – Coordination emergency response – Supervising chakbashies.
	Mirab and Elders	– External coordination (e.g. with Governor, Government and NGOs) – Conflict resolution – Intake construction and maintenance through local people

Secondary and tertiary System	Chakbashi	– Managing of branch water allocations and turns – Coordinating annual maintenance – Conflict resolution – Management of labor for maintenance when Merab inform him.

Based on mentioned description there is tow tier Mirab system in the area which is shown in following (Figure11).

Figure 11: Two wheel Mirab illustration system in the RBC service area.



4.3 Irrigation System on Right Balkh Canal

As is it mentioned before that informal irrigation system is prevalent in 90% of irrigated area of Afghanistan and virtually all 99% of the country's irrigation systems by number, nearly 29,000 informal irrigation systems are estimated to be in Afghanistan. The command area of Balkh district has 6 villages which are benefited from Right Branch of Balkh canal.

4.3.1 Water Right

The water law of 1981 was stated that water right for irrigation should be determined for each jerib (2000 m^2), which a fixed amount of water per jerib, also in 1981 law was stated, the amount of water needed for irrigation shall be determined according to the area under cultivation, the kind of crop, the irrigation regime, the water rights documents, the local practice and the amount of water in its resource. In water law of 1991 was mentioned that water rights can be ignored if they are surplus to requirements.

The Draft Water Law of June 2008 has approved by Parliament and by the Senate. There is mentioned in the draft water law of June 2008 that, fulfilling the rights of water considering the appropriate/suitable water uses traditions and customs in the country. This suggests that there will be a selective process to determine which traditions and customs should be kept.

In the article 2 of water law it specified that water belongs to the public and government facilities the management of it. In article 2 implies that there is no local right to water without the agreement of the state, since the water is the property of the state.

In the article 7: water is free, but the cost of investment and provision of services relating to supply, delivery, storage, diversion, treatment, operation and maintenance can be charged by the service provider.

4.3.2. Water Right Practices in RBC System

Water right in RBC service area is based on the traditional rules and understanding, concept of water right in traditional rule is: water is a gift of god and it is free for drinking, irrigation and other purposes. However, distribution of water for irrigation purpose is also dealing under traditional rule.

4.3.2. Water Allocation and distribution

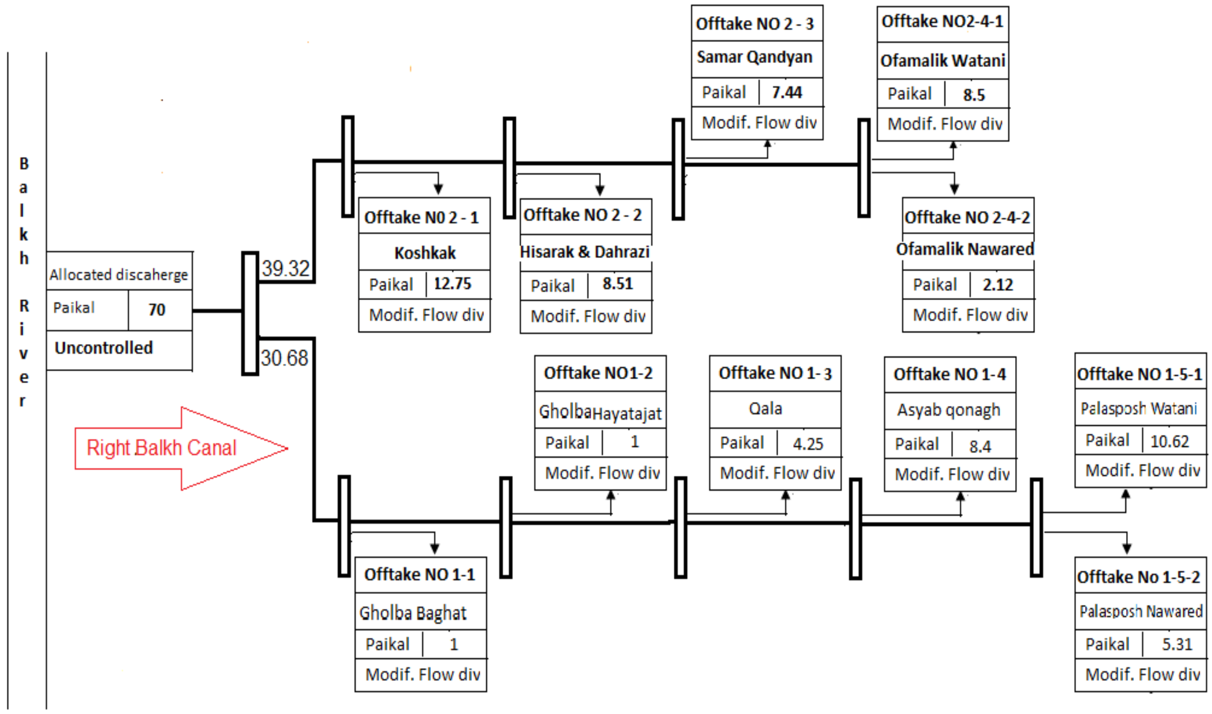
4.3.2.1. Water Allocation

Command area of the RBC irrigation scheme fed both side of the canal 2209 hectare land. The basic principle of canal water is allocated based on the size of land and it is shared proportionally by Paikal traditional system within the canal off-takes and dividers. Allocated water is delivered base on irrigable land size: the larger the land the greater water entitlement, while 1 paikal unit is 72 hectare or 360of irrigation land. The delivery of irrigation water for 1 paikal is determined for the width of the canal head or intake (Sarband). Initially, width of 1 paikal in Sarband was 3-3.5 inch but in the regime of King Nader shah (1939) it has reduced to 1square inch. Recently, the paikal system has revised under supervision of present governor (Ata Mohammad) in the 2005.

Paikal allocation had determined based on legal document (qawala) granted during the regime of King Nadersah in 1925. The water is diverting (flowing) to each area from specific off take which is constructed base on basic engineering logic while main intake of canal from river is constructed by sandy or gravel bags, which are uncontrolled as it is shown in (Image 1).

Image 1: Intake of Balkh Canal from Balkh River

Figure 12: Water allocation flow within Balkh Canal



The allocation of water from river is 70 Paikal which is equal to 0.91m^3 sec^{-1}, then it is divided into two canals Right Balkh Canal that has 30.68 Paikal which is equal to 0.40m^3 sec^{-1} and Lift Balkh Canal has 39.32 Paikal which is equal to 0.51m^3 sec^{-1} which is-shown in (Figure 12).Nonetheless, Right line division is representing RBC allocation and my study area. Water allowance has been determined 1Lit sec^{-1} $ha^{-1}$from the past for the land which its custom was paying. However, custom of land is not paying now but they get available water from the canal. Director of River basin of Balkh province said this is in case it we have enough water in the river, required water from Balkh river is 400m^3 hr^{-1} but presently we have only 18m^3 hr^{-1} the river. Therefore, farmers do not have this amount of allowance now.

4.3.2.2. Water distribution system

According to farmers responds water distribution is based on landholding at RBC scheme and water turn was informal. They stated that we have distributed water among us five minutes $Jerib^{-1}$(0.5 ha) from the past, if water discharge is low in the canal we get less water, if canal has more water we get more water. Furthermore, water in canal is distributing by turn, which everyone in the Head and Middle can receive water for irrigation after each 7 days while the Tail reaches farmers had irrigation interval after 10 days but in winter and late winter season we

Image 2: Canal occupied by weeds

have more water, without water turn, how much we want we can get it.

Variations of the discharge in the canal depends on water availability in the Balkh River, Balkh river is seasonal river , some time river has enough water even additional water which cause flooding and destruction in the area (specially in late winter season) while sometime there is no sufficient water for irrigation. Furthermore, canal infrastructure and physical structure was very poor. Canal was unlined, unclean with massive plantations (Image 2).

There was no intervention of government in water distribution system and it was completely managed by local community under supervision of one general water master which is called Mirab and every village's specific water master which is called Chakbashi (which is described in under stakeholders).

Major crops were irrigated by Flood irrigation method in this scheme by having insufficient land level.

General answers of farmers about how the
system can be improved were that, Government or any Donor NGO should care about our canal maintenance, turnout structures of tertiary canal and field should be lined for us.

4.3.2.2.1. Flexibility

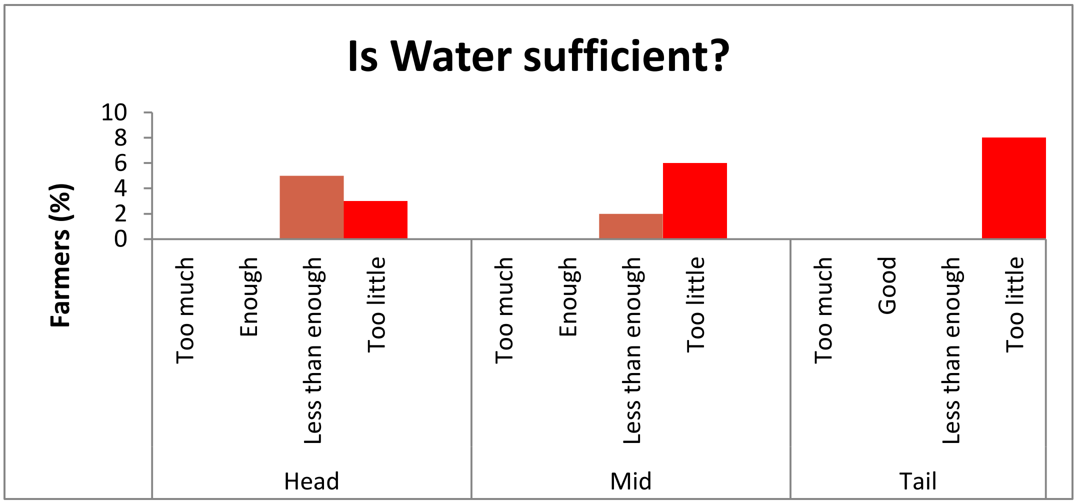
Flexibility in the RBC service area is insufficient, frequency, flow rate and duration in the main and secondary canal is changing frequently, and it is dependent on the availability of water in Balkh River because there is no reservoir to store the flood and snow melted water, however if the temporary and permanent weirs of the canal are functioning sufficiently in the whole period of availability of water in the canal still flow rate is not consistent because upstream water users using illegally more water and downstream is getting less water.

Flexibility in the farm level is more complex rather than main and secondary canals; each Jerib of the land has a fixed duration of the water, also water delivery is fixed which farmers get water after every 7 days in upstream and 10days in downstream of the canal, and there is no option for farmers to select frequency, duration and flow rate from canal water.

4.3.2.2.2. Adequacy

The adequacy of RBC irrigation service in the area is also improper as flexibility, due to the poor adequacy in the system, every year farmer losing their yield, as mention before flow rate in the systems are not constant and it is changing quickly. Farmer said flooding and over availability of water in canal destroys our lands and path in the winter season which this problem was higher in the downstream area because width of their canal was small and don't has capacity of massive water. Therefore, it rises to land, path and homes. On the other hand, frequency (irrigation turn) is constant which farmer cannot get water after water turn, in the summer season evapotranspiration is very high and crop require more water which farmer cannot supply water on time to the crops. On the other hand, in the winter when crops do not require water, still farmers supplying water to the crops which a huge water losses. Farmers of selected villages were asked about adequacy in canal system during the year (Figure 16). At the Head reaches 5 farmers answer was that, water is less than enough water for us and 3 said available water is poor for our crop. At the Middle reaches farmers answer was 2 less than enough and 6 too little. Meanwhile, answers in the Tail reaches were too little at all.

Figure 13: Adequacy of canal in the scheme.



Source: Field work

4.3.2.2.3Reliability

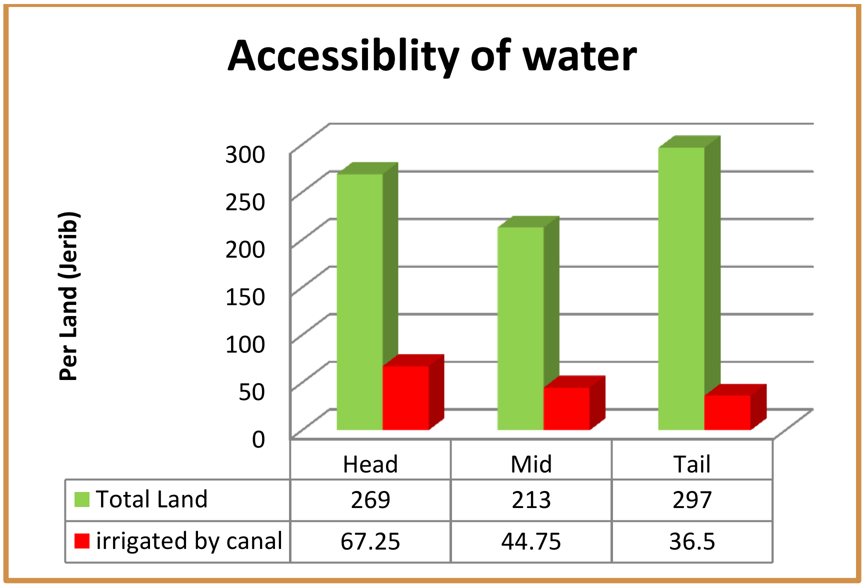
There is no confident for the farmers that how much and when they will get water for their crops, however it is possible that River supplying water more than requirement of irrigation, but there is no reservoir to save the water for agriculture. Rainy season in the area is winter (Balkh Rive is full of water) as well evaporation on that time is very low which crops do not require much water but from other side in the summer water discharge in Balkh River is limited and crop water requirement is also high which farmer don not have water, due to this inconsistence farmer cannot make irrigation schedule for his cultivated crops, may years it has been happened that farmers lost most of their yield, because some time rainy season is very short but with very high intensity which can say rain was enough for the crop life but there was no possibility to store the water and farmers in the summer season are not getting water to irrigate their crops.

4.3.2.2.4 Equity

Even though you may be the son of Mirab, it is better to be one intake higher up (the canal). Afghan proverb

Equity of irrigation service is also like other measures poor; however farmers receiving water which is specified by the water entitlement (they receiving frequency and duration when water is available in the Balkh River), but no one can guaranty flow rate (volume of water), e.g. sometimes farmers in one hour duration (winter season) getting water how much they want but from the same canal in the summer season they don't have water for few cultivated land. when the flood is occurring the level of water is going high in canal and a huge amount of water is conveying by canal, if it is the start of the irrigation turn that farmer will get the maximum water but by reducing level of water in the RBC and Balkh River volume of water also reducing in the canal, and farmer is in the last day of irrigation turn getting the minimum water. Equity between upstream and downstream of canals also considerable poor, for instance all the agriculture land by water law which is relevant to the same canal has to receive same fixed duration of water and same amount of water, but upstream farmers receive more water rather than middle and end farmers. Farmers are ranked accessibility of water from the canal as in the Head out of having 269 Jerib were 67.25 irrigated and in the Middle out of having 213 Jerib were 44.75 irrigated while from 297 Jerib only 36.5 Jerib were irrigated which is indicated in the Figure 14.

Figure 14: Accessibility of water from canal



Source: Field Work

4.4. Cleaning and maintenance

Watercourse, cleaning and maintenance of canal and Sarband (Main diversion of water from river) was responsibility of the community. There was no intervention of government or any NGo As it is stated under Mirab and Chakbasi that water users are informing for cleaning and maintenance in the Masjed by Chakbashi or Mirab and they collectively take decision with elders of village how and when to do it. Thus, cleaning and maintenance carry out based on participation but the one who is not present recover cost of labour. Cleaning and reconstruction of destroyed parts of the canal starts in month of Hoot till 3rd of Hamal (from 20th of April – 24th of March), the cleaning starts from downstream going to upstream finally reach to intake from river (Sarband). Mirab inform the farmers of downstream to start cleaning from your side, then farmers of downstream starts cleaning under supervision of own Chakbashi and going to upper side of the canal which farmer of each village join them when work reach to their area. Nonetheless, no one village stops their participation till completion of work. They also repair the destroyed parts of the canal jointly during the year and they said some time we clean the canal two times a year.

"We are unfortunate of this scheme because we get less agricultural income, less water but work more rather than others" Farmer in the downstream.

CHAPTER 5 DISCUSSION

This chapter has general overview to result and indicate proper options for its improvement combination with literature review and respondents of the informants to answer the main and sub question of the research.

5.1. Stakeholders and Policy Option

5.1.1. Policy Option

Water is the need of everyone in the society on daily basis, so the group of water user is the whole society, from other hand water is flowing across the countries boarders, people they are living outside of the country also may be influenced by water resource original country water allocation policy. So efficiency in water allocation should be an important issue for every one whom they share the same water source in the water scarce area. But the people they are directly influenced by the choice of irrigation water allocation policies are the farmers.

Charging tax policy to manage water use by farmers will put negative impact on farmers' income, to solve negative impact on the farmers' income issue, it will be more logical to spend tax revenue on the other services of irrigation system that farmers will be benefited. Water cost recovery and water scarcity in Egypt, reducing farmers' water use by 15 % through water charges would lead to a 22% reduction in net farm incomes (Gersfelt, 2007).

If water use for irrigation is regulated through a tax mechanism, It is assumed that farmers net income will be reduced, but if tax revenue is invest again to improve level of irrigation service it will have positive impact on the farmers income, because by improving level of irrigation structure and service, farmers will get more productions that will improve their livelihood.

For water regulating policies, tradition and religion also have implication for whether it will be possible to implement or not. As it is mentioned before in current condition there is no service and no charge for providing water for irrigation in the RBC Irrigation System. However, it is expected that when level of irrigation service be improved in the RBC Irrigation System farmers will be agree to pay for the services.

The policy instruments that can be used to regulate farmers' use of water include volumetric water taxes, non-volumetric taxes, quotas, market-based allocation mechanisms, and user-based allocation mechanisms (Johansson et al., 2002).

Volumetric water tax is the tax includes diverting a fixed amount of water for irrigation for his field and the farmers are charged directly by cash for the cost of water. Charging tax for providing water can be in different ways, e.g. when farmers required water for their field diverting and paying for the total volume, government is fixing tax per unit of water, It is also possible to charge tax for different volume of water different tax, e.g. each farmer can use a fixed volume of water for a fixed price in the year, but if he require more than fixed amount he has to pay more than fixed price (e.g. each farmer can use 7,000 m^3 water per year and cost of 1 m^3 of water is US$ 1/100 but if he required 10,000m^3 of water, for 5,000 m^3 has to pay US$

1/100/m^3 and for remaining 3,000 m^3 he has to pay US$ 1/80/m^3) because it will be convenience for small land holders and could be a good example of equity in the system.

Non-volumetric taxes are applied to regulate farmer's water use by other variables, which probably related directly with farmer water use of water, e.g. taxing the irrigated land, which means for fixed unit area farmer has to pay tax. However, farmers in the Balkh do not pay any tax currently, but they had paid taxes in the past based on irrigation system policy in Afghanistan. It is also possible to charge tax by type of crops and cropping pattern, by calculating crop water requirement of each crops on fixed tax based on it.

Quota is other option to regulate farmers' water use. The most direct approach is to assign individual water diversion quotas to farmers. However, the quota could in principle be related to land use or output quantities. Water markets can be established and water can than be allocated through the market mechanism, if water quotas of farmer water entitlement is made marketable (Gersfelt, 2007).

The farmers can also regulate the water use by user-based allocation mechanisms. In this way farmers allocate water among themselves. User-based allocation mechanisms require collective action institutions that have the authority to make decisions on water rights (Dinar et al., 1997).

Volumetric water pricing for the traditional irrigation system is very difficult to implement, it will be useful when traditional irrigation systems is modernized by upgrading the entire irrigation system. In reality, implementing a volumetric water pricing system is also not simply a matter of getting the technology in place for metering farmers' water diversions. A regulatory framework must also be established, with procedures for measuring the amount of water delivered as well as procedures for partial deliveries, missed deliveries, excess deliveries, late deliveries, polluted deliveries etc (Gersfelt, 2007). An administrative bureaucracy must be established to collect data on water deliveries to farmers and carry out the billing (Perry, 2001).

Implementation of the non-volumetric policy instrument of crop-specific land taxes does not require much investment in the physical structures, but it is required to collect information on each farmer, and it has to know each farmer how much land cultivated and which type of crops he is cultivated.

Implementation an output tax scheme requires information on output level of each farmer to measure cost of farmer output will be dependent on crop-market, but it will be difficult to implement in RBC service area because the crops cost in the local market does not have a fixed rate and it is changing very rapidly.

5.1.2. Stakeholders

The range of political, socio-economic and administrative system designated to develop, manage and distribute water resources. It is supported by the mechanization, process and institutions through which all stakeholders, including interest groups and all residents, articulate priorities, exercise legal rights, meet obligations and mediate differences can by supported by in it. The system determines who obtains what, when, where and how; it decide issue related the water right, related services and benefits. Thus, governance is centered on making choice and decisions. Water sector governance is complex and requires the representation of various decision-making interests. The actors may be local or central governments, sector agencies, river basin authorities, irrigation management authorities, representative of people, consumers, and private companies and so on. Thus, governance is not limited to government, but includes the private sector and civil society as well.

5.1.2.1. Directorate of River basin of Balkh Province

Based on field work it is observed that this organization had to some extent sufficient staff to have influence on water allocation from river basin to each canal intakes and off-takes along the canal but there was need of proper experts and trainings to measure water discharge, losses within canal level then allocate water for each region scientifically that all water users have equal water for specific dimension of land.

5.1.2.2. Department of Irrigation of Balkh Province

As it is mentioned under Department of Irrigation of Balkh Province in the result that there was only one officer which manage the irrigation system and have contact with all stakeholder across the Balkh River Watershed, this structure of organization by one officer can just dream and not to do anything. Prior to the 1980s, the role played by local governments, especially agriculture department, was significant at many levels. The rather rapid collapse of government support has contributed to the decline in the performance of local water management institutions, due to which all farmers and agriculture production have badly affected. Under Amir Amanullah Khan (1919-1929), Nadir Shah (1930-1933) and King Zahir Khan (1933-1937), the allocation of individual water rights, the publication of the Law on Irrigation and the establishment of the department if irrigation in Balkh laid the foundation for improving the management of the Hazhda Nahr system. However, in late 1938, the control and support exercised by the central government over the canal network, local water management personnel and agricultural department staff to monitor water distribution in the field regularly. But later on by collapse of government and department in the early 1980s, dramatic changes in water access began to occur in many places.

Thus, this department shall be redesign and support both financially and technically in order to be able to once again survive better irrigation system jointly with water masters and users.

5.1.2.3. Supporting existent Mirab system

As it is mentioned before (under Mirab) Afghanistan has a traditional system for managing irrigation water called the Mirab system (Mirab is the water master or administrator who is responsible for deciding the distribution of irrigation water to farmers and also responsible for operation and maintenance of the main canal, secondary canal and irrigation system main structures).

On the other hand, there is massive argument that Mirab does not have the organizational and institutional capability to manage irrigation system up to desired level. Existing Mirab system needs to be transformed into a legal entity and formal institution with greater efficiency and organizational capability, this is to enable water users and farmers take charge of O&M of irrigation infrastructure and to enable them to enter into agro-business contracts (USAID, 2006).

However, the result of this study revealed that most of the farmers were satisfy from their Mirab and Mirab system. They were insisting to have their historical management system but at the same time they emphasized on government support and coordination. They expected the government to help them in the improvement of physical condition of the canal and control structures. The question arises that why the Mirab was able to manage this system before 1870. The probable answer will be that the government of that time was supporting Mirab and monitoring the whole system. Meanwhile, the desire of communities to resolve their own disputes is an age-old, country wide experience. Communities see themselves as basically independent in matters of water management and resent imposed structure from outside. Therefore, in present situation it is proposed that the existing Mirab system should be strengthened and improved. The capacity building trainings should be given to Mirab. The Mirab system should be supported both financially and legally. The Mirab should be full authorized in the decision making with full back of the community and government to implement water rights. Public awareness in the community through elders and religious scholars would have positive results in persuading water users to stop illegal water use and respect water rights.
Mirab system should have a committee selected by electoral process which will be responsible for solving water problems and improve the system. The committee should have at least one educated and trusted person as treasurer who will be responsible for collection and management of fund raised by the mutual contribution of the water users.

5.1.2.5. Capacity Building of Farmers for a Better Agricultural Practices

The main aim for improving water management in agriculture is to achieve a greater yield (Critchley and Siegert, 1991) and farmer should have knowledge of the irrigation requirements for the different growth periods of the crops (Brouwer and Heibloem, 1986) and (Critchey and Siegert, 1991).

Capacity building definition according to the United Nation Development Program (UNDP): the process by which individuals, groups, organizations and societies increase their abilities to perform core infections, solve problems, achieve objectives and to understand and deal with their development needs in a broad context and a sustainable manner (UNDP, 1998).

Capacity building is differentiated at three levels: at the level of the enabling environment, at the level of institutions and at the level of the individual (FAO, 2004).

The enabling environment: The enabling environment relates to the policy making processes of national government, which can facilitate, or indeed hinder, the development of institutions and individuals. Specifically it refers in this case to the formulation of appropriate policies to support the sustainable development of irrigation and drainage, and the implementation of these policies through legislation and regulation (Tom, 2007).

Capacity building of organizations and institutions: capacity building of organizations and institutions provide the structures and processes through which individuals utilize their competencies in achieving their objectives and goals. However, if individual groups have good skill and knowledge but without capable organizations and institutions they will not able to perform up to desired level.

Capacity building at the individual level: capacity building initiatives at the individual level, through training programs and other human resource development activities should be launched. Training of individuals certainly has a role to play in increasing knowledge, improving individual competencies and in raising motivation and expectations in the appropriate circumstances.

For improving Irrigation System, Capacity building for each level (the enabling environment, organizations and institutions and the individual level) and participation in irrigation activities are essential for better coordination of implementation, operation and management of irrigation system.

Capacity building has to be based on each group responsibility in the irrigation system, e.g. for promotion RBC service Irrigation scheme farmers require trainings in land preparation, cropping patterns, crop rotation, sowing dates, selection of high yield crops (resistant to diseases, drought and required less water), introduction of cash crops, optimization of agriculture practice (application of fertilizer), irrigation management at field level in a more efficient way (irrigation method, irrigation scheduling, drainage, reduce water wastages, reuse of wastewater). Farmers have to realize the importance of water and agriculture, and keep in mind to increase production to take part for improving economy of their own selves and area.

5.2. Options to Improve Water Allocation and Distribution at Canal Level

Mankind cannot live without water resources which provide life as well as environmental values. The scarcity of water can both develop social and environmental problems along with economical disturbance that plays an increasingly important role in public decisions on water projects, reallocation proposals and other water policies (World Bank, 1997).

Water is a common pool resource that is consumed by several users from collective resources (river, lake, reservoirs, groundwater and floodwater) water is collected with the help of technologies for various economic sectors, such as industrial, agricultural, hydropower, domestic use and environmental playing the major role. Due to the expansion of population growth, urbanization, economic growth and improving life style competition for water is increasing especially in the countries they have mere sources of water. Therefore, the efficiently use of water and its allocation and distribution has become a major issue in the developing and least developed countries.

Despite differences across river basins, most systems maintain, in theory, relatively fair water rights based on the principle of the allocation of water proportionally based on land. However, in numerous locations, assigned rights are no longer respected. In fact, the gap between the water subject to rights and the amount of water distributed looms large as a major obstacle to equitable management of irrigation systems (Thomas and Sabawon, 2011).

There will be no need for water allocation if the exact quantity of water always available at right time, in right place, and with exact quality. However arrangement for equal distribution among the farmers becomes an important issue when water availability is limited. Therefore, the following option for the water allocation among the farmers in the Balkh district is necessary to be discussed below;

As it is mentioned in the Result Chapter, there is a big problem of water allocation between up and downstream farmers along the RBC. Upstream farmers get more water compared to downstream farmers. Therefore, the water allocation has to be arranged in such way that, the boundaries between the two sides has to be recognized and when the water is available in the canal, the downstream canals will get full quota and the extra water can be diverted to the upstream and can be divided proportionally between each of them. There is also a possibility of a fixed irrigation rotation, if both parties agrees. In which, the first irrigation turn downstream can receive the required amount of water and the upstream will be diverted to the left over water and in this way will be divided proportionally between themselves (upstream canals). while in the second irrigation turn upstream will receive the required amount of water and downstream will receive the leftover of water and will be divided proportionally among themselves (downstream canals). This practice will be repeated between upstream and downstream.

Other possible solution can be that upstream and downstream will share water proportionally. Under this agreement each water user split the trouble of water shortages proportionally. Therefore, they divide the risk of shortages proportionally (McCormick, 1994). This arrangement can be more logical compare to other, which is mentioned above, because total upstream or downstream will not effect by water shortage, risks of water shortage will be share within the canal proportionally. Furthermore, in water allocation, condition of this unlined canal is not taken; such as amount of losses is not calculated (AWAT, 2010). Thus, canal losses and available discharge of availability of water should be measured in different places and timings. Then, water allocation per area should be considered in order to authorize with community to take decision for reallocation and distribution of the system along the canal to every single water user has proportional water per specific irrigated land.

5.2.1 Options to Improve Flexibility

The flexibility of irrigation scheduling will be quite high if it is more convenient to the farmers. There are three parts of flexibility that includes components frequency, duration and flow rate. Farmers will be happy and theoretically acceptable if farmers receive water on full demand. However, every irrigation practice has its own flaws. For example, limitation in RBC scheme has water shortage, lack of irrigation structures, insufficient management, no government control of water usage by farmers and unskilled farming etc.

When availability of water is enough according to requirement and irrigation system is also modernized. It will result in practicing high degree of flexibility, which in turn will benefit the irrigation structure works and functions appropriately. Farming is a uncertain business and the one who is always ready for this risk is a successful farmer, which will result in the risk reduction and be able to invest on their farms and productive crops. Therefore, they must receive water with much flexibility. However, if high water flexibility to farmers might result in water loss, but it can be solved if the water delivery to the farmers are based on volumetric and crop water requirement (with frequent monitoring by responsible authority) due two which the farmers will use the water very carefully without wastage.

The following points should be taken into consideration to make irrigation scheduling more flexible for the farmer;

- Two or three days advance notice should be given for water delivery on demand.
- Water deliver must be volumetric, and the volume of water to supply must be known by water authorities and farmers during the entire crop season.
- The flow rate and duration of the irrigation can be changed on each season;
- Water delivery to small land owners should be given collectively. It means that the small farmers must be divided in groups, based on the type of crops they cultivate and their land location to avoid water losses, because it will be difficult to supply water for the small land owner with high flexibility.
- Training should be given for practice of volumetric water delivery to water officials and farmers.

5.2.3Options to Improve Adequacy

water supply scheduling has to design based on type of crops, all the crops which farmers have plan to cultivate has to divided into two parts, sensitive crops, which needs more water and resistance crops that can grown in presence of water shortage. The crops should be compared with water requirement and canal capacity with the help of technical group. Moreover, it could be further easy to calculate maximum required water season (summer is pick crop water requirement in RBC Irrigation System), and they can advise farmers to adjust their crops cultivation based on water requirement.

Adequacy can be affected due to the following reasons;

- If cleaning of the sediments and maintenance of the canals are not on time;
- Water availability is not estimated professionally, which is less than crops water requirement of cultivated crops.
- Canals capacity is low compared to the command area.

5.2.4 Options to Improve Reliability

Other important measure of irrigation services is reliability, which is the measure of confidence of the irrigation system to deliver water to farmers as it is expected from the system. By ensuring an adequate and reliable supply of water, irrigation can increase plant growth from 100 to 400 % (FAQ, 2003, Paudel, 2010).

We should not lose vision of the fact, if the water deliveries are unreliable, confidence in a new program will be immediately lost and irrigation scheduling program will never achieved. Given a choice between a programs having high flexibility but unreliable deliveries (due to operator errors, technical difficulties, politics, etc.) versus a less flexible but very reliable system, the latter is preferred (FAQ, 1996).

If the design of irrigation system and irrigation scheduling practically be confident for water delivery on time, it will give opportunity to farmers to invest (use of high yield seeds, use of fertilizer etc.) on their farms which will be able to get desired yields. Delivery of water in time is influenced by the water delivery schedules, sensitivity of the off-take structures, and hydrodynamic performance of the canal network in combination with the water level regulators and maintenance conditions of the schemes (Paudel, 2010).

To achieve reliability in the RBC Irrigation scheme all the factors which influence level of irrigation service parallel should be improved, however some of the factors (upgrading of farmer's and other responsible skill, making a data base to collect information before farmers starting cultivation and make an efficient irrigation scheduling, supporting water masters and having strong committee of farmers with Mirab etc.) will take time but could be best improvement in the current situations.

5.2.5 Options to Improve Equity

The inequity in water sharing is well captured by local proverbs pointing that access to irrigation water is mainly based on the location of fields within a canal systems: "Better to be a servant in the upstream area than a king in the down streams''.

Equity in irrigation is a measure of the access to a fair distribution of the water resource base on entitled water (Malano and Hofwegcn, 1996). It is very difficult to implement equity in an irrigation system. It will be become more difficult if several small irrigation systems using the same main canal because of their location upstream, middle and downstream. Upstream farmers get more water than middle and middle get more water than downstream that have direct impact on farmers' income. Furthermore, inequity in the system creates critical social problems, like nonpayment, not participating in operation and maintenance of the canal and confliction among the water users. The following suggestions to improve equity in the RBC scheme are discussed below;

A significant different between upstream and downstream flow rate is the major reason of inequity in the RBC Irrigation System. However, base on water law all farmers have to receive the same amount of irrigation water within a scheme. Other natural reason like flow rate in the main canal changing because water availability e.g. water variability in Balkh River is also supporting inequity in the system, which can be solved after making good structure of the system and reservoir. In order to improve equity in the RBC service area between upstream, middle and downstream, available water in the main canal has to be distributed proportionally and the flow rate measurement structures also has to install to check the flow rate. It means discharge of irrigation water for up, middle and tail user has to be the equal (off take of each secondary, tertiary canal and on farm water diversion point has to be fixed and the volume of water has to measure in each point).

CHAPTER 6 CONCLUSION AND RECOMEDATIONS

This Chapter concludes the thesis with significant points pointed out in research project and suggests some possible recommendations for the problem solution briefly.

6.1 Conclusion

Based on water law, the use of water is free, but the cost of providing services related to the operation such as delivery, storage, diversion, treatment, and maintenance can be charged by the service providers. Water is belonging of the people and government only facilitate its management.

Right Balkh Canal has 9 km length with 2120 ha cultivated land, which was fed by 30.38 Paikal water. Selected area cropping pattern shows that there is two season crops, by 60% wheat, 6% onion and 1% alfalfa during winter season while the rest of 33% land was fallow. During summer season 64% cotton,4% water melon, 3%melon and 2% vegetables were grown while remaining % land was fallow. Less cultivation of vegetable and high rate of fallow land indicates water scarcity and mismanagement of water in the scheme.

The factors influencing water distribution can be classified into physical and social factor;

- Equity, Adequacy, Reliability and Flexibility

Although, theoretically it was assumed that water was proportionally distributed and allocated among community but in fact there was no equity and adequacy between Head, Mid and Tail water users due to the losses of water by seepage and weeds in the canal. Usually the farmers at the tail gets less amount of water as compared to mid farmer while mid farmer less than head respectively. The availability of water is limited and the farmers do not have flexible and reliable water supply in time of demand for their crops in general, while the farmers at the tail in particular. This is because of the fixed and long distribution system of water where each farmer gets water after 10 days. This problem become more prevailing in summer, when the temperature is high and crop growth is fast where there is maximum evaporation of water. Moreover, this area is arid and minimum rainfall occurs in summer which further adds to this problem. Conversely there is more rain and snow fall in winter and this snow melts in spring season and then the situation becomes better in early spring season. But sometime the melting of snow also causes flooding which erode fertile land.

- Irrigation Schedule

As there was no intervention and guidance of any NGO and Government for the farmers, the Cropping system in the field was not based on calendar and irrigation schedule, rather it was practicing by having their own traditional experiences

- Water Allocation

Water allocation in the Balkh province, including Balkh district is based on the traditional Paikal system which is for 360 Jeribs or 72 hectares irrigated land. Water share along the canal is proportionally allocated based on irrigated land in every Off take, where the distance of irrigated land along this unlined canal is not taken into account.

- Stake holders' intervention

Directorate of River Basin was involve in allocation of water per canal, and each outlets but they do not have that much capacity to first measure the water losses per area and then allocate the water proportional to the loss of water per specific land in the scheme.

Irrigation Department is a part of Agriculture Directorate. It has the responsibility to deal with irrigation system of the entire province at community and governmental level as well as to have coordination with NGOs. But there was only one Irrigation officer in this Department for the whole province. Therefore, it is not possible for one person to accomplish so many tasks in proper way.

Mirab is the top manager for entire scheme and Chakbashi for specific village that means middle manager for managing of distribution and maintenance system in the command area. They were managing water distribution system traditionally and no one of them was educated. Based on farmers statements, they had less influence in keeping water distribution system equally within the community.

Farmers and elders were also involved in this system. For example, farmers were responsible to have part in the cleaning and maintenance of the canal under the supervision of Mirab and Chakbashi while elders were mostly involve in solution of conflict through jirga system and having contact with authority in case of problem encountering.

Population growth is the factor which enhances demand of food and it had direct effect of intensification of land growing and irrigation scarce as well as irrigation management tension.

Options for water productivity

The productivity of water can be increased by cleaning and lining the canal which will reduce the loss of water through seepage and evaporation of water through weeds. Moreover, measuring the losses of water through seepage and other means and then distribution of water proportional to the distance of land from the main canal will also improve the productivity of water. The flexibility in distribution system will also improve the availability of water during the time of demand for the crop.

Support of stakeholders

There is lack of capacity building training and financial support for Directorate of River Basin personnel in order to allocate and provide productive facility for best way of water management and water production.

Increasing the staff for Irrigation Department to play key role in controlling and monitoring of water allocation and distribution system will also improve water productivity. Training of farmers and all local stakeholders for better irrigation methods and preparing irrigation schedule by using Crop Water formula or software for community level stakeholders (Mirab, Chakbashi, Farmers and involved elders) will also help in improving the system.

Capacity building and public awareness through government elders and religious scholars is determined for using irrigation water legally which can solve conflict and equity phenomenon. Existent traditional Mirab system should be supported by government and farmers of the area. Furthermore, Farmers should be trained for better crop irrigation practices.

6.2 Recommendations

- Water use right for agriculture in the irrigation system which wants equal water should practically come into being.
- Free water use for agriculture has to be changed and water has to be projected as a valuable good which will improve accountability of water use. This will prevent water losses and will also help the irrigation system to become financially sustainable.

- All responsible stakeholders engaged in Agricultural water management need to be clearly defined, upgrade their capacity and appoint them significant responsibility along with authority.
- Mirab and Chakbashies should be supported by government and local community as well.
- In the existing condition water has to be distributed proportionally and equitably. To make it clearer, Head reaches, Middle reaches and Tail reached water users should receive the same amount of water ($m^3 ha^{-1}$) per unit area at the head of their land.
- Irrigation scheduling should be arranged based on crop water requirement and should be in hand to water users.
- The canal is unlined and having a lot of weeds growing in it which need to be constructed the major destroyed parts and should be kept cleaned.
- Farm turnout structures should be installed for better flow control and saving of leakage losses.
- Water variability in different season and floods has been suffered agriculture production. Thus, for saving flood and extra water soil and water conservation system should be applied.
- Adopting new technology (drip and sprinkler irrigation system) can improve adequacy and reliability in the system
- There was no technical data available for many technical parameters such as measured discharge of water per different area, even per outlet as well as calculated data of water losses along the canal. Therefore, further study is required to practically do research for gathering technical information.

References

Ahmad, M. and Wasiq, M. 2004. Water Resource Development in Northern Afghanistan and Its Implications for Amu Darya Basin ADB working Paper NO.36

Azam, M. and A.D. Hussain 1990. Irrigation water supplies and demand for the Rakh Branch Canal. Journal of Engineering and Applied Sciences, Vol 9 (2) pp. 49-459.

AWAT, 2010. Balkh Watershed Diagnostic Analysis Report. Water, Agriculture and Technology Transfer (AWAT) Project.

Balkh District Development Assembly (2008). Summary of the district development plan. Ministry of Rural Development. Available [online] at: <www.mrrd-nabdp.org/.../**Balkh**/**Balkh**/Summary.pdf> *Accessed at: [June01, 2001]*

Balkh Provincial Profile (2007)Available [online] at: <www.nps.edu/programs/ccs/**Balkh**/**Balkh**_PDP_**Provincial**_**profile**.pdf>Accessed at: [June03, 2011]

Bos, M.G., M.J. Burton, and D. J. Molden. 2005. Irrigation and Drainage Performance Assessment: Practical Guidelines. CABI Publishing Wallingford, UK.

Cook, S., F. Gickhuki and H. Turral. 2006. Water Productivity: Estimation at Plot, Farm and Basin Scal. Basin Focal Project Working Paper No. 2 (Draft).

FAO, 2003. The irrigation challenge: Increasing irrigation contribution to food security through higher water productivity from canal irrigation system. Issue Paper No. 4, FAO, Rome, Italy.

Gersfelt, B. 2007. Food Policy for developing countries: The Role of Government in the Global Food System. Cornell University, Ithaca, New York.(1)

Hengsdijk, H., W.V.D. Krogt., W. R. J. Verhaeghe. And P.S. Bindraban. 2006. Consequences of Supply and Demand Management Options for Integrated Water Resource Management in the Jabotabek-Citarrum Region, Indonesia. International Journal of River Basin Management 4(4): 1-8.

Heydari, and Nader. 2005. Determination of Agricultural water productivity of some major crops in different region of Iran (Regions: Kerman, Hamedan, Moghan, Golestan, Khuzestan). Agricultural Engineering Research Institute of Iran.

Hurmaz, S. 1999. Assessment of conveyance losses and maintenance status osSurizai Minor of Warsak Gravity Canal Irrigation System, Master Thesis (Unpublished) Department of Water management, NWFP Agricultural University Peshawar, Pakistan.

Igbadun, H.E., H.F. Mahoo., A. K. P. R. Tarimo. and B.A. Salim. 2006. Crop Water Productivity of an Irrigated Maize Crop in Mkoji, Sub-Catchment of the Great Ruaha River Basin, Department of Agricultural Engineering and Land Planning, Sokoine University of Agriculture, P.O. Box 3003, Morogoro, Tanzania

International Commission on Irrigation and Drainage (ICID), 2008, 20th International Congress on Irrigated and Drainage, Lahore, Pakistan.

International Commission on Irrigation and Drainage (ICID), 2009, Journal No. 58: 1-16.

Johnson, S.I, W.D. Kemper and W.K. Lowder Milk. 1978. Improving irrigation water management in the Indus Basin. Water Resource Bulletin. 15 (2): 52-60.

Johansson, R.,Tsur, Y., Roe, T.L., Doukkali, R., and A. Dinar. 2002. Pricing irrigation water: a review of theory and practices. Water Policy. 4:173-199(2)

Khan, M. Z. 1991. Net monthly and seasonal irrigation requirements for wheat crop in Peshawar vally, Sarhad Journal of Agri. VII (4) 454-460.

Khan, M.Z. 1992. Assessing water supply and demand for wheat crop at the Haji Zai, Peshawar M.Sc thesis unpublished, Department of Water Management NWFP Agricultural University, Peshawar, Pakistan.

Klemm, W. and S.S. Shobair. 1996. Agriculture Sector Study-Irrigation and Water Resource in Afghanistan. FAO, Rome, Italy

Lee, J.L. 2007. Water Management, Livestock and the Opium Economy; The performance of Community Water Management Systems. Research and Evaluation Unit, Kabul, Afghanistan.

Liu, J., J.R. Willium., A. J. B. Zehnder. and H. Yang. 2007. GEPIC Modeling Wheat Yield and Crop Productivity with High Resolution o a Global Scale. Agriculture System. 94: 478-493

Mdemu, M. V., C. Rodgers., P.L. G. Vlek. and J.J. Borgadi. 2008. Water Productivity (WP) in Resevoir Irrigated Schemes in the Upper East Region (UER) of Ghana. Center for Development Research (ZEF), Walter-Flex Str. 3, D-53113, Bonn, Germany

Molden, D., T. Oweis., P. Steduto., p. Bindraban and M.A. Hanjra. 2009. Improving Agricultural Water Productivity between optimum and Caution. International Water Management Institute, Colombo Sri Lanka.

Murray-Rust, H. and W.B. Snellen, 1991. Performance assessment diagnoeis. IIMI, ILRI, IHE, Glossary. pp.130

NIAS, 2008. Balkh Province Agricultural Profile. USAID (United State Aid)/ASAP (Accelerating sustainable program), Afghanistan.

Pacha, G. 2002. Performance evaluation of irrigation water management practices at three selected traditional karez schemes in Ghazni, Afghanistan. Master Thesis (Unpublished). Library of Peshawar Agricultural University, Pakistan.

Pain, A. 2006. Water Management, Livestock and Opium Economy. Afghanistan Research and Evaluation Unit (AREU). Pp.29.

Perry, C.J. 2001. Water at any price? Issues and options in charging for irrigation water. Irrigation and Drainage. 50:1-7

Qureshi. A. S. 2002. Water Resources Management in Afghanistan:The Issues and Options. International Water Management Institute (IWMI), Working Paper 49.pp.24.

Roe, A. 2006. Water Management, Livestock and Opium Economy. Afghanistan Research and Evaluation Unit (AREU). pp. 38.

Rout, B. 2008. Water Management, Livestock and Opium Economy, How the Water Flows: A Typology of Irrigation System in Afghanistan. Afghanistan Research and Evaluation Unit (AREU). Pp.80.

Riviere, N. 2005. Community based irrigation in northern Afghanistan. Linking Relief, Rehabilitation and Development Program (LRRD) in Afghanistan. pp.48.

Shah, S. Momeen and Khan, M. Jamal. 2011. Performance assessment of irrigation system in Nangrahar, Afghanistan. Master Thesis (Unpublished). Library of Peshawar Agricultural University, Pakistan.

Viala, E. 2004. Irrigation Management in Afghanistan. Water rights and related water supply issues. Us committee on irrigation and drainage. Pp. 125.

Walter. K. 1997, Water Resource and Irrigation, Afghanistan Agricultural Strategy, FAO. TCP/AFG/4552. Islamabada-Pakistan.

APPENDICES

APPENDIX A: QUESTIONAIRE PROFORMA

For the study of

"Improvement of Water Management Practices in Balkh, Afghanistan"

Field Work for MSc Thesis Research, VAN HALL LARENSTEIN Applied Science, Wageningen, the Netherlands.

General Information

Name of Interviewer ________________________ Dated_____ /_____ / ______

1. Particular of the farmer/Water Master
   a) Name of the farmer ______________________ Ph. No _________________
   b) Village name ____________________________
   c) Location of the village in the canal Head___ Middle___ Tail___
   d) Age _______________________years.
2. Education:
   a) Illiterate b) Primary C) Middle D) High school or greater
3. Main source of income _____________________
4. Total Land ______________________
5. Tenancy status
   a) Owner b) Tenant c)Owner cum tenant
6. Area cultivated by the farmer
   a) Total Gross area _____ b) Total Cultivated area ____
   c) Area rented in ____ d) Area rented out ____

Cropping Pattern

1. Winter season

Crop	Area (Jerib)	Irrigation Interval (Days)	Surface Irrigation method	Remarks
Wheat				
Alfalfa				
Onion				
Barely				
Cauliflower				

Fallow land

2. Summer Season

Crop	Area (Jerib)	Irrigation Interval (Days)	Surface Irrigation method	Remarks
Melon				
W/melon				
Cotton				
Vegetables				
Fallow land				

Farmer Perception about Water Management Practices

1. Do you know how this existent water allocated to you?

    a) Yes b) No

    If Yes, Let me know, how this is allocated to you?
2. Is there any difference between present and past water availability?

    a) Yes b) No

    If yes, could you pinpoint its reason?
3. What is your idea that the water right which is applied is good or not?
4. Have you remember any conflict arose due to current water right between water users. If yes, when and why?
5. How the disputes resolve between farmers?
6. What do you consider important to be changed or developed in the allocation priorities?
7. What solution you are proposing for better water right?
8. To what extent available water is sufficient for your crops (Adequacy)?
    a) Too much b) Enough c) Less than enough D) Too little
9. Are all fields throughout the scheme receiving the same amount of water delivery service?
    If no, what are the causes?
10. What is the major constraint with regard to canal water supply?
11. How it can be improved?
12. How much of the farm area you irrigate from canal water?
13. What is the role of Mirab in the water management?
14. To what extend he can play effectively in water distribution along the canal?
    a) Very good b) Good d) Fair c) Poor
15. What is the role of your village's Chakbashi?
16. To what extend he can play effectively in water distribution in order to reach water to your field?

a) Very good c) Good e) Fair d) Poor

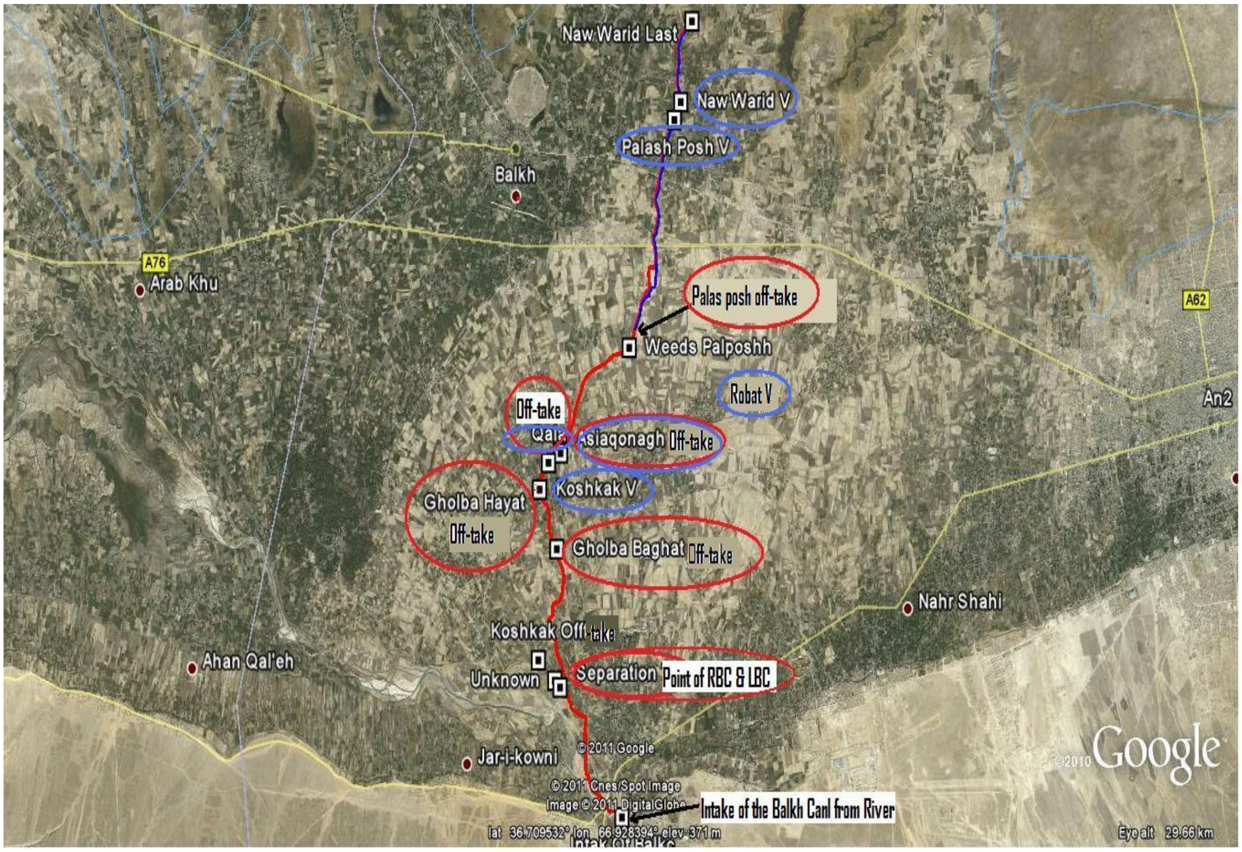
17. Who and How Mirab and Chakbashi are selected to this job?
18. How often do you have disputes over water with other farmers?
    a) Often b) Sometimes c) Seldom d) Never
19. How often is your canal cleaned?
    a) More than once per cropping season b) Once per cropping season
    c) Once per year d) Once every several year e) Never
20. If it cleans then who and how it is cleaned?
21. How funds are collected and used for maintenance of canal level?
22. How is the water distribution system here?
23. Is the reliability same to all farmers?
24. Are you receiving water supply according to your share?
25. Can you identify a month/season when you feel that water allocated to you is more than your requirement?
    a) Yes b) NO

    If yes, in which season (specific month____)
26. How you are measuring required water for your crops, base on your experience or get from any other sources (government, NGO and etc)?
27. To what extent are you confident in getting water at proper time and enough amounts for your crops?
28. Can you choose frequency, rate and duration of water when you require irrigation or it is fixed (Just receiving water on your turn), (Flexibility)?

Additional Questions from Mirab and Chakbashi

1. What is your responsibility over the irrigation system?
2. How do you manage the water distribution system?
3. Who give you salary that you do this job?
4. Do you have coordination with Chakbashi of other villages (from Chakbashi)?
   a) Yes ----- b) No
5. If yes, to what extent it is effective?
6. Can you manage the system effectively?
   a) Very good b) good c) fair d) poor
7. What are the major constraints that you have in water management in your responsible area?
8. What should be done that you able to strong your management system?

APPENDIX B: RBC Irrigated area



Source: Google earth (GPS by the researcher)

APPENDIX C: CALCULATION FOR CROPPING PATTERN

Winter Season Cropping Pattern Calculation

1. **Head**

a) Koshkak village

Farmer	Owned Land (Jerib)	Wheat	Alfalfa	Onion	Fallow
1	60	42	0.75	0	14.5
2	38	28	0.5	0.75	9
3	30	20	0	0	8

4	25	16	0.25	0	6
Total	153	106	1.5	0.75	37.5
Percentage		69.28	0.98	0.49	24.51

b) Qala village

Farmer	Owned Land (Jerib)	Wheat	Alfalfa	Onion	Fallow
1	45	33	0.5	0	11
2	31	22	0.25	0	8.5
3	22	13	0.25	0	6
4	18	12.5	0	0.75	5
Total	116	80.5	1	0.75	30.5
Percentage		69.39	0.86	0.64	26.29

2. Middle

a) Asyab qonagh village

Farmer	Owned Land (Jerib)	Wheat	Alfalfa	Onion	Fallow
1	52	34	0.5	0	16
2	30	19	0.25	0	10
3	20	12.5	0	0	7.5
4	12	8	0	0.75	4.5
Total	114	73.5	0.75	0.75	38
Percentage		64.47	0.65	0.65	33.33

b) Robat village

Farmer	Owned Land (Jerib)	Wheat	Alfalfa	Onion	Fallow
1	40	21.5	0.5	0	17
2	25	13	0	0	11
3	20	10	0.25	0	9.5
4	14	8	0	0.75	6.5
Total	99	52.5	0.75	0.75	44
Percentage		53.03	0.75	0.75	44.44

3. Tail

a) Palasposh Zozan

Farmer	Owned Land (Jerib)	Wheat	Alfalfa	Onion	Fallow
1	100	32	0.75	10	49
2	40	23	0.5	5	8.5
3	36	24	0.25	5.5	6
4	22	15.5	0.25	5	2
Total	198	94.5	1.75	25.5	65.5
Percentage		47.72	0.88	12.87	33.08

b) Palasposh Nawwarid

Farmer	Owned Land (Jerib)	Wheat	Alfalfa	Onion	Fallow
1	50	23	0.75	10	15.5
2	35	17	0.5	6	11
3	25	10.5	0	4.5	9.5
4	20	9.5	0.25	4	6
Total	130	60	1.5	24.5	42
Percentage		46.15	1.15	18.84	32.30

Summer Season Cropping Pattern

1. Head

a) Koshkak village

Farmer	Total Land (Jerib)	Cotton	Melon	W/Melon	Vegetable	Fallow
1	60	10	2	1.5	2	43
2	38	5	1	1.5	1.75	27.5
3	30	5	1	0.75	1.5	20
4	25	0	2	1.5	2	18
Total	153	20	5	5.25	7.25	108.5
Percentage		13.07	3.26	3.43	4.73	70.9

b) Qala village

Farmer	Total Land (Jerib)	Cotton	Melon	W/Melon	Vegetables	Fallow
1	45	6	1.5	1	1.25	34.5
2	31	5	1	0.75	1	23
3	22	0	1.5	2	1.25	17
4	18	5	0.5	0.25	0.5	11.5
Total	116	16	4.5	4	4	86
Percentage		13.7931	3.879310345	3.448275862	3.448275862	74.1373

2. Middle

a) Asyab qonagh village

Farmer	Total Land (Jerib)	Cotton	Melon	W/Melon	Vegetable	Fallow
1	52	5.5	2	3	0.5	40
2	30	5	1	1.5	0	22
3	20	3	1.25	1	0	14.5
4	12	0	1.5	2	0.5	7.5
Total	114	13.5	5.75	7.5	1	84
Percentage		11.84	5.04	6.57	0.87	73.68

b) Robat village

Farmer	Total Land (Jerib)	Cotton	Melon	W/Melon	Vegetable	Fallow
1	40	5	1	1.5	0	32
2	25	0	1.25	1.5	0.25	21.5
3	20	3.5	0	0.5	0	15.75
4	14	0	1	1	0.5	11.25
Total	99	8.5	3.25	4.5	0.75	80.5
Percentage		8.58	3.28	4.54	0.75	81.31

3. Tail

a) Palas Posh Zozan

Farmers	Total Land (Jerib)	Cotton	Melon	W/Melon	Vegetable	Fallow
1	100	40	1	0.5	1	32
2	40	20	0.5	0	0.5	18.25
3	36	20	0.5	0.5	0.25	14.5
4	22	10	0	0.5	0.5	10
Total	198	90	2	1.5	2.25	74.75
Percentage		45.45	1	0.75	1.136	37.75

b) Palas Posh NawWarid

Farmers	Total Land (Jerib)	Cotton	Melon	W/Melon	Vegetable	Fallow
1	50	25	0.75	0.5	0.5	23
2	35	20	1	0	0.5	12.5
3	25	12	0.5	0.5	0.25	11.25
4	20	10	0	0.25	0.5	8.75
Total	130	67	2.25	1.25	1.75	55.5
Percentage		51.53	1.73	0.96	1.34	42.69

Note: Calculation is based on Formula which is mentioned in the Methodology; (Cultivated Land of the crop/ Total owned land)* 100

APPENDIX D: PICTURES OF FIELD WORKING

Image 1 Interview and field observation

Image 2 Physical Structure of Secondary Canal

Image 3 Structure of turnout to the field in the-Secondary canal

Image 4 Structured off-takes

APPENDIX E: GENERAL GESCRIPTION OF AFGHANISTAN

- **Afghanistan Geography**

Afghanistan is landlocked country with 652,000 km2 area. It is located between latitudes 29.5N-38.5N and longitudes 60.5E-75E. It is bounded by the central Asian Plains and mountainous of the Turmenstan, Uzbeskistan and Iran to the west (Figure 2). Much of Afghanistan is mountainous, which is dominated by the Hindu Kush, the westernmost extension of the Karakoram and Himalayas. The divided the country into its Northern and Southern regions of Hindu Kush and Lower Mountain ranges of Baba and SafedKoh. The total arable land of the country is about 12%. 3% under forest cover, about 46% under permanent pastures, and the remaining 39% is based on mountains. The average mountain height is 1850 m. Here is little permanent snow and glaciers as the snow line are between 4000-5000. Outside the mountainous areas, much of Afghanistan is arid plain land. Deserts of different types occupy about 18% of Afghanistan. Only 17% of Afghanistan's area is occupied by river valleys, which include the valleys of the Amu, Harrirud, Helmand, and Kabul, as well as smaller rivers. Runoff from the mountains into the Kunduz, Kabul, Helmand, and Harrirud Rivers is heavy for a brief of period during the spring thaw, sometimes causing floods and landslides. During the rest of the year, runoff tends to be irregular and low (Ahmad, Wasiq, 2004).

- **Afghanistan Climate**

Afghanistan is located at sub-tropical latitudes, but the high range of high mountains in the middle of the country, is the decisive factor in its climate and precipitation. Areas to the north of the high mountains and ridges have a dry, continental climate. In the northern valleys, annual precipitation averages 300 mm, most falling from December to May, while in the north overall, annual precipitation average 400 mm per year. The areas to the south of the high mountains are characterized by a less- continental climate, summer is relatively cool, winter precipitation is 800 mm annually, concentrated in the summer when the monsoon brings rain and precipitation on the northern plains is 125 mm, and average on the southern plains 110 mm. while the overall national average temperature in July is +32 C, and in January -2c, temperatures drop to -50 C, in the Hindu Kush Mountains, while in the deserts (Dasht-e-Margo) summer temperatures reach +50 C (Ahmad, Wasiq, 2004).Average precipitation average 170-196 mm.

- **Afghanistan Water Resources**

Afghanistan has plenty of water resources due to the high precipitation on high mountains. The average annual precipitation is estimated to be approximately 180 billion m^3, which more than 80% of the country water resources that come from snowmelt in the Hindu Kush (Rout, 2008).

Most of the winter's snow accumulation melts in the summer, In the eastern most part of the country where elevation is highest, there is snow accumulation contributing to long term storage of water resources. Based on FAO and groundwater studies that place surface water and 12% (11 billion m^3) groundwater.

Annual water use for irrigation is 20 billion m^3 that is drawn mostly from surface water. The source of ground water is recharge from the river flows, because precipitation is very limited. Afghanistan is divided into hydrological units by the mountain range that goes Helmand River, the Kabul River, and the Amu Darya. The Helmand River originates on the southern slopes of the Hindu Kush and flows southwest to the Sistan Basin in Iran.

The Kabul River originates in the south-eastern Hindu Kush and flows south through the city of Kabul, then turns east and joins the Indus River in Pakistan. The Amu Darya originates on the northern slopes of the Hidu Kush and from Wakhan in the Pamir Murghab, Helmand, Kabul (Indus), Northern and Amu Darya- as well as five non drainage areas. Approximately 11% of the territory of rivers on the northern slope of the Hindu Kush, has no surface water resources.

- **Agriculture Sector in Afghanistan**

Agriculture through irrigation is the largest water-consuming sector in Afghanistan, which accounts for more than 93% of the country's total water use. Afghanistan's history of irrigated agriculture goes back 5,000 years, as ancient settlements excavated near Kandahar show. Even today, allocations of land and water remain closely related to consumes and traditions of the sedentary population and maintenance works of irrigation schemes are concentrated in areas to the north, west and southwest of the central mountains and highlands. Agriculture has been the mainstay of the Afghan economy although decades of war and drought have depressed agricultural activities and contributed to the variations in production from the rain fed sector, however, the progress in agriculture sector is traditionally impossible without irrigation. Afghanistan's eastern region, its only major forested area, enough for double cropping, but precipitation is inadequate or unpredictable. In the north between blind rivers and the Amu Darya, and the southwest, where elevation drops below 300 meters, the terrain is mostly desert; there are no water resources and as a result little vegetation (Ahmad, Wasiq, 2004).

The major crop grown in Afghanistan is wheat, which accounts for about 70% of total cereal consumption in Afghanistan. Other grains include rice, maize, barely, and pulses. Potatoes, onions, and several fruit crops including melons, water melons, apricots, pomegranates and grapes are also grown both for domestic consumption and exports. Exports of dried fruits and nuts, mainly apricots and almonds, are still a significant source of foreign exchange but they are nowhere near the levels of the 1980s when Afghan dried fruits accounted for a significant percentage of the world market share.

- **Irrigation Practice in Afghanistan**

The cultivable area of Afghanistan is estimated to be 7.7 million ha, which is roughly 12% of the country's area, approximately 42% is intensively or intermittently irrigated. Much of this land lies in the fertile alluvium of major river valleys. Taken from on FAO satellite survey conducted in the early 1990s, shows total irrigated area as 3.21 million ha of which 48% is intensively cultivated and 52% is intermittently cultivated with one or more crops each year. It is assumed that the survey covers both informal and formal irrigation systems (Rout, 2008).

Irrigated land cover by river basin in Afghanistan (source: FAO 1990)

Water basin	**Area (ha)**				**Total (%)**
	Intensively cultivated (2crops/year)	Intensively cultivated (1crop/year)	Intermittently cultivated	Total	
Amu Darya	106,000	248,000	48,100	402,000	13
Kabul	62,000	244,000	178,000	484,000	15
Helmand	95,000	380,800	900,000	1,380,000	43
Hari Rod-Murghab	34,500	138,000	128,000	301,000	9
Northern	40,000	198,000	387,000	625,000	19
Non-drainage	3,880	10,000	6,700	20,600	1

area					
Total	341,580	1,218,400	1,648,500	3,208,480	100

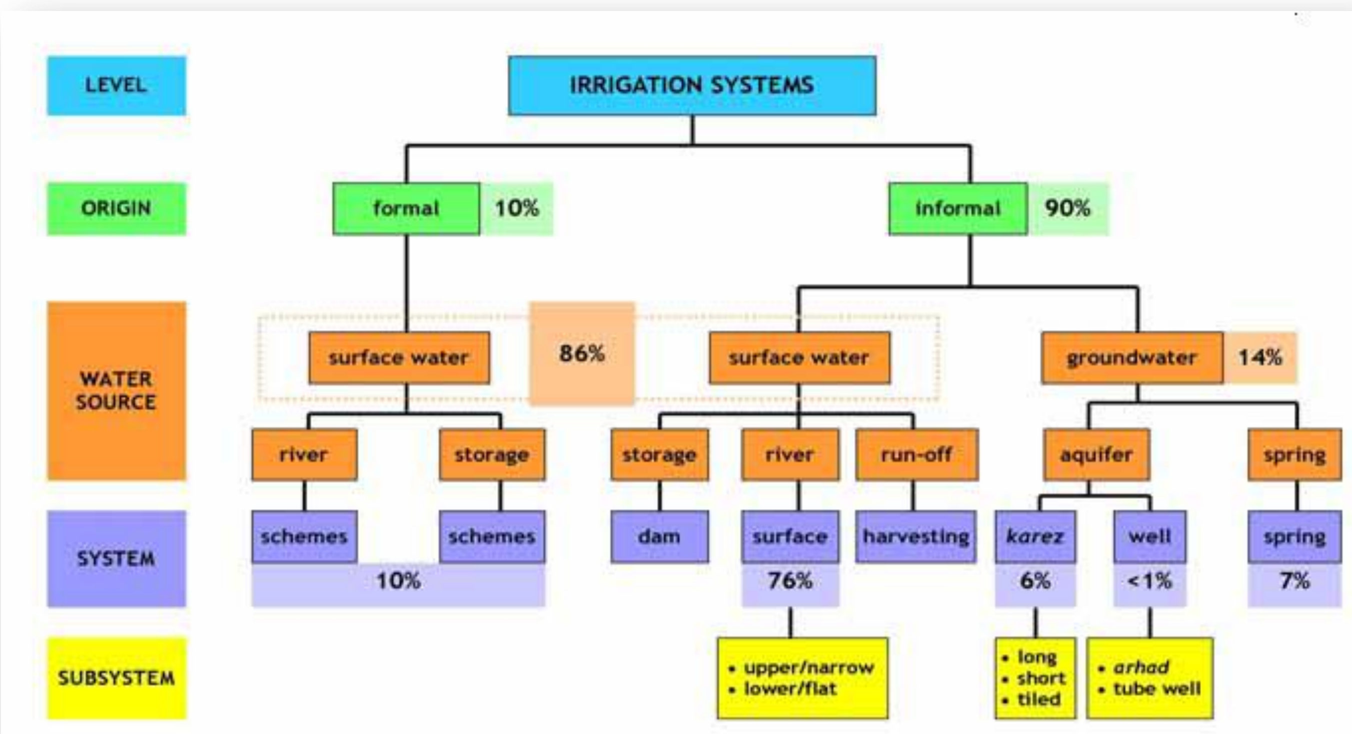
A survey of irrigation systems from the late 1960s usefully indicates the number of systems and water sources and is summarized in Table 4. It shows the existence of nearly 29,000 systems, of which 27% drew from surface water sources (rivers and streams) and the remainder from groundwater sources (spring, karez and wells). While a large number of systems are supplied from groundwater, they accounted for less than an average irrigated area of less than 20 hectares per system (Rout, 2008).

Irrigation area by water source in Afghanistan (source: Faver and Kamal)

System and area	River and streams	Springs	Karez	Wells (arhad)	Total
System(no.of)	7,822	5,558	6,741	8,595	28,716
System (%)	27	19	23	30	
Area(ha)	2,348,000	187,000	168,000	12,000	2,715,000
Area (%)	86	7	6	<1	

– **Irrigation system Typology in Afghanistan**

Classification of irrigation system types in Afghanistan are divided by formal irrigation systems and informal irrigation systems. The hierarchy of classification approximates shares of total



irrigated area for water sources and system types are shown in figure.

Classification of irrigation system types in Afghanistan (source: Afghanistan Research and Evaluation Unit, 2008)

- **Formal Irrigation Systems**

The large scale irrigation system or formal schemes have been developed with the help of central government assistance, financing, management, operation and maintenance. Most of the schemes were made by bilateral and multilateral donors, in the late 1940s and the 1970s. there are 10 formal schemes totaling an area of nearly 333,000 ha in Afghanistan. Helmand-Arghandab scheme (Helmand Province) is the biggest of all. The other system includes Sardeh (Ghazni), Parwan (Parwan and Kabul), Nangarhar (Nangrahar), Sang-i-Mehr (Badakhshan), Kunduz-Khanabad (Kunduz), Shahrawan(Takhar), Gawargan (Baghlan), Kelagy (Baghlan) and Nahr-i-Shahi (Balkh). Most of these schemes contain storage dams as well as capacity to generate hydropower. The annex 2 summarizes the irrigable area and main structure dams and hydropower production.

Surface Water System

A) Surface water system with storage: Theirrigation departments maintain and operate this system, which have permanent intake structures. This system uses the large-scale traditional surface water scheme. However, regulation of water flow to the system depends on the interaction between government authorities and the village communities.

B) Surface water system with storage: Large scale irrigation system development is relatively newer (1960-1978). But five large-scale modern irrigation systems had also been built and in operation since late 1970s. Land tenure is different from that in the traditional systems. Parts of these schemes have been operated as state farms, owned by the government. The government heavily subsidized these schemes due to which farmers have limited choice concerning crop selection or farm practices.

C) Canal Irrigation: Canal irrigation is by far the most widely-used irrigation method as they irrigate nearly 1.9 million ha of land in Afghanistan. Most of the canal-irrigated land is located in the north, west, and southwest of the country, where canals are takes water from snowmelt Rivers. At periodic locations along the river small diversion structures are installed to divert water from the river to the irrigation canals. Some diversions are open; some are fitted with gates to control the flow of water. They are traditionally constructed of loose masonry and more recently with sandbags. However, some modern-built river diversion structures are designed and constructed at a higher level from these irrigation canals, water is diverted to small irrigation channels.

Ground Water Systems

Ground water systems: very little documented literature regarding irrigation schemes supplied by groundwater from wells (whether deep or shallow) is available. Province surface water irrigation schemes were supplied by some 100 deep wells until the late 1980s in Khost/Paktia.

In some other cases, particularly in the lower reaches of the traditional schemes, where water shortage are common, individual farmers undertook irrigation reports by various institutions indicate that the number of wells in the south has mushroomed during the last decade (UNDP/FAO 1993).

- **Informal Irrigation systems**

Informal systems are traditionally developed and managed by local communities, largely with local resources and knowledge. In most cases, these systems have existed for generations and have undergone many social and physical changes arising from the last 30 years of the conflict. Importance of informal systems, which account for 90% of irrigated area, as well as the significant of surface water, which supplies 86% of irrigated area. Nearly 29,000 informal irrigation systems are estimated to be in Afghanistan.

Surface water system

A) Traditional Irrigation Schemes: it is a century old system. In this system, water is supplied by streams diverted with the help of temporary weirs which are made of woods, stones, gravel and sandbags. These systems are available in each part of the country. It varies in size comprising up to 100 ha. The systems are constructed and maintained in the traditional and informal manner on a communal, village basis, e.g. canal of the systems generally built with unlined earth wherever site and soil conditions are suitable. Similarly, water rights are determined and recognized in the same way.

B) Large –scale Surface Water Systems: These systems are mainly located in the plain areas along the main river valleys. Many villages are Sharing water from the same system but some of the big villages have separate systems. According to the water law of 1981, the amount of water needed for irrigation is determined according to the area under cultivation, surface water resources are largely early to later spring and early summer snowmelt that result in peak flows in the duration of the annual water supply, the kind of crop, the irrigation regime, the water rights document, local practices and the amount of water in its sources. Agreements between farmer, water owner and each village has at least one delegation of scheme. Structures in the surface water systems were traditionally based on local knowledge and experience.

Groundwater systems

A) Shallow well (arhad) system: In this system, groundwater is lifted from a large diameter shallow well with the help of an animal-powered wheel (arhad) to supply irrigation water to the fields of an individual farmer Such an irrigation system waters a limited area not larger than three ha. Altogether, about 6,600 shallow wells in total irrigates about 12,000 ha.

B) Springs: When the groundwater table rises above the surface, it forms springs that flows over the surface of the land. Many rural communities dependent on spring water for irrigation and other uses. There are about 5,560 springs in the country irrigation 188,000 ha which are accounted for 19% of all irrigation systems by number and 7% by area. Spring flow directly depends on the groundwater level. When the groundwater level goes down, for example, during drought years, this causes a reduction of outflow from springs. Usually, the most affected areas during droughts are areas heavily dependent on springs. The infrastructure of spring- fed systems is typically made up of simple unlined canals and structures. Some of the springs have high water storage because of less canals and structures. However, some of the springs have low water storage because of less outflow. It stores water during the night and then is used for irrigation in day time, by this way to improve distribution efficiency. This type of irrigation from springs is widely is common in the east and in the south.

C) Karez (qanat) system: Karezes are traditional underground galleries that tap groundwater from aquifers of the alluvial fans. Underground tunnels with gentle slopes carry water from its source to settled areas. The karez system has been use for thousands of years in Afghanistan. Its origins are largely attributed to the expansion of the Persian Empire since similar systems are found in Iran (qanat), Oman (falaj) and North Africa (foggaras). Karezes are small in cross section but may be many kilometers in length. On average, their discharge varies from 10 L/s, but it can be as high as 500 L/s. Karez water is used for irrigation (karezes serve irrigated areas ranging in size from 10 ha to 200 ha) and groundwater for irrigation, environmentally safe and powered by gravity. There are 7,000 karezes in Afghanistan, irrigating about 170,000 ha of land (Rout,2008). Convenience and distribution of water to the command area is via a surface network of unlined canals and structure. Karez irrigation is common in the south and southwest of the country, but less so in the north. A disadvantage of kareze is that when there is no way to stop water from flowing during winter and annual total flow through karezes is not used, which intern can damage the crops but this problem can be solved by modernizing the Karez System.

APPENDIX F: WATER CONSERVATION OPTIONS AND OPPORTUNITIES

Reasons for Annex-E

The Balkh district is one of the important agricultural districts of the Balkh Province of Afghanistan. Majority of the people of this district rely on agriculture for their livelihoods. Canal water is a vital source of irrigation water in this district. There is one main canal (Balkh canal) which provides irrigation water to whole districts and covering a total area of 5040 ha. This canal is further divided into two branches i.e. Right Balkh Canal and Left Balkh Canal. The right canal has a total command area of 2209 ha of land.

The Right Balkh Canal is 9 Km long and has a total command area of 2209 hectare agricultural land. Research has found out that currently, only 50.5% of the total agriculture land is cultivated and the remaining is left fallow due to the shortage of irrigation water in the canal.

The increasing water scarcity and occurrence of drought conditions in different parts of Afghanistan including Balk province has become a serious problem affecting the socio-economic development. Moreover, the high population growth has put more pressure on irrigation water. High population means more demand for food and thus more demand for irrigation water for agriculture.

In order to tackle the scarcity problem of irrigation water and meet the food requirements of the growing population, the water productivity must be increased. Efficient on-farm water use techniques with improved irrigation infrastructure, better crops selection will help increase water productivity.

In this annex, several possible options are discussed and calculations are made for irrigation water efficiency for Right Balk canal area.

1. Main Problems in the irrigation system

During the field work various problems of the RBC were discovered which are described below:

- Less water availability in the main canal
- Poor structure of canal
- Insufficient water institution
- Improper extension services
- In-efficient irrigation method
- In-efficient irrigation method
- Inequity in the scheme
- No flexibility and reliability of available water
- Inadequacy in the scheme

Less water availability in the main canal

Water flow discharge in the Right Balkh Canal is 0.40 m3 sec^{-1} and has 2209 ha irrigated land which water can be allocated 0.18 liters sec^{-1} ha^{-1}. Thus, this available water is insufficient to fulfill crop water demand of irrigated land in the area. Research has found that around 49.50 % of the total land is fallow although most of downstream land was irrigated by tube wells.

Poor structure of canal

Physical structure of canal is very poor and has excessive plantation along the sides which has led to significant water losses. The irrigation water losses of the RBC are assumed 10 percent for each one kilometer of the canal. Length of the canal is 9 Km and the losses are measured till end of the canal. The table below describes the total losses and the amount of available water till the off-takes.

Table 4: Available water till every off-take

1	Gholba Baghat	Length from intake (3km)	289.379
2	Gholba Hayat Ajat	Length from intake (4.5km)	247.408
3	Qala	Length from intake (5km)	234.154
4	Asyab Qanagh	Length from intake (5.5km)	222.446
5	Palas Posh	Length from intake (9km)	200.135

AWAT (2010) project has measured conveyance losses of secondary canals which are 22 % per kilometer at the head, 24 % per kilometer at the mid while 30% per kilometer at the tail reaches area of the canal respectively. The length of each secondary canal is unknown. Thus, one kilometer of each canal is

Table 5: Available water in every off-take after one kilometer (lit sec-1)

Gholba Baghat	225.318
Gholba Hayat Ajat	192.183
Qala	181.138
Asyab Qanagh	167.884
Palas Posh	139.167

Insufficient water institution

Institution of irrigation service is 1000 years old traditional system that has no influence in water productivity. This leads to poor water distribution resulting low productivity.

Improper extension services

The extension department is poor in term of resources and technical persons to provide extension services especially in irrigation water management. The potential area where extension services could be provided is better use of irrigation water, irrigation scheduling, land leveling, proper irrigation methods and low water consuming crops to the farmers.

In-efficient irrigation method

Irrigation water is applied in the field through a traditional method which is a kind of wild flood irrigation method. It is very poor method particularly in the water scarce areas such as command area of RBC. The application efficiency of wild flood irrigation is low in comparison to other irrigation methods that can be adopted in the command area. The application efficiency of wild irrigation method is from 20-40 percent.

Improper land leveling
Land leveling is one of the key factors for saving irrigation water and increasing water productivity. Unfortunately, the agriculture land in the RBC command area was not leveled and that has led significant water losses.

Inequity in the scheme
Water is allocated in every off take proportionally based on land size but poor physical structure and weeds of canal caused significant losses till end users (Table 2). Furthermore, the illegal water use by upstream water users makes the access to water inequitable for downstream users.

No flexibility and reliability of available water
Water is allocated for every farmers based on irrigated land size. The water distribution is applying according to local units such as 5 minutes jerib^{-1} (25 minutes ha^{-}1) and 7 minutes jerib^{-1} (35 min ha^{-1}). Therefore, water is not flexible and farmer cannot determine amount of water according to their crops demand. Due to fluctuation of water in the scheme reliability is also insufficient.

Inadequacy in the scheme
In the winter and spring season due to high rainfall and snow melting, the water in river and canal increases due to which occasional flood occurs which destroy parts of canal and causes erosion. In summer, there is no sufficient water for irrigation of crops.

2. Improving Irrigation Efficiency

Climatic conditions, soil type and structure, plant type and irrigation techniques applied are among the main factors that influence the efficiency and effectiveness of irrigation practices. For a selected location, climatic and soil conditions, the efficiency of water irrigation practices can be improved by making the right decisions regarding:

- Crops type
- Controlling of conveyance losses in the canal
- Irrigation scheduling
- Land leveling
- Irrigation method
- Water harvesting

2.1 Cropping pattern and its water requirement

Major winter crops of the RBC service area are wheat, onion, alfalfa while in the summer season cotton, melon and water melon are sown. Crops differ both in terms of their daily water needs and the duration of their total growing period. Consequently, crop type is a chief factor influencing irrigation water needs. Crops with high daily needs and a long total growing season require much more water than those with relatively lower daily needs and shorter growing seasons. Therefore, a key step towards reducing irrigation water needs is selecting those crop varieties that have a lower water demand but still provide the same or more income for farmers. Crop water requirement of major crops which are measured by Cropwat 8.0 computer software is in the (Table 3) and further details are in (annex).

Table 6: Crop water requirement for major crops

Crops	Crop water requirement mm $season^{-1}$	Crop water requirement in peak season (lit sec^{-1} ha^{-1})
Wheat	250.5	0.42
Cotton	1287.5	1.4
Bean	778.7	1.4
Onion	706.6	1
Melon	772.4	1.15
Water Melon	709.9	1.5

The table shows that instead of cotton which has high water requirement (128.75 mm $season^{-1}$) bean cultivation should be encouraged which has relatively low water requirements (77.85 mm $season^{-1}$). Some farmers have tried cultivation of beans and gave good production. Furthermore, bean crop has higher economic value and less water demand. Total 43 ha cotton was cultivated from different sources of water in the area if we cultivate 21.5 ha cotton and replace half of it by bean then 130 lit sec^{-1} $season^{-1}$ of water could be saved. Therefore, 14 ha of land (beans) could be cultivated with the saved water. It is worth mentioning that the farmers are not familiar with agronomic practices of beans but still this problem could be solved through few trainings and demonstrations.

2.1 Irrigation scheduling

Water distribution is based on farmers traditional system that has 35 min ha^{-1} in the head and mid of the canal while in the downstream 25 min ha^{-1} respectively, While demand of different crops are fluctuated in the each season. Hence, good agronomic practices to store moisture and selection of crops having low water demands can help to cope with this problem. Moreover Irrigation schedule should be based on the available water and demand of crops grown in the command area of the canal (annex).

2.2 Canal lining

Seepage and infiltration losses can be reduced by compaction of clay soil on layer of ditches but the standard technique to reduce seepage losses from irrigation canals is to line them with rigid construction materials. The initial cost of lining canal is high but still it has relative advantage over the un-lined canal on the long run. Before making such an investment there must be a clear understanding of the benefits to be obtained. Although the farmers will contribute in raising the fund for lining the canal but still all the cost will not be covered. The Government or Donor NGOs should help farmers in lining the canal. By lining of canal, outlets and turnout structures conveyance efficiency of the canal will increase to 90 percent. In this case tertiary canals and ditches are also considered that may have losses that are why 90% conveyance efficiency is assumed. After lining of the canal water will increase from current (181 lit sec^{-1}) to (360 lit sec^{-1}) and definitely equity in the scheme will come into being. High standards in design and construction are essential for long canal lining longevity.

Current water allocated discharge is $0.40m^3$ sec^{-1} in the intake of RBC but water is fluctuated in the river then in the canal. Thus, we assume that the RBC shall has $1m^3$ discharge flow capacity and construction material use as 1:2:4 which are (0.428 m^3 sand), (0.857 m^3 gravel) and (6 bags cement). Total volume of canal is measured by following formula:

Total volume= Length*Width* Depth (free board+ depth)

Cost of 1 meter main canal is assumed 3081 Afg and cost for all secondary canals per one meter is 5136 Afg and this calculation is for 9 km main canal and 1 km per secondary canal.

2.3 Irrigation method

2.3.1 Surface Irrigation system

Surface irrigation method is further divided into two methods;

- Wild Flood Irrigation method

The Irrigation method is kind of wild flood irrigation system which has no proper control and is commonly practiced for irrigation of major crops in the RBC service area. This is one of the oldest irrigation methods, the easiest and with less cost which is adaptable where abundant water supply is available for irrigation. Due to scarcity of water in the command area of RBC this method needs to be improved. Application efficiency of wild flood irrigation method is around 25-40 percent.

- Raise bed basin Irrigation method

This method is mainly used in vegetable gardens and cotton crops. Water flows along the small basin between the rows of plants and sinks is slow. Application efficiency of the basin method is around 45-65 percent but raise bed basin method which cannot be designed the slop, wide and length by the farmers. Thus, it is assumed that could be around 35-50 percent.

Based on this and other researches that obtained higher water application and use efficiency of basin and furrow irrigation method rather than wild flood irrigation particularly in sandy loam soil. The raise bed basin irrigation method is recommended which is easy, efficient and known irrigation method for the farmer in the RBC service area. By applying this irrigation method for cotton, vegetables, Melon and Watermelon application efficiency would be increased.

2.3.2 Micro Irrigation method

- Drip Irrigation method

Drip irrigation delivers water through the use of pressurized pipes and drippers that run close to the plants and that can be placed on the soil surface or below ground. The on-farm irrigation efficiency of properly designed and managed drip irrigation system is estimated to be about 90 percent, while the same is only about 35 to 40 percent for surface method of irrigation (INCID, 1994). Although this method is very efficient but the initial installation and executing both are very difficult because of insufficient facilities such as lack of knowledge, no electricity in the most command area of RBC scheme.

– Sprinkler Irrigation method

Sprinkler irrigation method is also one of the efficient irrigation method, but water saving is relatively low (up to 70 percent) as compared to drip irrigation since SIM supplies water over the entire field of the crop (INCID, 1998; Kulkarni, 2005). This system is also not applicable system in the current situation due the reason which is mentioned under drip irrigation method.

2.4 Land leveling

Precision of land leveling helps uniform application of water, better crop stands and improves input use efficiency. Land leveling is one of the most effective water saving method particularly laser land leveling that increase water efficiency and production.
Through studies conducted elsewhere under similar environmental conditions a direct relationship between field levelness and water saving and crop yields has been shown (ICARDA, 2002). Evaluation of several fields after precision land leveling in various parts of Pakistani Punjab have shown that there is a saving of from 33% to 50% water on precision leveled fields as compared to traditional un-level fields. These studies have also related land leveling to improved crop yields (ICARDA, 2002).
Due to poverty and lack of knowledge it is not preferred to apply directly laser leveling but précised conventional leveling should be done under guidance of Governmental or NGOs technical extension person for some time in order to farmer get familiar. Application efficiency of good conventional leveling is assumed 45% in this area. The current available water after one km in the secondary canal is compared with leveled and unleveled land application efficiency.

Table 7: Comparison between unleveled and leveled land efficiency

Area under each off-take	Unleveled	Leveled
Gholba Baghat	56.3	101.3
Gholba Hayat Ajat	48	86.4
Qala	45.2	81.5
Asyab Qanagh	42	75.5
Palas Posh	34.8	81.5
Average	**45.2**	**426.2**

Evaluation of water saving options

There are various options for water conservation for Right Balkh canal. The adoption of these options depends upon various factors. Based on some indicators or factors (water saving, yield/income, marketing, installation cost and skills required) these options are evaluated in the table below. It is worth mentioning that all factors are not applicable for some options. Marks from 1 to 4 are given to evaluate these options; 1= Very high, 2=High, 3= Medium, 4=low

Table5: Evaluation of water saving options

Intervention options	Water saving	yield income	Marketing	Material installation cost	Skill training level

Replacing cotton with bean	3	3	2	4	2
Land leveling	2	1		3	3
Canal lining	1	2		1	4
Drip Irrigation method	1	1		1	1
Sprinkler Irrigation method	1	1		1	1 1
Irrigation schedule	4	3		4	2

Based on the relative more advantages after the evaluation of the possible options, first priority is given to change in cropping pattern (replacing cotton with beans), second priority is given to land leveling which is less costly and effective in water saving and need less skill. Third priority is given to irrigation scheduling which is effective in water saving, less costly and required some trainings. In fourth place is the canal cleaning which is very important but with one limitation of high cost. In fifth position is the drip irrigation, although it is very effective in water saving but it requires high skills and the cost is very high and is not adoptable for this scheme. The last option is the sprinkler irrigation which is effective in water saving but the high cost and skills are the limiting factors.

Table 6: Recommended improvement

Improvement	Water saving	Increasing of irrigated land (ha)	Income per season (Afg)	Cost	Remarks
Prevailing of the bean instead of cotton	30 lit sec^{-1}	14 ha of bean	840000	350000	only extension services
Land leveling	36.2 lit sec^{-1}	26 ha of cotton	1450000	500000	
Irrigation schedule					cont not predicted the quantity
Canal lining	179	70.3 ha cotton and 208 ha wheat	55769 (cotton in ha) and (wheat per ha)		

Appendix F. 1: Crop water requirement of wheat

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			Coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	1	Init	0.3	0.4	4	8.6	0
Dec	2	Init	0.3	0.33	3.3	10.2	0
Dec	3	Deve	0.39	0.43	4.7	9.7	0
Jan	1	Deve	0.53	0.6	6	8.7	0
Jan	2	Deve	0.68	0.76	7.6	8.3	0
Jan	3	Deve	0.82	1.02	11.3	9	2.3
Feb	1	Deve	0.97	1.33	13.3	9.8	3.5
Feb	2	Mid	1.11	1.65	16.5	10.4	6.1
Feb	3	Mid	1.15	2.1	16.8	11	5.8
Mar	1	Mid	1.15	2.48	24.8	11.9	12.9
Mar	2	Mid	1.15	2.87	28.7	12.6	16.1
Mar	3	Mid	1.15	3.35	36.9	12	24.9
Apr	1	Mid	1.15	3.76	37.6	11.7	26
Apr	2	Late	1.15	4.2	42	11.4	30.6
Apr	3	Late	1	4.61	46.1	8.9	37.2
May	1	Late	0.76	4.27	42.7	6	36.8
May	2	Late	0.52	3.42	34.2	3.6	30.6
May	3	Late	0.29	2.24	20.2	1.9	17.8

Appendix F. 2: Crop water requirement of cotton

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
May	1	Init	0.4	2.25	22.5	6	16.6
May	2	Init	0.4	2.63	26.3	3.6	22.7
May	3	Deve	0.4	3.06	33.6	2.4	31.2
Jun	1	Deve	0.5	4.46	44.6	0.1	44.5
Jun	2	Deve	0.66	6.64	66.4	0	66.4
Jun	3	Deve	0.82	8.34	83.4	0	83.4
Jul	1	Deve	0.98	10.05	100.5	0	100.5
Jul	2	Mid	1.14	11.96	119.6	0	119.6
Jul	3	Mid	1.2	12.19	134.1	0	134.1
Aug	1	Mid	1.2	11.93	119.3	0	119.3
Aug	2	Mid	1.2	11.68	116.8	0	116.8
Aug	3	Mid	1.2	10.44	114.8	0	114.8
Sep	1	Mid	1.2	9.12	91.2	0	91.2

Sep	2	Late	1.16	7.67	76.7	0	76.7
Sep	3	Late	1.04	6.01	60.1	0.1	60
Oct	1	Late	0.91	4.55	45.5	0.9	44.6
Oct	2	Late	0.79	3.29	32.9	1.4	31.6
Oct	3	Late	0.69	2.32	16.2	1.7	13.5

Appendix F. 3: Crop water requirement of bean

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			Coeff	mm/day	mm/dec	mm/dec	mm/dec
Apr	2	Init	0.15	0.55	0.5	1.1	0.5
Apr	3	Init	0.15	0.69	6.9	8.9	0
May	1	Deve	0.15	0.86	8.6	6	2.7
May	2	Deve	0.37	2.41	24.1	3.6	20.5
May	3	Deve	0.72	5.45	60	2.4	57.6
Jun	1	Mid	1.06	9.35	93.5	0.1	93.4
Jun	2	Mid	1.15	11.49	114.9	0	114.9
Jun	3	Mid	1.15	11.64	116.4	0	116.4
Jul	1	Mid	1.15	11.74	117.4	0	117.4
Jul	2	Late	1.14	11.93	119.3	0	119.3
Jul	3	Late	0.87	8.84	97.2	0	97.2
Aug	1	Late	0.56	5.52	38.6	0	38.6

Appendix F. 4: Crop water requirement of Onion

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			Coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	3	Init	0.5	0.56	3.9	6.1	0
Jan	1	Init	0.5	0.56	5.6	8.7	0
Jan	2	Deve	0.53	0.6	6	8.3	0
Jan	3	Deve	0.66	0.82	9	9	0
Feb	1	Deve	0.79	1.08	10.8	9.8	0.9
Feb	2	Deve	0.91	1.35	13.5	10.4	3.1
Feb	3	Mid	1.02	1.86	14.8	11	3.8
Mar	1	Mid	1.05	2.27	22.7	11.9	10.8
Mar	2	Mid	1.05	2.62	26.2	12.6	13.6
Mar	3	Mid	1.05	3.06	33.7	12	21.7
Apr	1	Mid	1.05	3.44	34.4	11.7	22.7

Apr	2	Mid	1.05	3.85	38.5	11.4	27.1
Apr	3	Mid	1.05	4.86	48.6	8.9	39.7
May	1	Mid	1.05	5.91	59.1	6	53.2
May	2	Late	1.04	6.82	68.2	3.6	64.6
May	3	Late	1	7.58	83.4	2.4	81
Jun	1	Late	0.95	8.43	84.3	0.1	84.2
Jun	2	Late	0.91	9.1	91	0	91
Jun	3	Late	0.87	8.79	87.9	0	87.9
Jul	1	Late	0.83	8.45	84.5	0	84.5
Jul	2	Late	0.8	8.4	16.8	0	16.8

Appendix F. 5: Crop water requirement of melon

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	3	Init	0.5	0.56	3.9	6.1	0
Jan	1	Init	0.5	0.56	5.6	8.7	0
Jan	2	Deve	0.53	0.6	6	8.3	0
Jan	3	Deve	0.66	0.82	9	9	0
Feb	1	Deve	0.79	1.08	10.8	9.8	0.9
Feb	2	Deve	0.91	1.35	13.5	10.4	3.1
Feb	3	Mid	1.02	1.86	14.8	11	3.8
Mar	1	Mid	1.05	2.27	22.7	11.9	10.8
Mar	2	Mid	1.05	2.62	26.2	12.6	13.6
Mar	3	Mid	1.05	3.06	33.7	12	21.7
Apr	1	Mid	1.05	3.44	34.4	11.7	22.7
Apr	2	Mid	1.05	3.85	38.5	11.4	27.1
Apr	3	Mid	1.05	4.86	48.6	8.9	39.7
May	1	Mid	1.05	5.91	59.1	6	53.2
May	2	Late	1.04	6.82	68.2	3.6	64.6
May	3	Late	1	7.58	83.4	2.4	81
Jun	1	Late	0.95	8.43	84.3	0.1	84.2
Jun	2	Late	0.91	9.1	91	0	91
Jun	3	Late	0.87	8.79	87.9	0	87.9

Jul	1	Late	0.83	8.45	84.5	0	84.5
Jul	2	Late	0.8	8.4	16.8	0	16.8

Appendix F. 6: Crop water requirement of water melon

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Apr	1	Init	0.4	1.31	13.1	11.7	1.4
Apr	2	Init	0.4	1.47	14.7	11.4	3.2
Apr	3	Deve	0.53	2.46	24.6	8.9	15.7
May	1	Deve	0.77	4.35	43.5	6	37.5
May	2	Mid	0.98	6.41	64.1	3.6	60.5
May	3	Mid	1	7.61	83.7	2.4	81.3
Jun	1	Mid	1	8.85	88.5	0.1	88.4
Jun	2	Mid	1	9.99	99.9	0	99.9
Jun	3	Late	1	10.11	101.1	0	101.1
Jul	1	Late	0.95	9.68	96.8	0	96.8
Jul	2	Late	0.87	9.09	90.9	0	90.9
Jul	3	Late	0.81	8.25	33	0	33

Appendix F. 7: Irrigation schedule for Wheat

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
1-Dec	1	Init	0	0.89	89	60	45.4	0	0	64.8	7.51
12-Mar	102	Mid	0	1	100	46	36.6	0	0	52.3	0.06
30-Mar	120	Mid	0	1	100	46	36.9	0	0	52.8	0.34
12-Apr	133	Mid	0	1	100	46	37	0	0	52.9	0.47
22-Apr	143	End	0	1	100	46	36.8	0	0	52.6	0.61
1-May	152	End	0	1	100	46	36.5	0	0	52.1	0.67
10-May	161	End	0	1	100	40	32.3	0	0	46.1	0.59
20-May	171	End	0	1	100	38	30.6	0	0	43.8	0.51
29-May	End	End	0	1	0	19					

Appendix F. 8: Irrigation schedule for cotton

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
2-May	2	Init	0	1	100	70	32	0	0	45.7	2.64
18-May	18	Init	0	1	100	68	35.4	0	0	50.6	0.37
31-May	31	Dev	0	1	100	69	38.9	0	0	55.6	0.5
9-Jun	40	Dev	0	1	100	70	41.7	0	0	59.6	0.77
15-Jun	46	Dev	0	1	100	62	38.8	0	0	55.4	1.07
21-Jun	52	Dev	0	1	100	66	42.6	0	0	60.9	1.18
26-Jun	57	Dev	0	1	100	64	42.6	0	0	60.9	1.41
1-Jul	62	Dev	0	1	100	65	44.3	0	0	63.4	1.47
5-Jul	66	Dev	0	1	100	59	40.9	0	0	58.5	1.69
9-Jul	70	Dev	0	1	100	57	40.9	0	0	58.5	1.69
13-Jul	74	Dev	0	1	100	64	46.7	0	0	66.7	1.93
17-Jul	78	Dev	0	1	100	65	48.6	0	0	69.4	2.01
21-Jul	82	Mid	0	1	100	64	48.3	0	0	68.9	2
25-Jul	86	Mid	0	1	100	65	48.8	0	0	69.7	2.02
29-Jul	90	Mid	0	1	100	65	48.8	0	0	69.7	2.02
2-Aug	94	Mid	0	1	100	64	48.2	0	0	68.9	1.99
6-Aug	98	Mid	0	1	100	64	47.7	0	0	68.2	1.97
10-Aug	102	Mid	0	1	100	64	47.7	0	0	68.2	1.97
14-Aug	106	Mid	0	1	100	62	46.7	0	0	66.7	1.93
18-Aug	110	Mid	0	1	100	62	46.7	0	0	66.7	1.93
22-Aug	114	Mid	0	1	100	59	44.2	0	0	63.2	1.83
26-Aug	118	Mid	0	1	100	56	41.8	0	0	59.6	1.73
30-Aug	122	Mid	0	1	100	56	41.8	0	0	59.6	1.73
3-Sep	126	Mid	0	1	100	50	37.8	0	0	54	1.56
8-Sep	131	Mid	0	1	100	61	45.6	0	0	65.1	1.51
13-Sep	136	End	0	1	100	55	41.2	0	0	58.9	1.36
18-Sep	141	End	0	1	100	51	38.3	0	0	54.8	1.27
24-Sep	147	End	0	1	100	52	39.3	0	0	56.2	1.08
30-Sep	153	End	0	1	100	48	36	0	0	51.5	0.99
8-Oct	161	End	0	1	100	47	35.5	0	0	50.7	0.73
17-Oct	170	End	0.7	1	100	41	30.8	0	0	44	0.57
27-Oct	End	End	0	1	0	28					

Appendix F. 9: Irrigation schedule for bean

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
20-Apr	1	Init	0	0.73	73	62	14	0	0	20	2.31
14-	25	Dev	0	1	100	50	13.1	0	0	18.8	0.09

May											
21-May	32	Dev	0	1	100	66	18.1	0	0	25.9	0.43
24-May	35	Dev	0	1	100	55	15.2	0	0	21.7	0.84
27-May	38	Dev	1.2	1	100	54	15.2	0	0	21.7	0.84
30-May	41	Dev	0	1	100	57	16.4	0	0	23.4	0.9
2-Jun	44	Dev	0	1	100	83	24.2	0	0	34.5	1.33
4-Jun	46	Dev	0	1	100	64	18.7	0	0	26.7	1.55
6-Jun	48	Dev	0	1	100	63	18.7	0	0	26.7	1.55
8-Jun	50	Dev	0	1	100	62	18.7	0	0	26.7	1.55
10-Jun	52	Mid	0	1	100	62	18.7	0	0	26.7	1.55
12-Jun	54	Mid	0	1	100	77	23	0	0	32.8	1.9
14-Jun	56	Mid	0	1	100	77	23	0	0	32.8	1.9
16-Jun	58	Mid	0	1	100	77	23	0	0	32.8	1.9
18-Jun	60	Mid	0	1	100	77	23	0	0	32.8	1.9
20-Jun	62	Mid	0	1	100	77	23	0	0	32.8	1.9
22-Jun	64	Mid	0	1	100	78	23.3	0	0	33.3	1.92
24-Jun	66	Mid	0	1	100	78	23.3	0	0	33.3	1.92
26-Jun	68	Mid	0	1	100	78	23.3	0	0	33.3	1.92
28-Jun	70	Mid	0	1	100	78	23.3	0	0	33.3	1.92
30-Jun	72	Mid	0	1	100	78	23.3	0	0	33.3	1.92
2-Jul	74	Mid	0	1	100	78	23.5	0	0	33.6	1.94
4-Jul	76	Mid	0	1	100	78	23.5	0	0	33.6	1.94
6-Jul	78	Mid	0	1	100	78	23.5	0	0	33.6	1.94
8-Jul	80	Mid	0	1	100	78	23.5	0	0	33.6	1.94
10-Jul	82	Mid	0	1	100	78	23.5	0	0	33.6	1.94
12-Jul	84	Mid	0	1	100	80	23.9	0	0	34.1	1.97
14-Jul	86	Mid	0	1	100	80	23.9	0	0	34.1	1.97
16-Jul	88	Mid	0	1	100	80	23.9	0	0	34.1	1.97
18-Jul	90	Mid	0	1	100	80	23.9	0	0	34.1	1.97
20-Jul	92	End	0	1	100	80	23.9	0	0	34.1	1.97
22-Jul	94	End	0	1	100	59	17.7	0	0	25.2	1.46
24-Jul	96	End	0	1	100	59	17.7	0	0	25.2	1.46
27-Jul	99	End	0	1	100	88	26.5	0	0	37.9	1.46
30-Jul	102	End	0	1	100	88	26.5	0	0	37.9	1.46
2-Aug	105	End	0	1	100	66	19.9	0	0	28.4	1.1
6-Aug	109	End	0	1	100	74	22.1	0	0	31.5	0.91
7-Aug	End	End	0	1	0	0					

Appendix F. 10: Irrigation schedule for onion

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha

25-Dec	1-Jan	Init	0	0.5	50	62	7.9	0	0	11.2	1.3
31-Dec	7-Jan	Init	0	1	100	21	2.9	0	0	4.1	0.08
12-Jan	19-Jan	Init	0	1	100	22	3.4	0	0	4.9	0.05
22-Jan	29-Jan	Dev	0	1	100	24	4	0	0	5.8	0.07
31-Jan	7-Feb	Dev	0	1	100	22	4.1	0	0	5.8	0.08
11-Feb	49	Dev	0	1	100	28	5.7	0	0	8.1	0.08
16-Feb	54	Dev	0	1	100	26	5.4	0	0	7.7	0.18
20-Feb	58	Dev	0	1	100	25	5.4	0	0	7.7	0.22
25-Feb	63	Dev	0	1	100	25	5.6	0	0	8	0.18
1-Mar	67	Mid	0	1	100	27	6	0	0	8.5	0.25
5-Mar	71	Mid	0	1	100	30	6.8	0	0	9.7	0.28
9-Mar	75	Mid	0	1	100	30	6.8	0	0	9.7	0.28
12-Mar	78	Mid	0	1	100	33	7.5	0	0	10.7	0.41
15-Mar	81	Mid	0	1	100	35	7.8	0	0	11.2	0.43
19-Mar	85	Mid	0	1	100	35	7.8	0	0	11.2	0.32
21-Mar	87	Mid	0	1	100	25	5.7	0	0	8.1	0.47
24-Mar	90	Mid	0	1	100	27	6.1	0	0	8.7	0.34
26-Mar	92	Mid	0	1	100	27	6.1	0	0	8.7	0.51
28-Mar	94	Mid	0	1	100	27	6.1	0	0	8.7	0.51
30-Mar	96	Mid	0	1	100	27	6.1	0	0	8.7	0.51
1-Apr	98	Mid	0	1	100	29	6.5	0	0	9.3	0.54
4-Apr	101	Mid	0	1	100	31	6.9	0	0	9.8	0.38
6-Apr	103	Mid	0	1	100	31	6.9	0	0	9.8	0.57
8-Apr	105	Mid	0	1	100	31	6.9	0	0	9.8	0.57
10-Apr	107	Mid	0	1	100	31	6.9	0	0	9.8	0.57
12-Apr	109	Mid	0	1	100	34	7.7	0	0	11	0.64
14-Apr	111	Mid	0	1	100	34	7.7	0	0	11	0.64
16-Apr	113	Mid	0	1	100	34	7.7	0	0	11	0.64
18-Apr	115	Mid	0	1	100	34	7.7	0	0	11	0.64
20-Apr	117	Mid	0	1	100	34	7.7	0	0	11	0.64
22-Apr	119	Mid	0	1	100	43	9.7	0	0	13.9	0.8
24-Apr	121	Mid	0	1	100	43	9.7	0	0	13.9	0.8
26-Apr	123	Mid	0	1	100	43	9.7	0	0	13.9	0.8
28-Apr	125	Mid	0	1	100	43	9.7	0	0	13.9	0.8
30-Apr	127	Mid	0	1	100	43	9.7	0	0	13.9	0.8
1-May	128	Mid	0	1	100	26	5.9	0	0	8.4	0.98
2-May	129	Mid	0	1	100	26	5.9	0	0	8.4	0.98
3-May	130	Mid	3.1	1	100	26	5.9	0	0	8.4	0.98
4-May	131	Mid	0	1	100	26	5.9	0	0	8.4	0.98
5-May	132	Mid	0	1	100	26	5.9	0	0	8.4	0.98
6-May	133	Mid	0	1	100	26	5.9	0	0	8.4	0.98
7-May	134	Mid	3.1	1	100	26	5.9	0	0	8.4	0.98
8-May	135	Mid	0	1	100	26	5.9	0	0	8.4	0.98
9-May	136	Mid	0	1	100	26	5.9	0	0	8.4	0.98
10-May	137	Mid	0	1	100	26	5.9	0	0	8.4	0.98
11-May	138	Mid	0	1	100	30	6.8	0	0	9.7	1.13

12-May	139	Mid	0	1	100	30	6.8	0	0	9.7	1.13
13-May	140	Mid	1.8	1	100	30	6.8	0	0	9.7	1.13
14-May	141	End	0	1	100	30	6.8	0	0	9.7	1.13
15-May	142	End	0	1	100	30	6.8	0	0	9.7	1.13
16-May	143	End	0	1	100	30	6.8	0	0	9.7	1.13
17-May	144	End	1.8	1	100	30	6.8	0	0	9.7	1.13
18-May	145	End	0	1	100	30	6.8	0	0	9.7	1.13
19-May	146	End	0	1	100	30	6.8	0	0	9.7	1.13
20-May	147	End	0	1	100	30	6.8	0	0	9.7	1.13
21-May	148	End	0	1	100	34	7.6	0	0	10.8	1.25
22-May	149	End	0	1	100	34	7.6	0	0	10.8	1.25
23-May	150	End	1.2	1	100	34	7.6	0	0	10.8	1.25
24-May	151	End	0	1	100	34	7.6	0	0	10.8	1.25
25-May	152	End	0	1	100	34	7.6	0	0	10.8	1.25
26-May	153	End	0	1	100	34	7.6	0	0	10.8	1.25
27-May	154	End	1.2	1	100	34	7.6	0	0	10.8	1.25
28-May	155	End	0	1	100	34	7.6	0	0	10.8	1.25
29-May	156	End	0	1	100	34	7.6	0	0	10.8	1.25
30-May	157	End	0	1	100	34	7.6	0	0	10.8	1.25
31-May	158	End	0	1	100	34	7.6	0	0	10.8	1.25
1-Jun	159	End	0	1	100	37	8.4	0	0	12	1.39
2-Jun	160	End	0	1	100	37	8.4	0	0	12	1.39
3-Jun	161	End	0.1	1	100	37	8.4	0	0	12	1.39
4-Jun	162	End	0	1	100	37	8.4	0	0	12	1.39
5-Jun	163	End	0	1	100	37	8.4	0	0	12	1.39
6-Jun	164	End	0	1	100	37	8.4	0	0	12	1.39
7-Jun	165	End	0.1	1	100	37	8.4	0	0	12	1.39
8-Jun	166	End	0	1	100	37	8.4	0	0	12	1.39
9-Jun	167	End	0	1	100	37	8.4	0	0	12	1.39
10-Jun	168	End	0	1	100	37	8.4	0	0	12	1.39
11-Jun	169	End	0	1	100	40	9.1	0	0	13	1.5
12-Jun	170	End	0	1	100	40	9.1	0	0	13	1.5
13-Jun	171	End	0	1	100	40	9.1	0	0	13	1.5
14-Jun	172	End	0	1	100	40	9.1	0	0	13	1.5
15-Jun	173	End	0	1	100	40	9.1	0	0	13	1.5
16-Jun	174	End	0	1	100	40	9.1	0	0	13	1.5
17-Jun	175	End	0	1	100	40	9.1	0	0	13	1.5
18-Jun	176	End	0	1	100	40	9.1	0	0	13	1.5
19-Jun	177	End	0	1	100	40	9.1	0	0	13	1.5
20-Jun	178	End	0	1	100	40	9.1	0	0	13	1.5
21-Jun	179	End	0	1	100	39	8.8	0	0	12.6	1.45
22-Jun	180	End	0	1	100	39	8.8	0	0	12.6	1.45
23-Jun	181	End	0	1	100	39	8.8	0	0	12.6	1.45
24-Jun	182	End	0	1	100	39	8.8	0	0	12.6	1.45
25-Jun	183	End	0	1	100	39	8.8	0	0	12.6	1.45
26-Jun	184	End	0	1	100	39	8.8	0	0	12.6	1.45

27-Jun	185	End	0	1	100	39	8.8	0	0	12.6	1.45
28-Jun	186	End	0	1	100	39	8.8	0	0	12.6	1.45
29-Jun	187	End	0	1	100	39	8.8	0	0	12.6	1.45
30-Jun	188	End	0	1	100	39	8.8	0	0	12.6	1.45
1-Jul	189	End	0	1	100	38	8.4	0	0	12.1	1.4
2-Jul	190	End	0	1	100	38	8.4	0	0	12.1	1.4
3-Jul	191	End	0	1	100	38	8.4	0	0	12.1	1.4
4-Jul	192	End	0	1	100	38	8.4	0	0	12.1	1.4
5-Jul	193	End	0	1	100	38	8.4	0	0	12.1	1.4
6-Jul	194	End	0	1	100	38	8.4	0	0	12.1	1.4
7-Jul	195	End	0	1	100	38	8.4	0	0	12.1	1.4
8-Jul	196	End	0	1	100	38	8.4	0	0	12.1	1.4
9-Jul	197	End	0	1	100	38	8.4	0	0	12.1	1.4
10-Jul	198	End	0	1	100	38	8.4	0	0	12.1	1.4
11-Jul	199	End	0	1	100	37	8.4	0	0	12	1.39
12-Jul	End	End	0	1	0	0					

Appendix F. 11: Irrigation schedule for melon

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
4-Apr	1	Init	0	0.69	69	49	10.5	0	0	15.1	1.74
10-Apr	7	Init	0	1	100	24	5.7	0	0	8.2	0.16
16-Apr	13	Init	0	1	100	23	6.1	0	0	8.7	0.17
20-Apr	17	Init	0	1	100	21	5.9	0	0	8.4	0.24
26-Apr	23	Init	0	1	100	25	7.5	0	0	10.8	0.21
30-Apr	27	Dev	0	1	100	23	7.5	0	0	10.8	0.31
4-May	31	Dev	0	1	100	29	10	0	0	14.3	0.41
8-May	35	Dev	0	1	100	28	10	0	0	14.3	0.41
11-May	38	Dev	0	1	100	32	11.9	0	0	17	0.66
14-May	41	Dev	0	1	100	38	14.4	0	0	20.5	0.79
16-May	43	Dev	0	1	100	28	10.8	0	0	15.4	0.89
19-May	46	Dev	0	1	100	40	16.2	0	0	23.1	0.89
21-May	48	Dev	0	1	100	31	12.9	0	0	18.5	1.07
23-May	50	Dev	1.2	1	100	33	13.9	0	0	19.9	1.15
25-May	52	Mid	0	1	100	36	15.1	0	0	21.6	1.25
27-May	54	Mid	1.2	1	100	33	13.9	0	0	19.9	1.15
29-May	56	Mid	0	1	100	36	15.1	0	0	21.6	1.25
31-May	58	Mid	0	1	100	36	15.1	0	0	21.6	1.25
2-Jun	60	Mid	0	1	100	42	17.7	0	0	25.3	1.46

4-Jun	62	Mid	0	1	100	42	17.7	0	0	25.3	1.46
6-Jun	64	Mid	0	1	100	42	17.7	0	0	25.3	1.46
8-Jun	66	Mid	0	1	100	42	17.7	0	0	25.3	1.46
10-Jun	68	Mid	0	1	100	42	17.7	0	0	25.3	1.46
12-Jun	70	Mid	0	1	100	48	20	0	0	28.6	1.65
14-Jun	72	Mid	0	1	100	48	20	0	0	28.6	1.65
16-Jun	74	Mid	0	1	100	48	20	0	0	28.6	1.65
18-Jun	76	Mid	0	1	100	48	20	0	0	28.6	1.65
20-Jun	78	Mid	0	1	100	48	20	0	0	28.6	1.65
22-Jun	80	Mid	0	1	100	48	20.2	0	0	28.9	1.67
24-Jun	82	Mid	0	1	100	48	20.2	0	0	28.9	1.67
26-Jun	84	Mid	0	1	100	48	20.2	0	0	28.9	1.67
28-Jun	86	Mid	0	1	100	48	20.2	0	0	28.9	1.67
30-Jun	88	Mid	0	1	100	48	20.2	0	0	28.9	1.67
2-Jul	90	Mid	0	1	100	48	20.4	0	0	29.1	1.68
4-Jul	92	Mid	0	1	100	48	20.4	0	0	29.1	1.68
6-Jul	94	Mid	0	1	100	48	20.4	0	0	29.1	1.68
8-Jul	96	End	0	1	100	48	20.4	0	0	29.1	1.68
10-Jul	98	End	0	1	100	48	20.4	0	0	29.1	1.68
12-Jul	100	End	0	1	100	47	19.9	0	0	28.4	1.64
14-Jul	102	End	0	1	100	47	19.9	0	0	28.4	1.64
16-Jul	104	End	0	1	100	47	19.9	0	0	28.4	1.64
18-Jul	106	End	0	1	100	47	19.9	0	0	28.4	1.64
20-Jul	108	End	0	1	100	47	19.9	0	0	28.4	1.64
22-Jul	110	End	0	1	100	43	18	0	0	25.7	1.49
24-Jul	112	End	0	1	100	43	18	0	0	25.7	1.49
26-Jul	114	End	0	1	100	43	18	0	0	25.7	1.49
28-Jul	116	End	0	1	100	43	18	0	0	25.7	1.49
30-Jul	118	End	0	1	100	43	18	0	0	25.7	1.49
1-Aug	End	End	0	1	0	21					

Appendix F. 12: Irrigation schedule for water melon

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
1-Apr	1	Init	0	0.69	69	49	10.6	0	0	15.1	1.75
6-Apr	6	Init	0	1	100	24	5.7	0	0	8.1	0.19
10-Apr	10	Init	0	1	100	20	5.2	0	0	7.5	0.22
16-Apr	16	Init	0	1	100	21	5.9	0	0	8.4	0.16
21-Apr	21	Dev	0	1	100	27	8.3	0	0	11.9	0.28
25-Apr	25	Dev	0	1	100	23	7.4	0	0	10.6	0.31
30-Apr	30	Dev	0	1	100	28	9.9	0	0	14.1	0.33

3-May	33	Dev	3.1	1	100	27	10	0	0	14.2	0.55
6-May	36	Dev	0	1	100	35	13	0	0	18.6	0.72
9-May	39	Dev	0	1	100	33	13	0	0	18.6	0.72
12-May	42	Dev	0	1	100	42	17.2	0	0	24.5	0.95
14-May	44	Dev	0	1	100	31	12.8	0	0	18.3	1.06
16-May	46	Mid	0	1	100	31	12.8	0	0	18.3	1.06
18-May	48	Mid	0	1	100	31	12.8	0	0	18.3	1.06
20-May	50	Mid	0	1	100	31	12.8	0	0	18.3	1.06
22-May	52	Mid	0	1	100	36	15.2	0	0	21.7	1.26
24-May	54	Mid	0	1	100	36	15.2	0	0	21.7	1.26
26-May	56	Mid	0	1	100	36	15.2	0	0	21.7	1.26
28-May	58	Mid	0	1	100	36	15.2	0	0	21.7	1.26
30-May	60	Mid	0	1	100	36	15.2	0	0	21.7	1.26
1-Jun	62	Mid	0	1	100	39	16.5	0	0	23.5	1.36
3-Jun	64	Mid	0.1	1	100	42	17.6	0	0	25.2	1.46
5-Jun	66	Mid	0	1	100	42	17.7	0	0	25.3	1.46
7-Jun	68	Mid	0.1	1	100	42	17.6	0	0	25.2	1.46
9-Jun	70	Mid	0	1	100	42	17.7	0	0	25.3	1.46
11-Jun	72	Mid	0	1	100	45	18.8	0	0	26.9	1.56
13-Jun	74	Mid	0	1	100	48	20	0	0	28.6	1.65
15-Jun	76	Mid	0	1	100	48	20	0	0	28.6	1.65
17-Jun	78	Mid	0	1	100	48	20	0	0	28.6	1.65
19-Jun	80	Mid	0	1	100	48	20	0	0	28.6	1.65
21-Jun	82	Mid	0	1	100	48	20.1	0	0	28.7	1.66
23-Jun	84	Mid	0	1	100	48	20.2	0	0	28.9	1.67
25-Jun	86	Mid	0	1	100	48	20.2	0	0	28.9	1.67
27-Jun	88	Mid	0	1	100	48	20.2	0	0	28.9	1.67
29-Jun	90	Mid	0	1	100	48	20.2	0	0	28.9	1.67
1-Jul	92	End	0	1	100	47	19.8	0	0	28.3	1.64
3-Jul	94	End	0	1	100	46	19.4	0	0	27.7	1.6
5-Jul	96	End	0	1	100	46	19.4	0	0	27.7	1.6
7-Jul	98	End	0	1	100	46	19.4	0	0	27.7	1.6
9-Jul	100	End	0	1	100	46	19.4	0	0	27.7	1.6
11-Jul	102	End	0	1	100	45	18.8	0	0	26.8	1.55
13-Jul	104	End	0	1	100	43	18.2	0	0	26	1.5
15-Jul	106	End	0	1	100	43	18.2	0	0	26	1.5
17-Jul	108	End	0	1	100	43	18.2	0	0	26	1.5
19-Jul	110	End	0	1	100	43	18.2	0	0	26	1.5
21-Jul	112	End	0	1	100	41	17.3	0	0	24.8	1.43
23-Jul	114	End	0	1	100	39	16.5	0	0	23.6	1.36
24-Jul	End	End	0	1	0	0					